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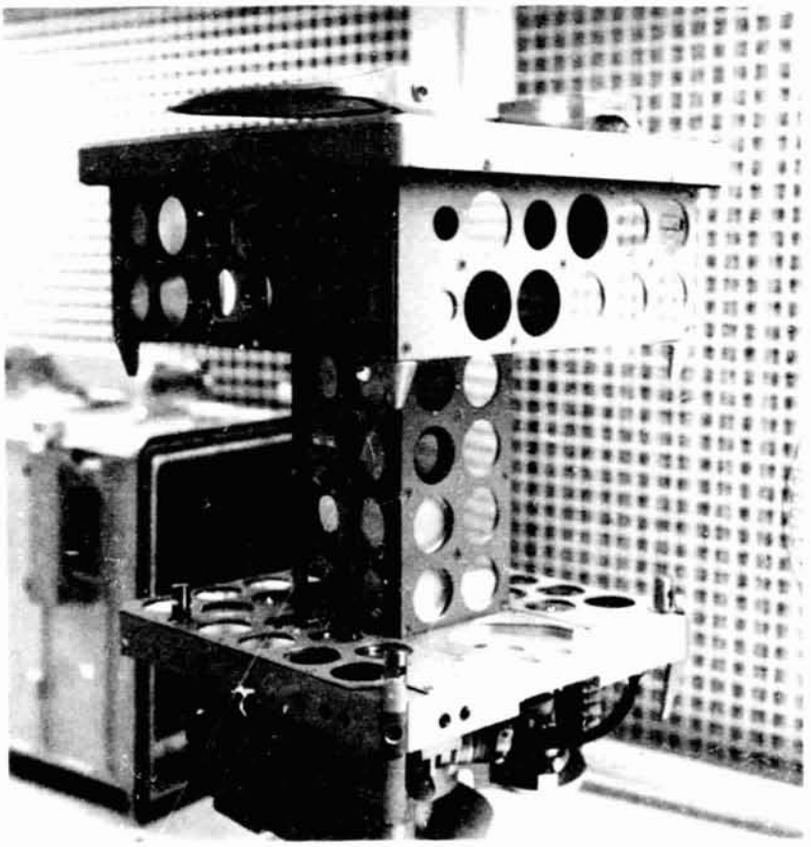

MARTIN MARIETTA

ED-2002-1744
July 31, 1974

SKYLAB PROGRAM
PAYLOAD INTEGRATION

Technical Report

T027 Sample Array
Final Report

Contract NAS8-24000

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FOREWORD

This document is submitted in accordance with the requirements of Plan, Line Item Number 3 of the Data Requirements List, Annex I to Exhibit A, Statement of Work Payload Integration of Contract NAS8-24000.

This plan is in response to the Job Output List, PL 2082, Volume I Rev. E, Work Breakdown Structure No. 1322-3; T027 Scientific Effort and Scientific Calibration/Measurement, Item 4g, Sample Array Experiment Report (Final).

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1. BACKGROUND

1.1 Purpose - This document reports on the final results of the Skylab 1/2 T027 Sample Array postflight data analysis program.

1.2 Reference Documents - In an attempt for completeness, several important documents have key portions summarized in the appendices at the end of this report. Other sample array documents have their table of contents listed. The following list of documents in chronologic order are included in the appendices.

1. Experiment Proposal for Manned Space Flight, ATM Contamination Measurement, Experiment Number T027, August, 1967, 75 pages.

2. MCR-68-78 Potential AAP Cluster Or Apollo Contamination Monitor in Support of ATM, March, 1968, 131 pages.

3. MCR-70-136 Sample Array Mass Properties, May 7, 1970, 23 pages.

4. MCR-70-135 T027 Cleaning And Handling Procedures For Optical Samples, 6 pages.

5. SE-010-028-2H, Experiment Requirements Document for Contamination Measurement (Experiment T027) Sample Array System, May 28, 1971, 56 pages.

6. MCR-70-140 (Rev 1) Operating, Maintenance and Handling Procedures for T027 Sample Array System Flight Hardware, September 10, 1971, 29 pages.

7. TR1-61M0001 Qualification Test Report on Sample Array System, Optical Scattering and Contamination Experiment (T027), November 29, 1971, 68 pages.

8. MCR-70-133 (Rev 3) Sample Array Acceptance Test Procedure, June 1, 1972, 23 pages.

9. Specification Number 61M10006 End Item Specification Performance and Design Requirements (End Item No. 89900000114) for the T027 Sample Array System, July 1, 1972, 23 pages.

10. MCR-72-226 T027 Sample Array Guest Scientist Program, August 25, 1972, 35 pages.

11. ED-2002-1547, KSC Sample Installation Plan, September 15, 1972, 6 pages.

12. ED-2002-1655, Preflight and Post Flight T027 Sample Measurement Plan, March 23, 1973, 84 pages.

13. ED-2002-1698, 30 Day T027 Sample Array and Photometer Status Report, July 25, 1973, 18 pages.

14. ED-2002-1708, T027 SL-1/2 Experiment Report (Preliminary), October 1, 1973, 77 pages.

15. T027-SA-11-73, Sample Array Carrousel Operation Post Flight Test Report, November 19, 1973, 9 pages.

16. T027-SA-1-74, Sample Array Carrousel Operations Post Flight Test Report, January, 1974, 13 pages.

1.3 Objective of T027 Sample Array - T027 will determine the change in optical properties of various transmissive windows, mirrors, and diffraction gratings caused by the deposition of contaminants found about the orbital assembly (OA). A guest scientist program provides sample space on the array to involve interested scientists (Apollo Telescope Mount, ATM, investigators and others) to determine the effect of space contaminants on their optical components.

1.4 Goals - The expected information to be obtained from the total T027 sample array program is as follows:

A. Effect of space contaminants on transmittance, reflectance, grating efficiency, and polarization;

B. Variations in deposition of contaminants due to substrate, solar radiation, period of exposure, direction of exposure, and geometry effects;

C. Identification of contaminants and source of evolution;

D. Time of contaminant evolution and lingering time; and finally

E. Guidelines for a model of spacecraft contamination.

1.5 History - T027 was originally proposed to determine the extent and degree of a potential contamination problem for the planned ATM experiments. The experiment was proposed for inclusion on the Command Service Module IA mission to provide early information on the contribution of the service module to the contamination problem. The tragic Apollo fire during a ground simulation test eliminated the scientific airlock (SAL) from the command module; the T027 instruments used the airlock for exposure into space. The array was then proposed for the early flights of the Apollo Applications Program to determine the conditions for later ATM missions. Subsequent delays in the program and changes in the mission resulted in the sample array being flown with the ATM experiments on the Skylab (SL) 1/2 flight.

The delay in the actual performance of the sample array from the proposed flights did not effect the basic configuration of the instrument. The only major change was the inclusion of two quartz crystal microbalances (QCM) by Marshall Space Flight Center (MSFC) to monitor the real-time deposition of contaminants. Figure 1 is a photograph of the mockup built to illustrate the initial concepts of exposing different sets of samples manually by the crew from inside the spacecraft. Figure 2 shows the first engineering model designed during the feasibility phase of the T027 instruments. At this time the array was entirely independent of the spacecraft except for the mechanical interface with the SAL. Batteries would power the two rotating carrousels. Figure 3 is a photograph of the flight sample array being loaded with samples at Kennedy Space Center (KSC).

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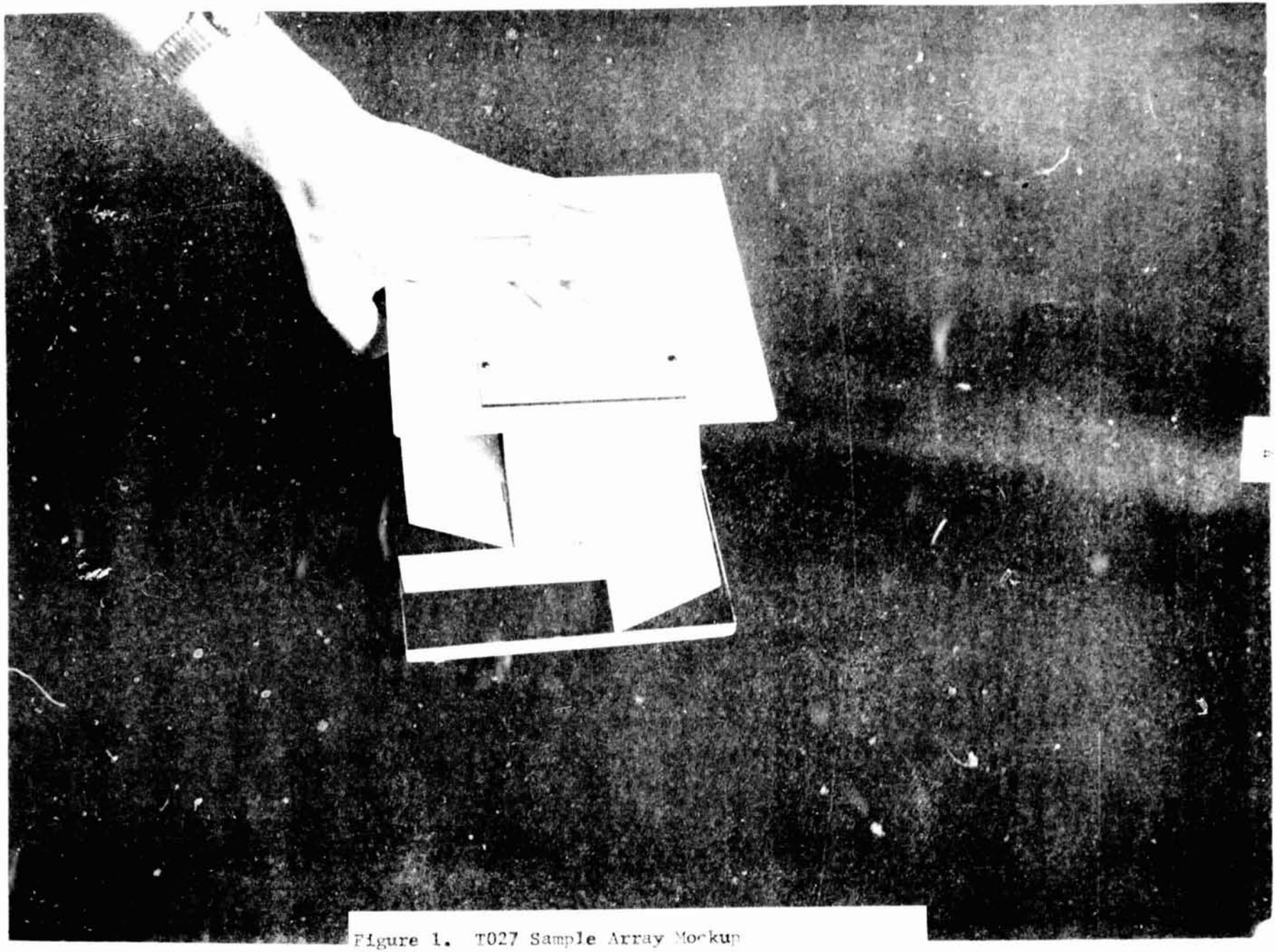

Figure 1. T027 Sample Array Mockup

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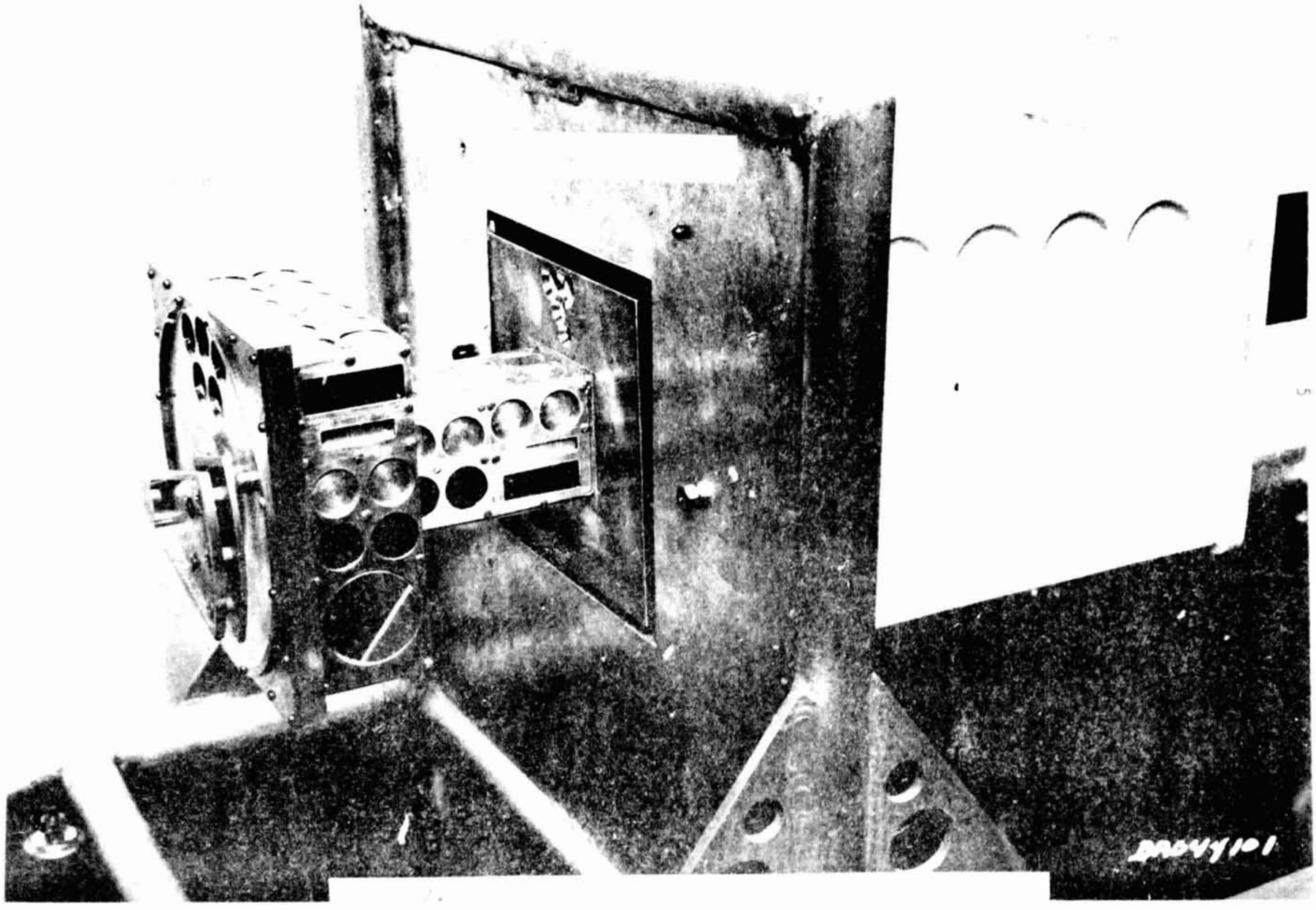

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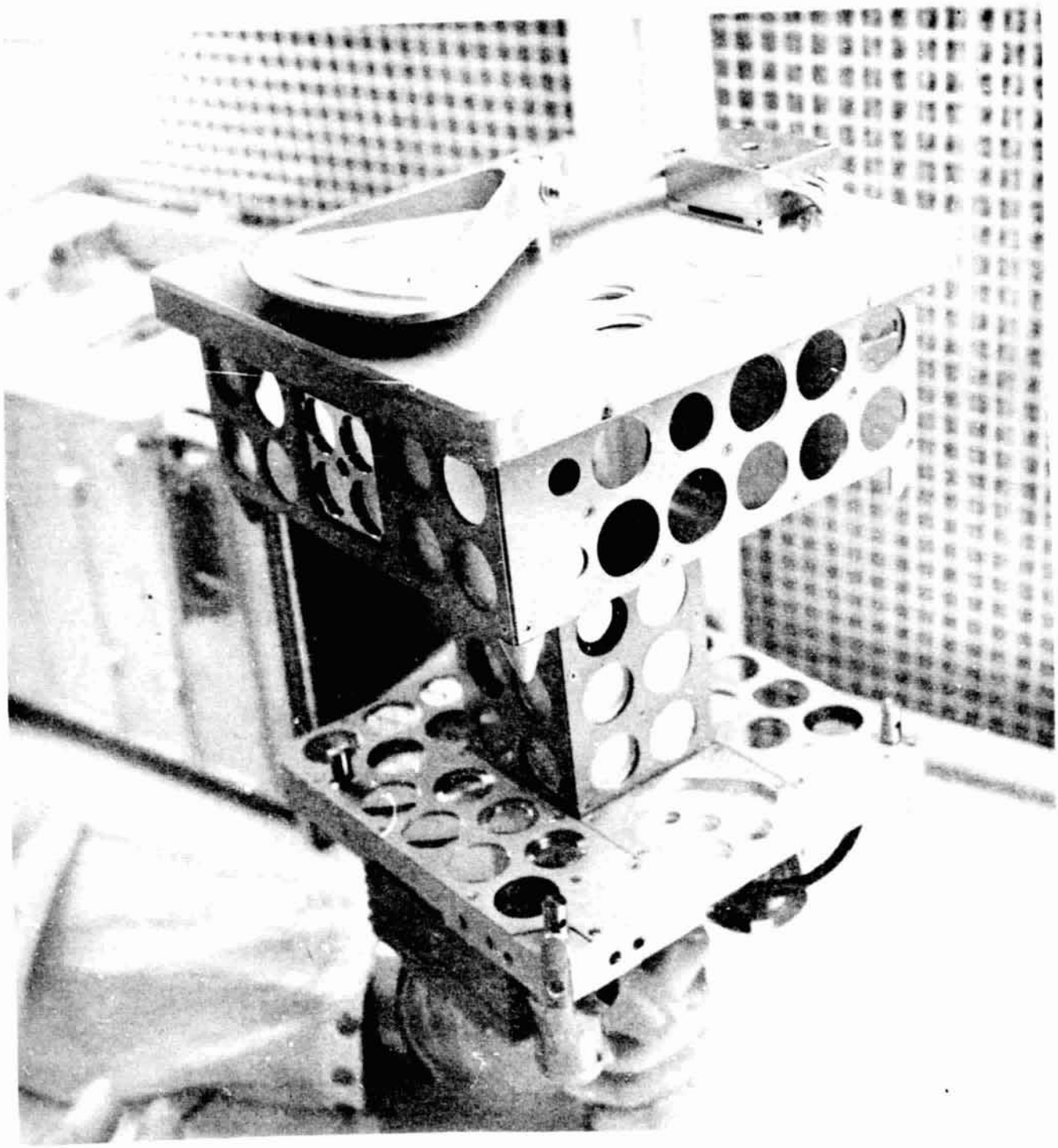

Figure 3. Flight Sample Array Loaded With Samples

2. SAMPLE ARRAY HARDWARE

2.1 Hardware Description - The sample array system is stowed in a stowage container in the orbital workshop (OWS) during launch. The array system and stowage container protects the samples at all times except when they are exposed to the external OA environment. The sample array system as shown in Fig. 4; consists of an upper carrousel, two quartz crystal microbalances, a box, a post, a top lower carrousel, a lower carrousel, a canister, extension rod, and the control electronics.

The upper carrousel contains 30 samples and one quartz crystal microbalance. The carrousel exposes five samples for one day each for five consecutive days. The upper carrousel samples are protected by a valve on the front of the carrousel before and after experiment operation.

The box contains one microbalance and 36 samples, the post contains 30 samples, and the top lower carrousel contains 29 samples. These samples are all exposed continuously during the five day exposure period.

The lower carrousel has three rings of 26 samples each. The inner two rings simultaneously expose one sample each for one hour. The outer ring simultaneously exposes two samples for two hours. These ring samples are only exposed during the first 24 hours.

On the inside of the rear canister section there are 45 control samples. These samples are located on the four inner walls and on the back side of the control panel. Sliding plates automatically cover approximately half of these samples when the array is deployed. When the sample array is retracted, all of the control samples are exposed to the internal canister environment.

The two quartz crystal microbalances will provide near real-time contaminant deposition. One microbalance is oriented toward the sun and the other is oriented along the OWS longitudinal axis facing the ATM.

Appendix A has more details on the sample array hardware and a brief description of its flight operation.

2.2 Flight Qualification Test -The sample array system was subjected to numerous tests to verify its flight readiness.

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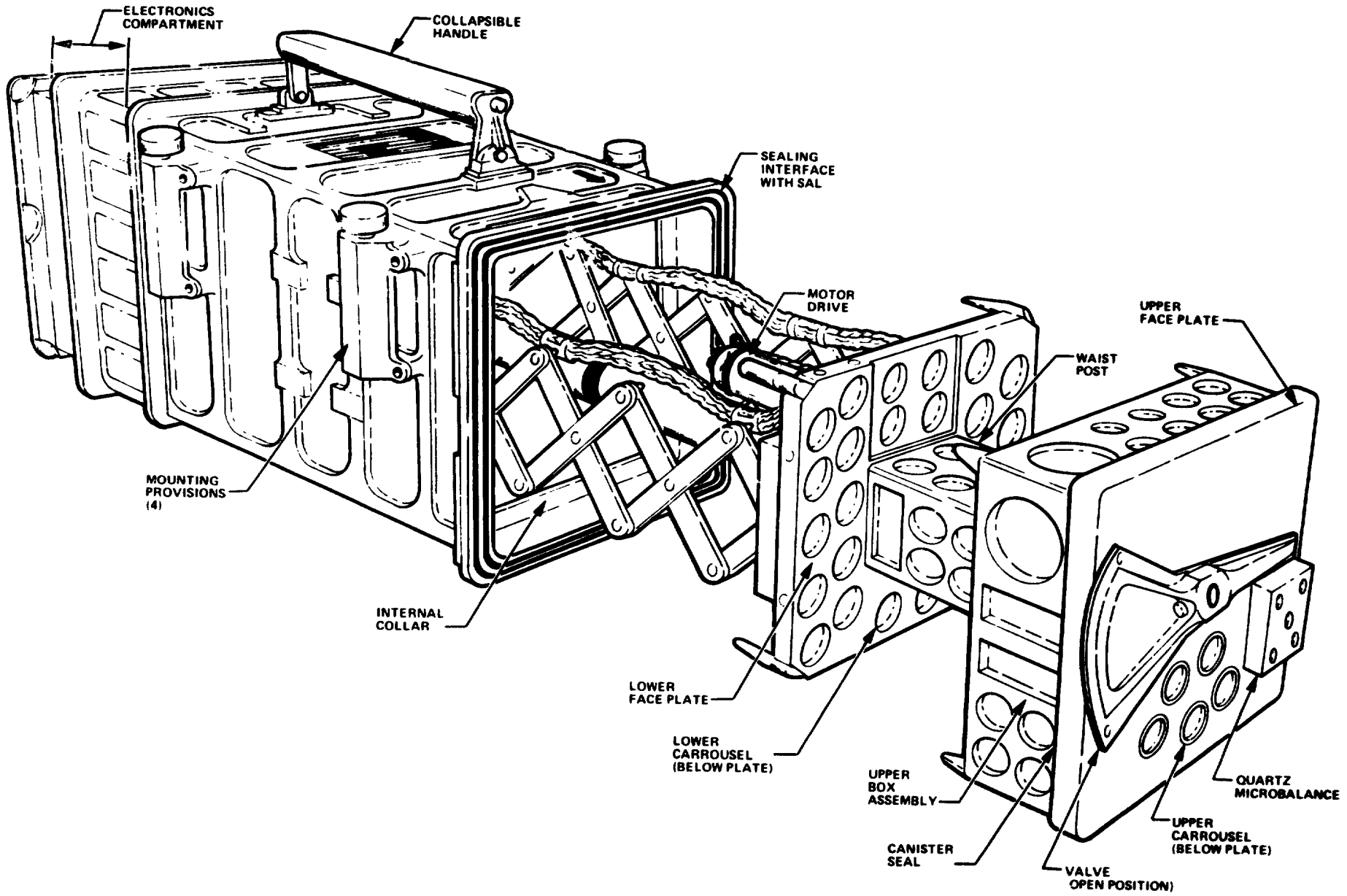

Figure 4. T027 Sample Array Extended

A few operational difficulties occurred but were later resolved. Appendix B contains selections from the qualification test report and a few letters of correspondence concerning the test and operational difficulties. Unfortunately, the total original test report was not detailed enough to fully reflect all the data from the tests. Of particular importance were the thermocouple measurements which registered the temperature at 30 different positions on the array. Data taken by the principal investigator during the test and later T027 furnished tabular lists show that during the start of the thermal vacuum test, the areas around both carrousels were colder than -100°F. When power was applied the lower carrousel operated and 24 hours later the upper carrousel rotated and both continued to rotate the samples under the exposure holes. It should be noted that when the upper carrousel operated, the low temperature extreme was cycling down to about -50°F during the 30 minute solar simulator off periods (60 minutes solar simulator on,then 30 minutes off). Figures 5 and 6 are photographs of the array in its separate chamber to simulate the temperatures and pressures of the OWS interior and again mounted to the large chamber to simulate space and solar radiation.

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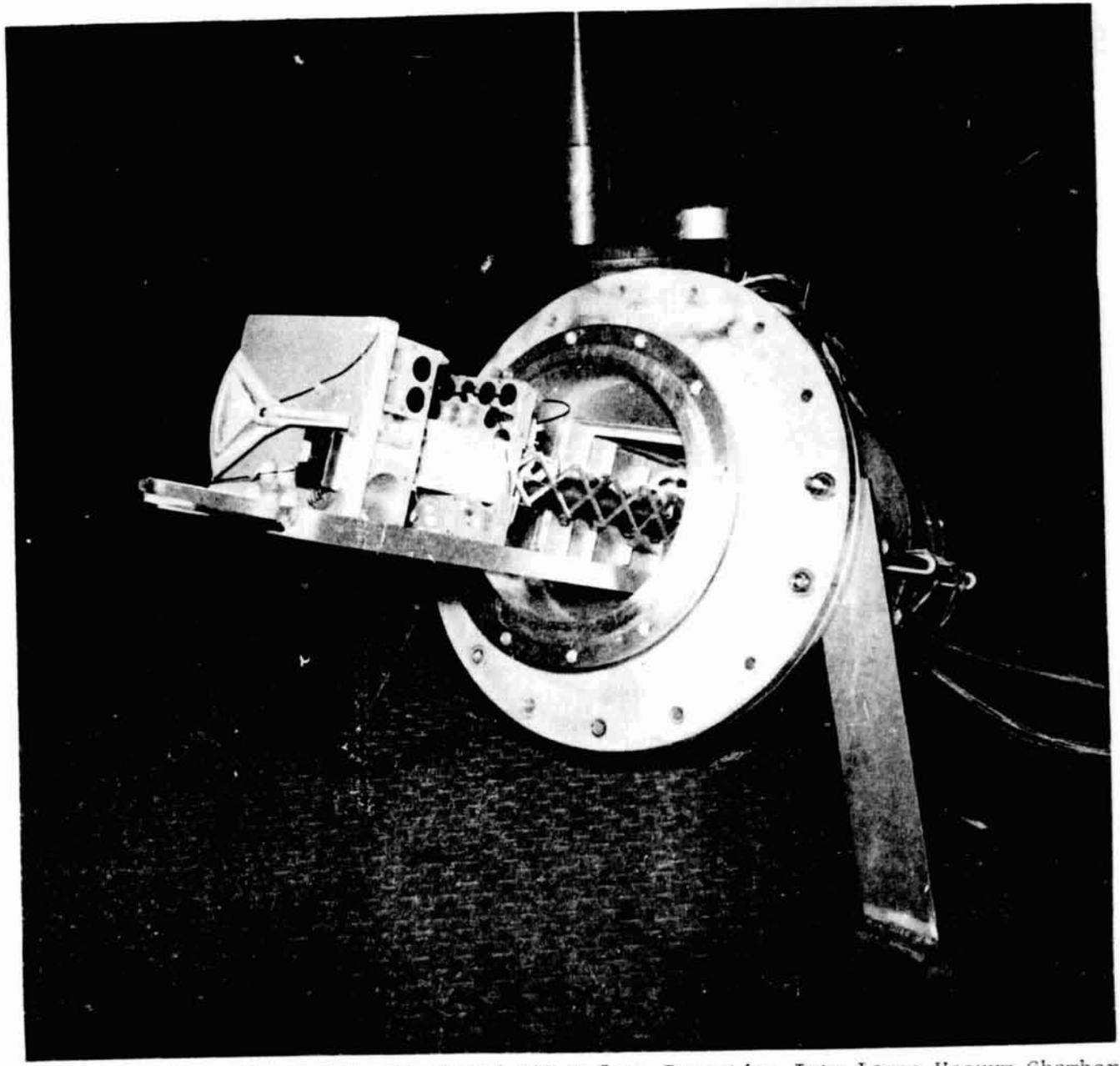

Figure 5. Array Mounted To Simulated SAL Before Insertion Into Large Vacuum Chamber For Flight Qualification Testing

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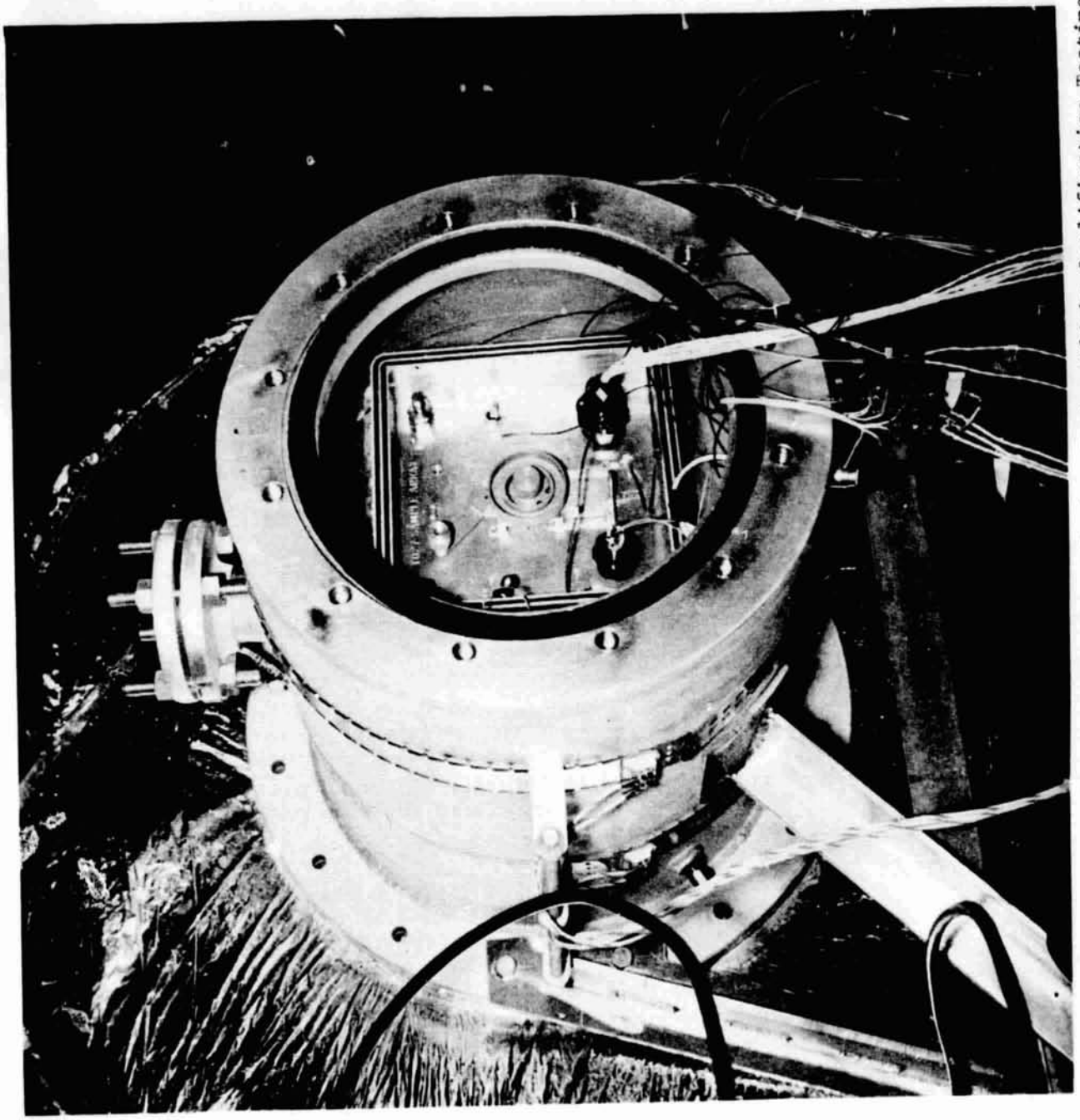


Figure 6. Array And SAL Mounted To Vacuum Chamber During Flight Qualification Testing

3. SAMPLES

3.1 Sample History - The history of each sample was recorded from the initial specifications to the final disposition of the sample. The following outline briefly describes the control and documentation of the samples in general.

a. Selection - The initial selection of the samples began in 1967 as documented in Experiment Proposal, NASA Form 1346, ATM Contamination Measurement, August 1967. After numerous reviews and the natural evolution of the array and the Skylab mission itself, the final sample designation is listed in drawing 89900000124. Initial vendor bids were obtained for the procurement of the samples from this drawing.

b. Procurement - After reviewing the bids, key vendors were visited to fully explain the use and requirements of the samples and to inspect the testing facility of each vendor. The final packaging of the samples and handling precautions allowed the measurement program to begin upon receipt of samples and no cleaning was necessary.

c. Receiving and Inspection - Each sample received was inspected according to the procedures called out in MCR 72-129, Procedures for Receiving Inspection, Handling, Test Inspection, and Storage T027 Samples. In general, every sample was measured by Quality Control for correct dimensions and reviewed for compliance to the specifications called out in drawing 89900000124. After inspection the samples were logged into the sample log book and placed into the ground storage container.

d. Storage - Three containers were built to drawings SSL 233339 through SSL 233343 to control the samples during the preflight and postflight periods. The all metal containers were kept in a locked metal cabinet to control access to the samples. Since each sample did not have a serial number, each position in the container was numbered and the containers were labelled 1, 2, and 3. The positions were labelled 2-250 (except 54)

corresponding to the positions of the sample array itself shown in drawing 89900000124. The QCM's are numbers 1 and 54.

e. Measurement Control - As each sample was removed from the storage case, it was recorded into the Sample Log In/Out Book along with the name of the person and work to be performed. Each laboratory technician only removed one sample at a time to reduce errors in replacement and the return was recorded in the log book. Periodic reviews of the log books verified the workings of the procedure and corrected any problems. All handling and cleaning of the samples was controlled by MCR 72-135 T027 Cleaning and Handling Procedures For Optical Samples.

f. Preflight Readiness Review - Before the samples were shipped to KSC for installation into the sample array, a review of the samples by NASA, AFPRO, and MMC Quality was held. The completeness of the preflight measurements was determined; inspection and certification of cleanliness of the samples and container, compiling the acceptance package, and final installation of all flight samples and spares into the ground storage/transportation container were documented for shipment to KSC. All of the samples were individually photographed before placing into the container.

g. Installation at KSC - Document ED-2002-1547 KSC Sample Installation Plan, September 15, 1972 describes the procedure to be used at KSC. The work was performed on a class 10000 clean bench using gloves and clean tools. Photographs of the installed samples documented the position and condition of the samples at installation. At the completion of the final on-module test, the sample array and the area beneath the cover plates is evacuated and back filled with dry gaseous nitrogen to 5 psi. The array is then placed into the flight stowage container, evacuated, and back filled to 5 psi with nitrogen and sealed.

3.2 Specification and Preflight Location of Samples - The following six (6) sheets of Drawing Number 89900000124 specify the location and requirements for each sample in the preflight planning. Thirty three guest sample positions were originally planned to provide controlled exposure and return of samples to scientists for their assessment. Replacement samples were assigned in case the samples were not ready for installation into the array at Kennedy Space Center (KSC). The original list of six laboratories has decreased to those shown in Table 1.

Each guest scientist was responsible for all measurements performed on his samples. The sample array system provides the mechanism of exposure for his samples. Complete details on the guest scientist program can be found in the 35-page report MCR-72-226 T027 Sample Array Guest Scientist Program, August 25, 1972.

3.3 Preflight Measurements - The preflight measurements consisting of transmission, reflection, ellipsometry, attenuated total reflection, grating efficiency/resolution, and photography were performed during a period of nine months. Throughout this period, measurements of numerous samples were repeated to document the repeatability of the measuring instruments. As it was necessary to clean some of the samples, these measurements were repeated to prove the cleaning procedure did not change the optical property of the sample.

In order to reduce the necessary handling of each sample, special holders were designed and built to interface with all the measuring instruments. Figures 7-11 show examples of these holders.

3.3.1 X-Ray Measurements - The fused quartz flats and the beryllium foil are used to simulate the surface of a grazing incidence X-ray mirror and window of an X-ray proportional counter. The X-rays are produced by a tungsten target tube (Bremsstrahlung) continuously from 2Å to 60Å. An ADP crystal will provide 2.75Å and 5.4Å wavelengths; a KAP crystal will provide 8.34Å. The detector is a proportional counter using an xenon-methane gas mixture and a 0.15 mil mylar window. The foils are measured at all three wavelengths, while the optical flats were only measured at 8.34Å.

The transmission of the foils was determined by inserting and removing the sample from the beam. The detector was placed so as to intercept the direct X-ray beam. The reflection was determined by moving the detector in increments of 10

NOTES AND SPECIFICATIONS:

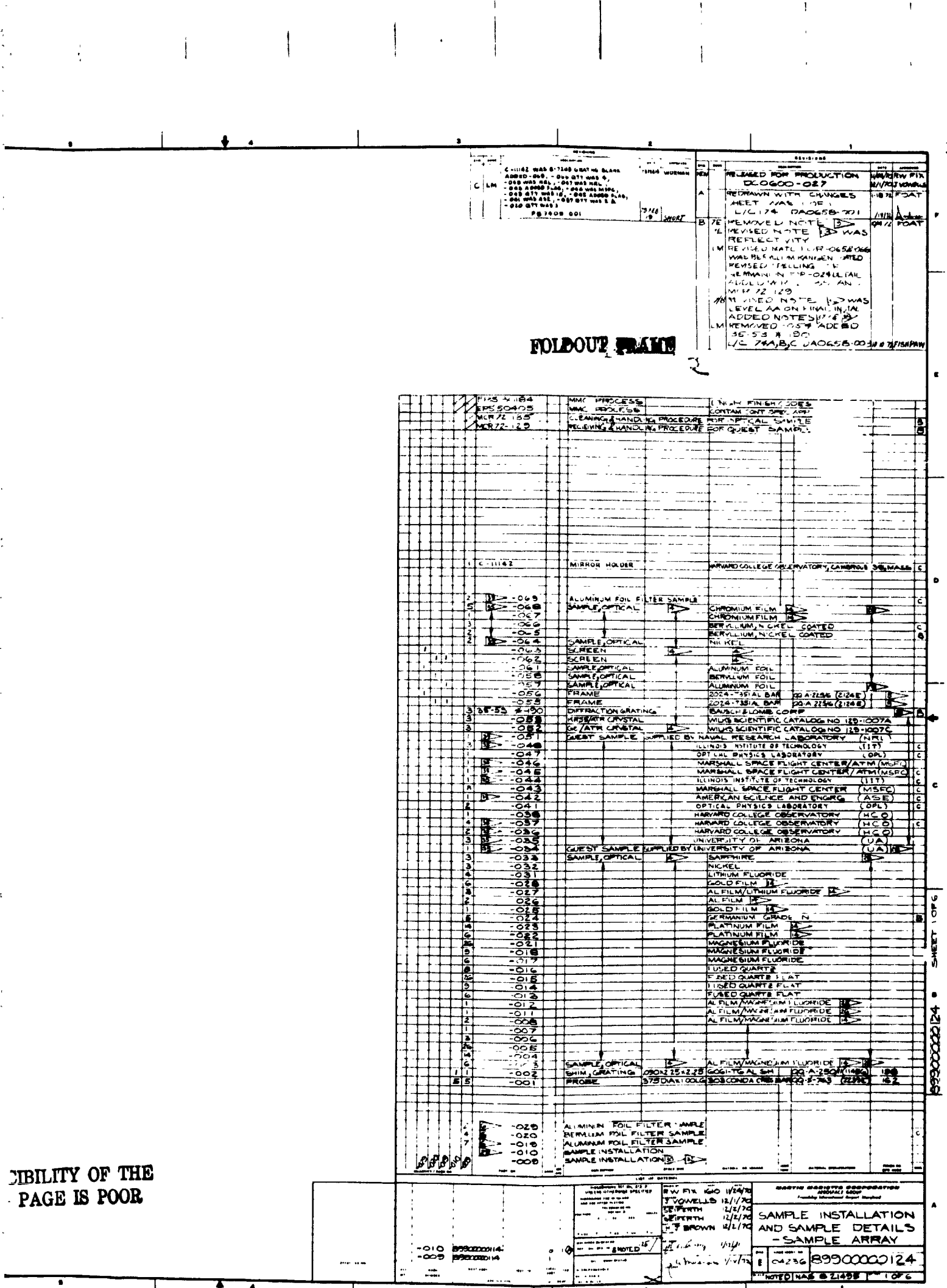
1. DEBURR AND BREAK ALL SHARP EDGES.
2. THREADS PER MIL-S-8879.
3. (A) QTY REQUIRED FOR QUALIFICATION TEST.
4. TO BE DETERMINED BY VENDOR.
5. VENDOR TO APPLY DULL BLACK ANODIZE.
6. VENDOR TO BOND FOIL AND SCREEN TO FRAME WITH MMC APPROVED EPOXY.
7. (XXX) INDICATES SAMPLE LOCATIONS.
8. OPTICAL SURFACES OF THE SAMPLE WILL MEET THE SCRATCH/DIG 60/40 TEST PER MIL-O-13830.
9. DELETED

10. ADHERENCE - NO PART OF THE MIRROR SHALL BE REMOVED WHEN TESTED WITH CELLULOSE TAPE AS IN MIL-M-13508B. NOTE: THIS TEST SHALL NOT BE PERFORMED ON THE SAMPLES THEMSELVES BUT ON A REPRESENTATIVE SAMPLE
11. FLATNESS - ONE WAVELENGTH (N_a D LINE) OVER THE CENTRAL 75 % OR MORE.
12. FLATNESS - 1/30 WAVELENGTH (N_a D LINE) OVER THE CENTRAL 75 % OR MOVE, ONE SIDE ONLY, FLATNESS SURFACE PEAK TO PEAK. THE FLAT SIDE SHOULD BE CODED IN SOME WAY THAT DOES NOT DEGRADE THE OPTICAL QUALITY OF THE MATERIAL, FOR EXAMPLE, A LABELED CONTAINER CLEARLY DESIGNATING FLAT SURFACE.
13. REFLECTANCE FOR WAVELENGTHS GREATER THAN 2000Å 80 %, AT 1216Å 60% OR BETTER HIGH REFLECTANCE IN THE VACUUM ULTRAVIOLET IS REQUIRED.
14. SUBSTRATE MATERIAL USED FOR THE MIRRORS SHALL BE FUSED QUARTZ
15. SUPRASIL NO.1 QUALITY OR EQUIVALENT
16. SUPRASIL NO.1 QUALITY OR EQUIVALENT CERTIFICATION OF FLATNESS EACH SAMPLE. TO BE USED AS GRAZING INCIDENCE MIRROR AND WINDOW. SCRATCH DIG 40/20 OR BETTER
17. OPTICAL AXIS TO BE NORMAL TO SURFACE.
18. TRANSMISSION MINIMUM 36% ± 2% AT 304Å, 15% ± 2 % AT 584Å.
19. THE FOIL THICKNESS TO BE 1/2 MIL OR LESS AND PIN HOLE FREE.
20. GOLD FILM THICKNESS 800Å ± 100Å.
21. PLATINUM FILM THICKNESS 100Å ± 30Å.
22. FLATNESS 1/20 WAVELENGTH (N_a D LINE) OVER CENTRAL 75% OR BETTER, ONE SIDE ONLY, FLATNESS SURFACE PEAK TO PEAK
23. ALUMINUM FILM THICKNESS 800 Å ± 100 Å
24. MAGNESIUM FLUORIDE OVERCOAT THICKNESS 220 Å ± 30 Å
25. SUBSTRATE MATERIAL CERVIT.
26. SUBSTRATE MATERIAL BOROSILICATE CROWN GLASS.
27. LITHIUM FLUORIDE OVERCOAT THICKNESS 170 Å ± 30 Å
28. MMC APPROVAL REQUIRED ON ALL MATERIAL VENDOR TO SUPPLY MATERIAL SPECIFICATION LIST.
29. ALL SAMPLES USED IN THE QUALIFICATION TEST UNIT CONSISTED OF COMMERCIAL GRADE FUSED QUARTZ AND CONFORMED IN SIZE TO SAMPLES SHOWN FOR THE -009 INSTALLATION
30. DISASSEMBLY AND ASSEMBLY OF UNIT FOR SAMPLE INSTALLATION MUST BE PREFORMED BY QUALIFIED MARTIN MARIETTA CORPORATION PERSONAL
31. RECEIVING INSPECTION OF OPTICAL SAMPLES AT MARTIN MARIETTA CORPORATION TO BE LIMITED TO VERIFICATION OF QUANTITY, TYPE AND PRESENCE OF ANY PHYICAL DAMAGE. ALL OTHER INSPECTION TO BE PREFORMED BY MARTIN MARIETTA CORPORATION OPTICS LAB PERSONNEL QC PERSONNEL TO WITNESS THE PHYSICAL INSPECTION
32. SAMPLES -008 THROUGH -009, -011, -012, -022, -023, -025 THROUGH -028, -032 AND -064 THROUGH -068 ARE TO BE INSTALLED WITH MIRROR SURFACE FACING OUTBOARD.
33. FACING INCIDENCE WITH X RAY QUALITY
34. CHROMIUM FILM THICKNESS 800Å ± 100Å.
35. INDICATES SAMPLES THAT WILL BE INSTALLED IF GUEST SAMPLES ARE NOT SUPPLIED.
36. CLEAN -001 AND -002 PER EPS 50405 LEVEL AA.
37. CLEAN ALL SAMPLES EXCEPT GUEST SAMPLES AND THOSE SPECIFIED IN NOTE 36 PER OPTICAL CLEANING PROCEDURE MCR 72-135.
38. PROCEDURE FOR RECEIVING INSPECTION, HANDLING OF GUEST SAMPLES MCR 72-129

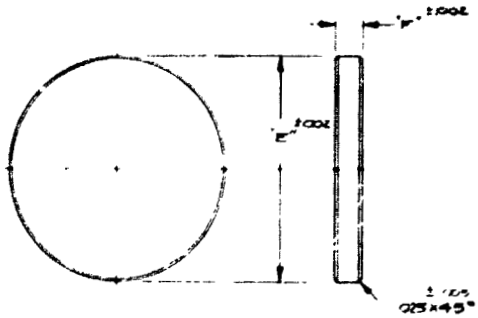
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FOLDOUT FRAME 1

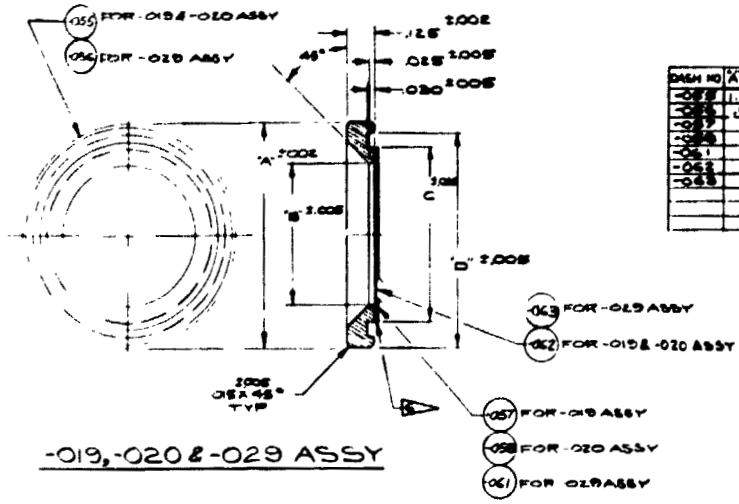
-010
-009



CIBILITY OF THE
PAGE IS POOR



DETAIL -XXX



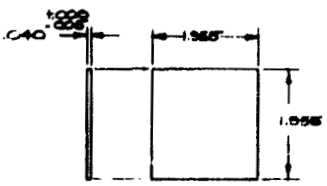
-019, -020 & -029 ASSY

DASH NO	A DIA	B DIA
-018	1.000	.878
-019	.878	1.000
-020		
-029		
-051		
-052		
-053		

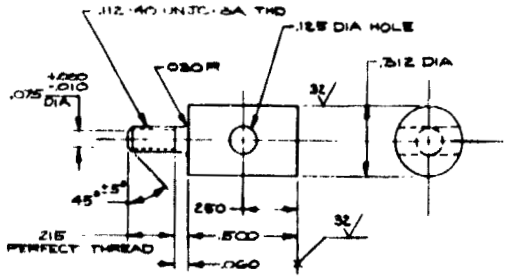
DETAIL NO	C DIA	F DIM	SPECIFICATIONS
-003	.878	.125	
-004	1.000	.125	
-005	.878	.125	
-006	1.000	.125	
-007	.750	.125	
-008	.500	.125	
-011	1.000	.125	
-012	1.000		
-013	.878		
-014	1.000		
-015	.878		
-016	1.000		
-017	.878		
-018	1.000		
-021	1.000		
-022	.878		
-023	1.000		
-024	1.000	.125	
-025	1.000	.125	
-026	1.000	.125	
-027			
-028			
-031			
-032			
-033		.125	
-034		.125	SUPPLIED BY UA
-035		.125	UA
-036		.125	HCO
-037	1.000	.125	HCO
-038	.878		HCO
-041	1.000		OPL
-042	.878		ASE
-043	1.000	.125	MSFC
-044	1.000	.125	IIT
-045	.878	.125	MSFC/ATM
-046	1.000	.125	MSFC/ATM
-047	.878	.125	OPL
-048	1.000	.125	IIT
-061		.125	SUPPLIED BY NAL
-062			
-063			
-064			
-065			
-066			
-067			
-068	1.000	.125	

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

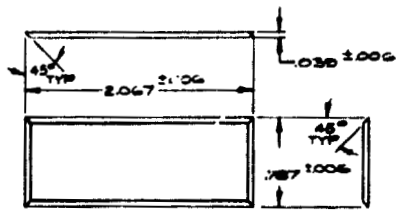
FOLDOUT FRAME 1



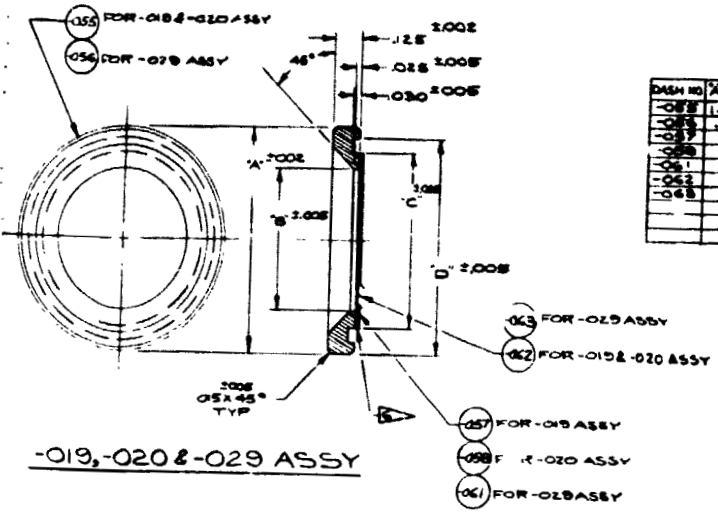
DETAIL -002
SCALE 1/1



DETAIL -001
SCALE 4/1



DETAIL -052 & -053
SCALE 2/1

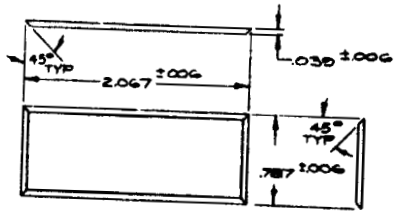


-019, -020 & -029 ASSY

DASH NO	'A' DIA	'B' DIA	'C' DIA	'D' DIA	SPECIFICATIONS
-018	1.000	.678	.780	.800	
-020	.678	.500	.611	.778	
-029			.780		
-060			.780		
-061			.628		
-062			.780		
-063			.628		

REVISIONS			
LTR	ZONE	DESCRIPTION	DATE / APPROVAL
A		RELEASED FOR PRODUCTION LC 174 DAO698-001	1 OCT 74 FOAT
		REVISE & REC TABLE AS FOLLOWS: REMOVED FLAG ▷ FROM -003 THRU -008, -011-012, -022, -025 THRU -028, -055 THRU -062 REMOVED FLAG ▷ FROM -022 & -023 FROM -015 REMOVED FLAG ▷ ADDED ▷	
	4/8	REVISED DIM TOL WAS 2.067±.01; .787±.002, .039±.002 REMOVED -054 DETAIL VC 176 A,B,C LAO665 -003	19 DEC 74 FOAT
B	8/9	-041 WAS ASE, -044 WAS MSPC, -047 WAS MBL, -048 WAS MBL PB 3688-001	15 MAR 75 FOAT

EPRODUCIBILITY OF THE
RIGINAL PAGE IS POOR

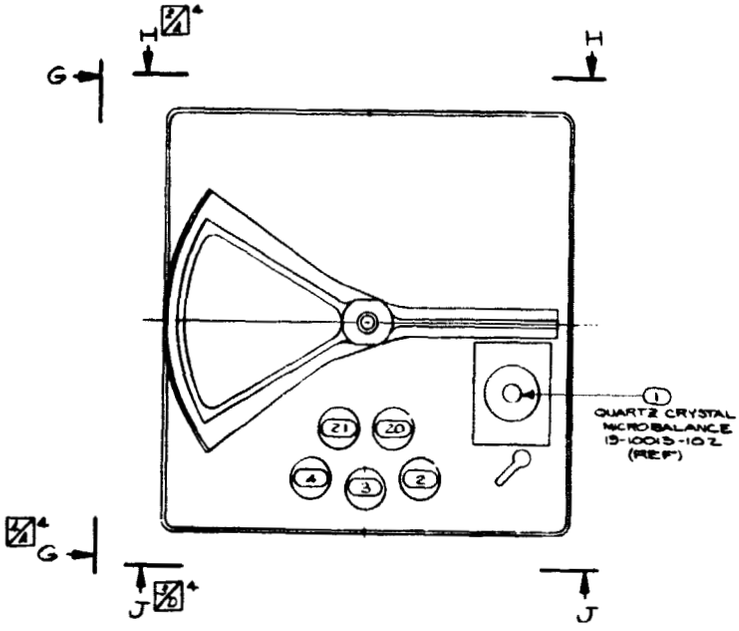


DETAIL -052 & -053
SCALE 2/1

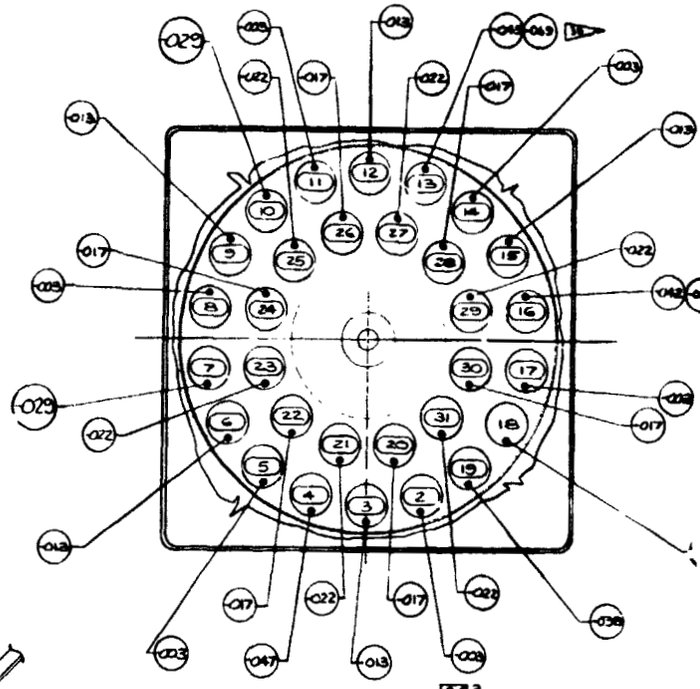
FOLDOUT FRAME 2

SHEET 2

599000000124

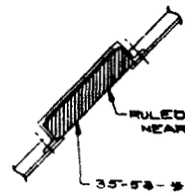


VIEW A-A



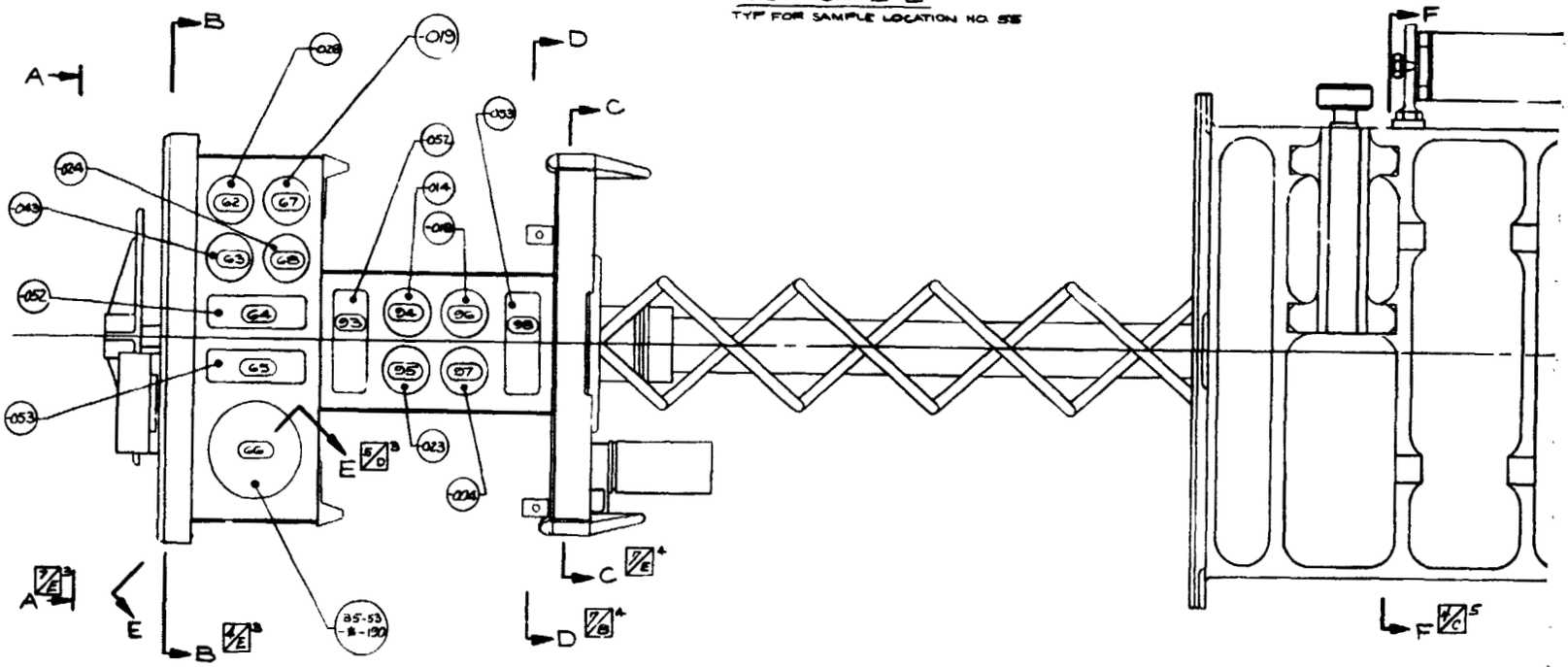
SECTION B-B

CARROUSEL ROTATION IS CCW



SECTION E-E

TYP FOR SAMPLE LOCATION NO. 55

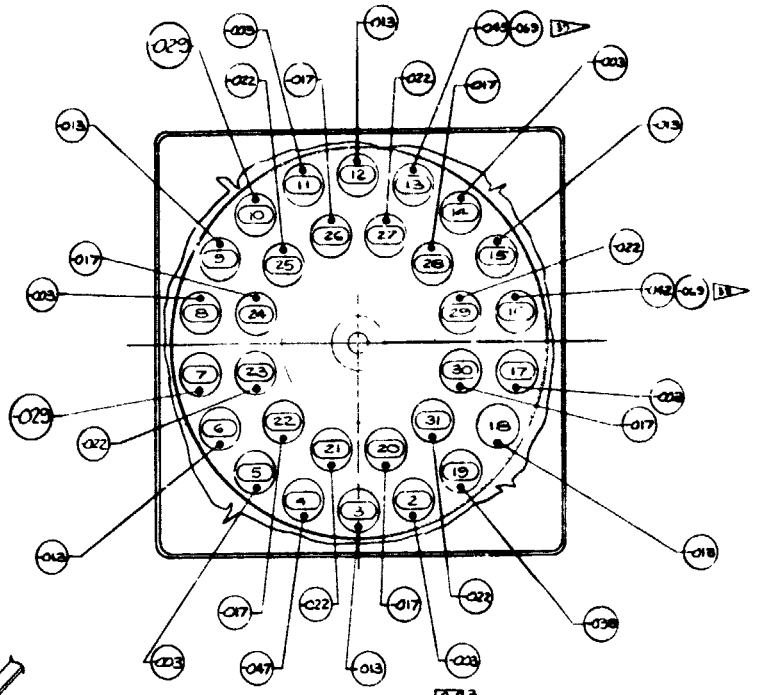


-009 & -010 INSTALLATION

FOLDOUT FRAME 1

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

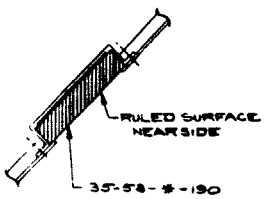
REVISIONS				
LTR	ZONE	DESCRIPTION	DATE	APPROVED
NEW		RELEASED FOR PRODUCTION L/C 174 DA0658-001	1-18-72	FOAT
A		#8 35-53-8-190 WAS -05 L/C 174C DA0658-003	4-4-72 4-18-72	FOAT ISHPAM
B	B/8 B/8	A0080-049 ▷ TO -048 CALLOUT A0080-049 ▷ TO -048 CALLOUT P&S 3498-001	7349B-9	SHORT



SECTION B-B [8/8]3

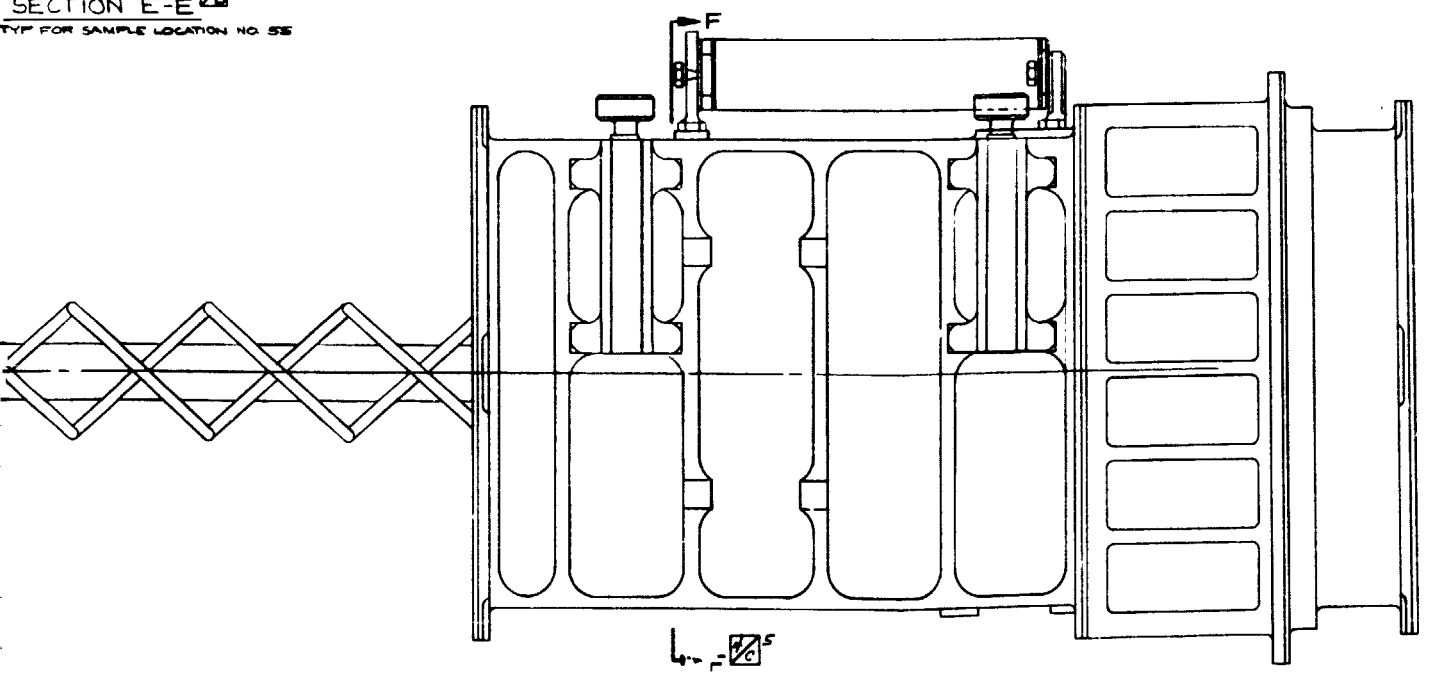
CARROUSEL ROTATION IS CCW

CRYSTAL BALANCE -102



SECTION E-E [7/8]3

TYP FOR SAMPLE LOCATION NO 55

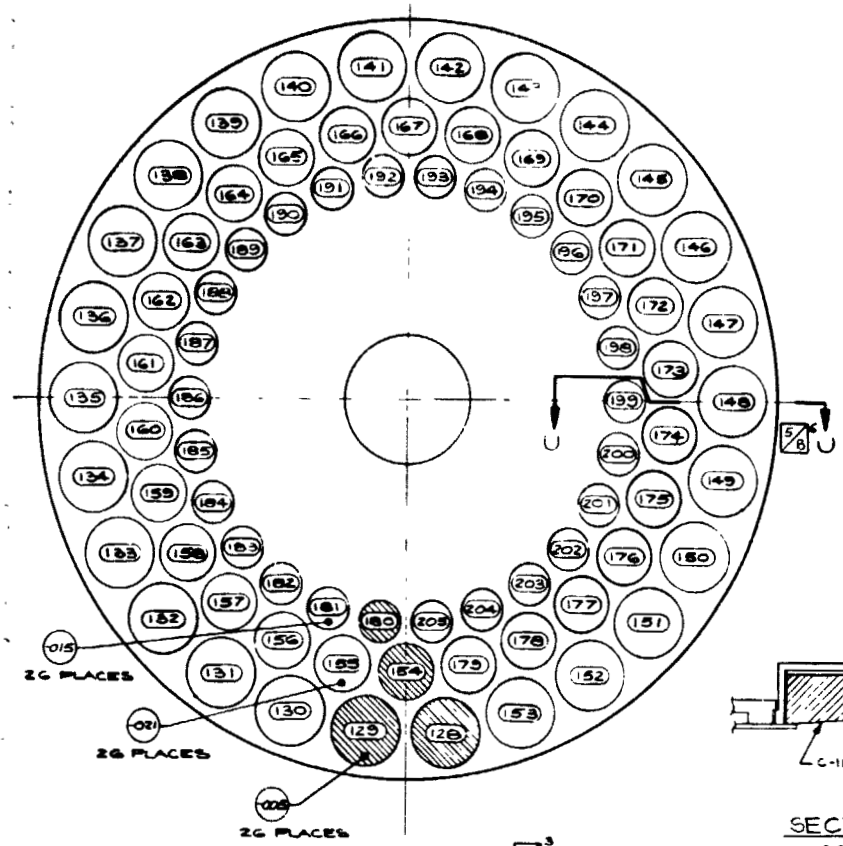


[8/C]5

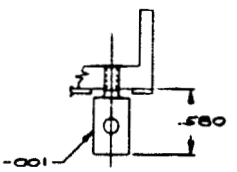
-009 & -010 INSTALLATION

BULKHEAD FRAME 2

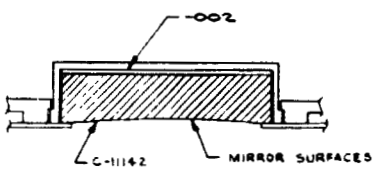
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



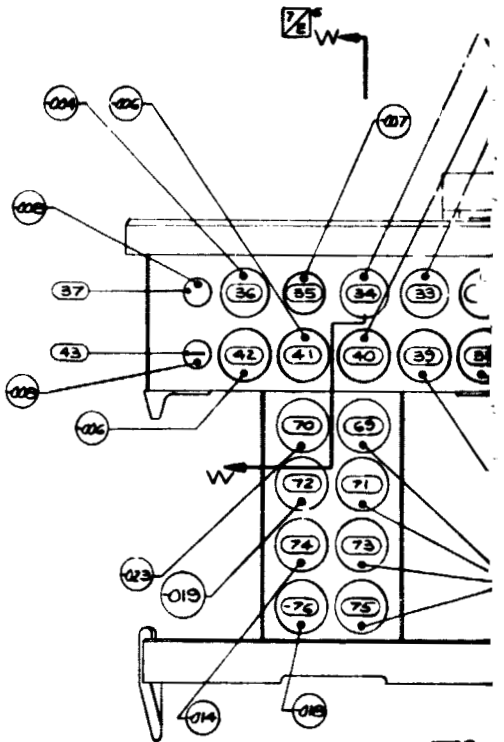
SECTION C-C
SCALE 2/1
CAROUSEL ROTATION IS CCW



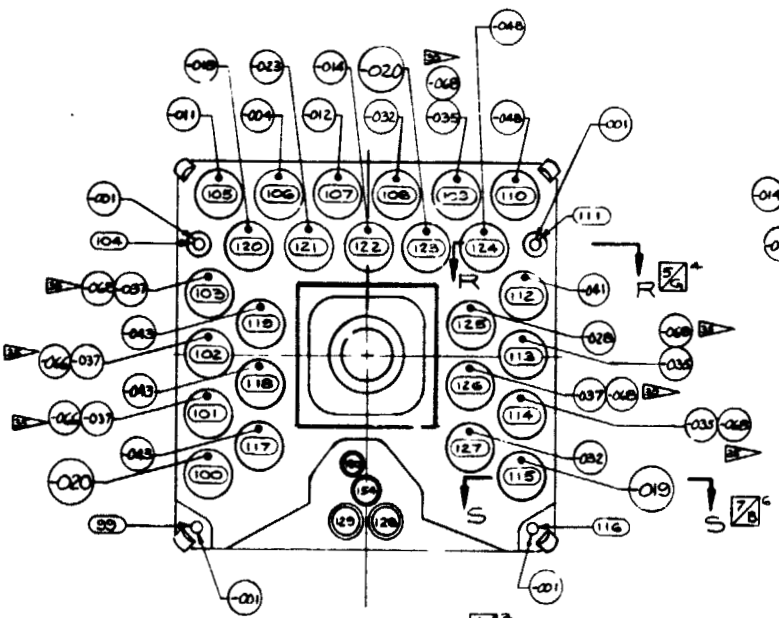
SECTION R-R
SCALE 2/1
SIMILAR AT SAMPLE LOCATIONS
NO. 89, 104, 116 & 207



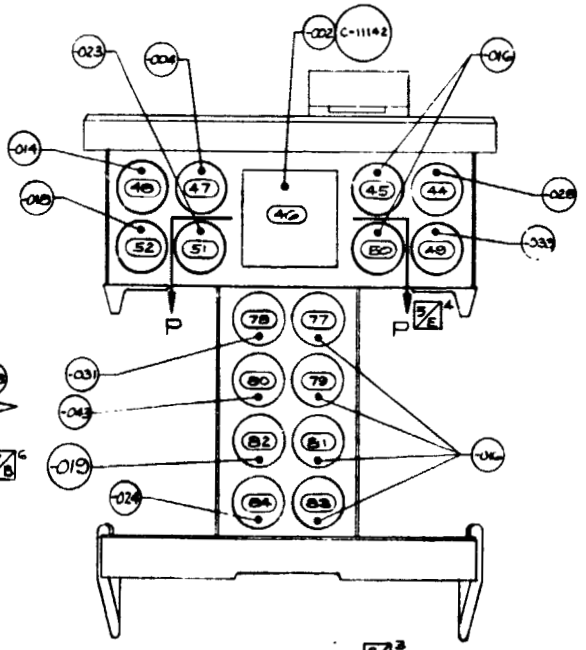
SECTION P-P
SCALE 2/1



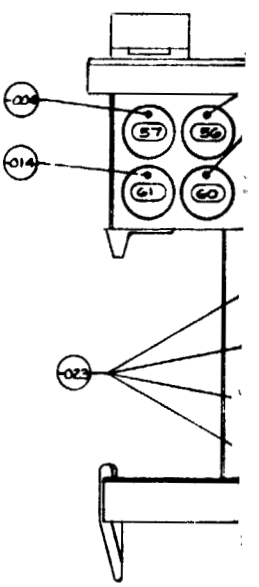
VIEW J-J
SCALE 1/1



SECTION D-D
SCALE 1/1



VIEW G-G
SCALE 1/1
ROTATED 90° C C W

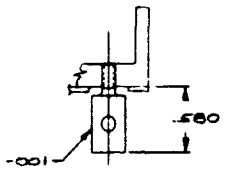


VI
ROTAT

FOLDOUT FRAME 1

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

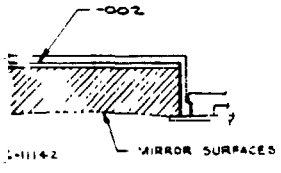
REVISIONS					
LTR	ZONE	DESCRIPTION	DATE	APPROVED	
		RELEASED FOR PRODUCTION L/C 174 DAC658-001			FLOAT
A	3D	35-53-#-190 WAS -054 L/C 174C DAC678-003			#4 X FLOAT
B	3C	-037 WAS -048			
	7D	-348 WAS -068			
	2E 5E	C-11142 WAS B-7208			
	5E	MIRROR SURFACES WAS SPHERICAL AND RULED SURFACE PB 3409-001			



SECTION R-R 6/C 4

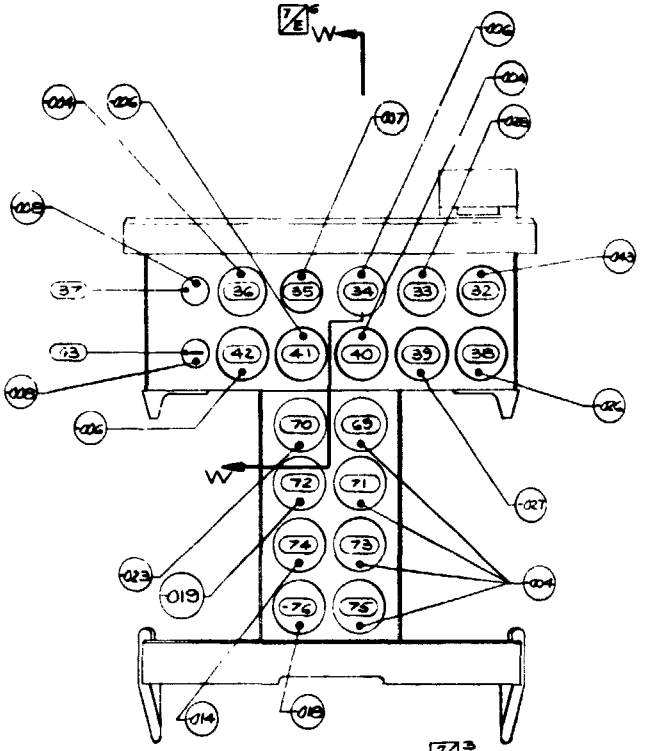
SCALE 2/1

SIMILAR AT SAMPLE LOCATIONS NO. 98, 104, 116 & 207



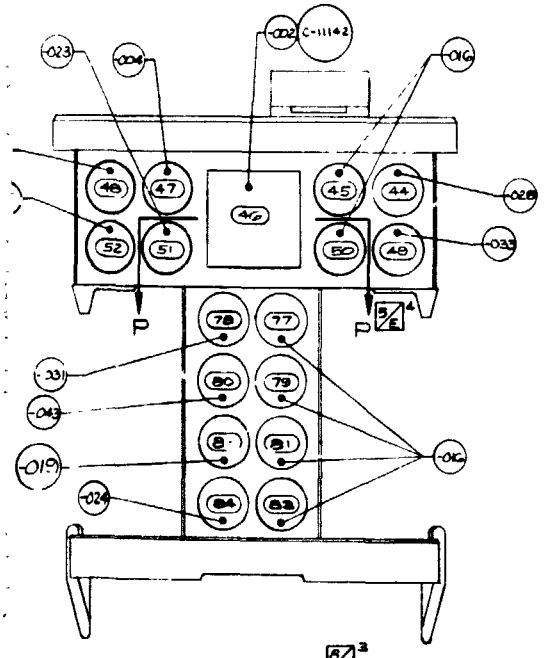
CTION P-P 8/C 4

SCALE 2/1



VIEW J-J 7/F 3

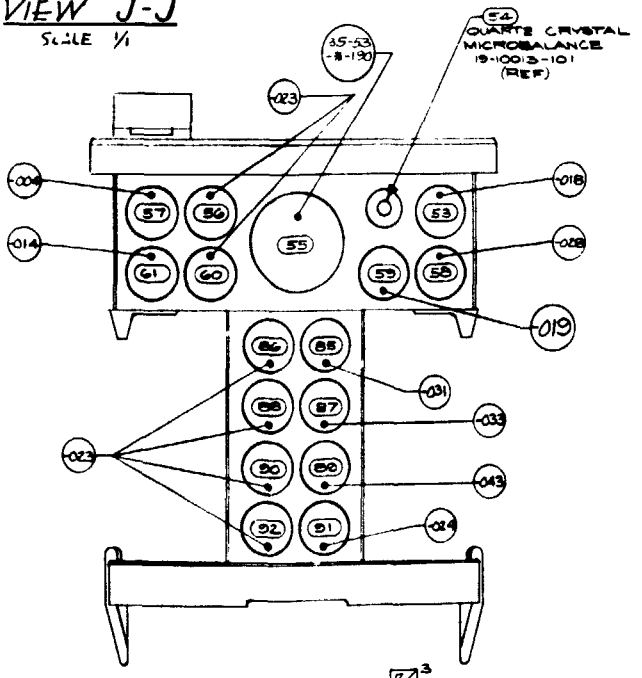
SCALE 1/1



VIEW G-G 8/F 3

SCALE 1/1

ROTATED 90° C C W



VIEW H-H 7/H 3

SCALE 1/1

ROTATED 180 DEGREES

FOLDOUT FRAME 2

OF THE
POOR

	E	04839	8990 0000 124

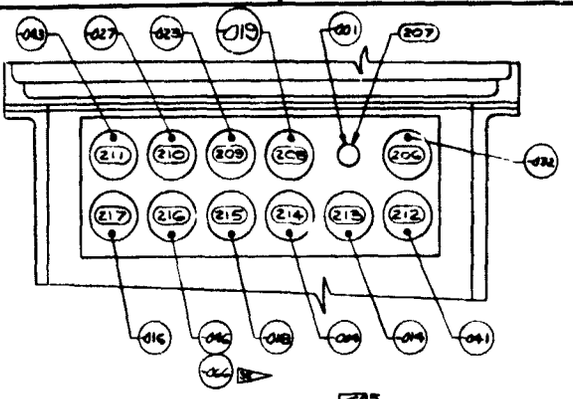
Noted WAS B 2/49-1

SHEET 3

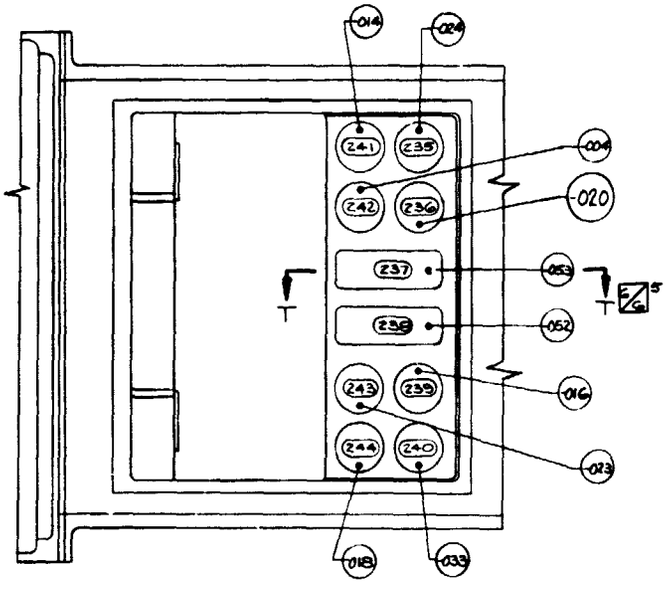
SECTION T-T 6/D 5

SCALE 2/1

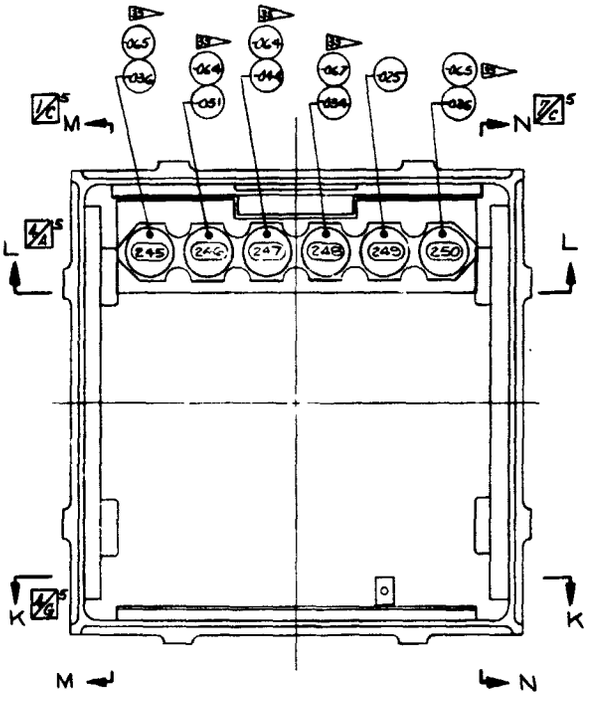
SIMILAR AT SAMPLE LOCATION NO. 64, 65, 93, 98 & 238



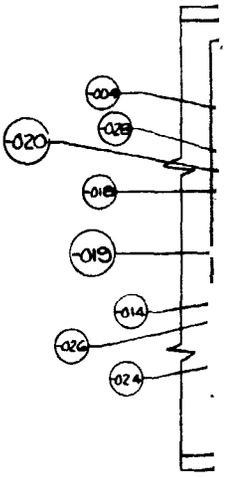
SECTION K-K 5/D 5

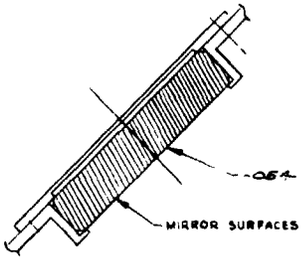


SECTION N-N 5/F 5



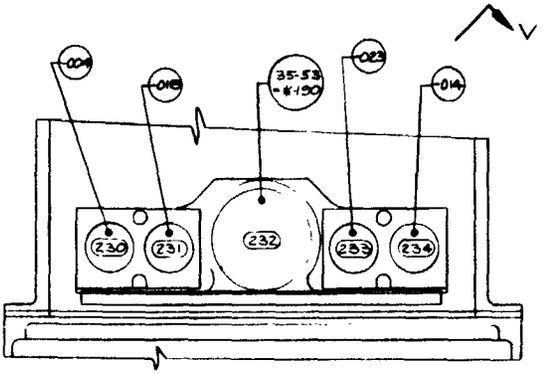
SECTION F-F 3/B 3





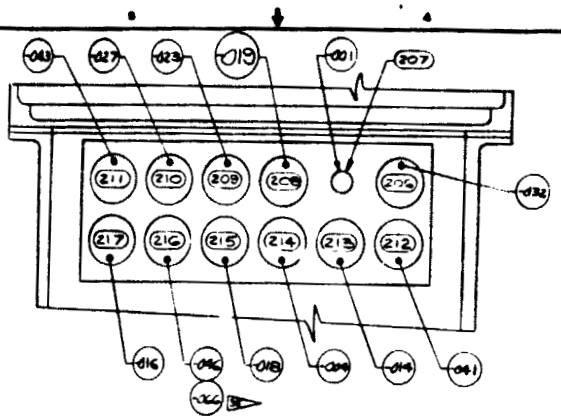
SECTION V-V 5/A 5

SCALE 2/1

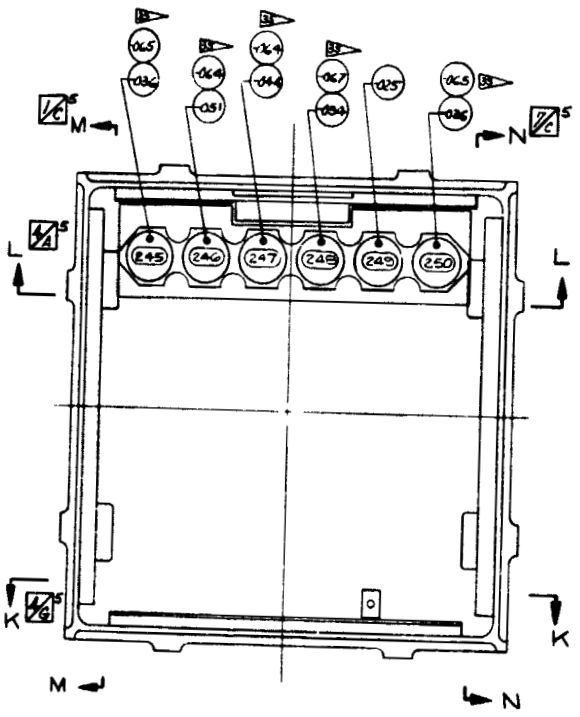


SECTION L-L 5/E 5

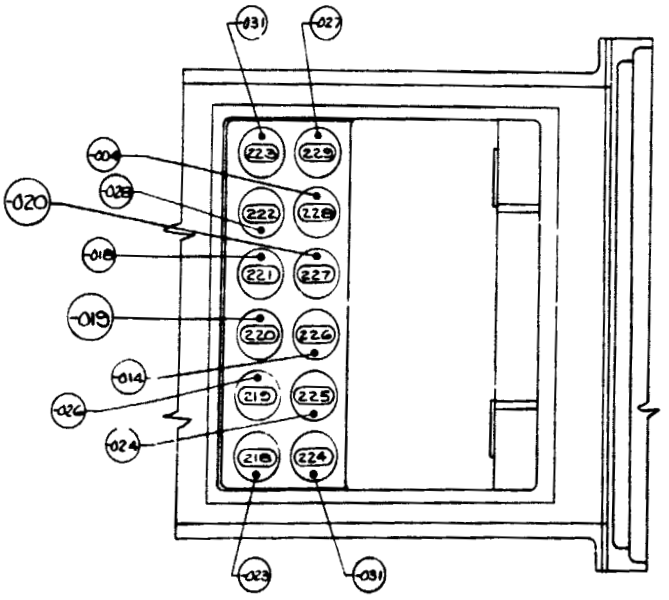
FOLDOUT FRAME 1



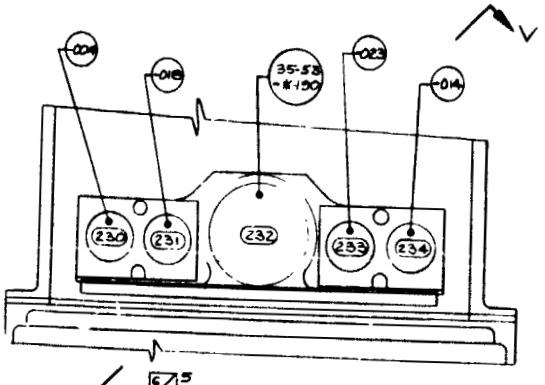
SECTION K-K



SECTION F-F



SECTION M-M



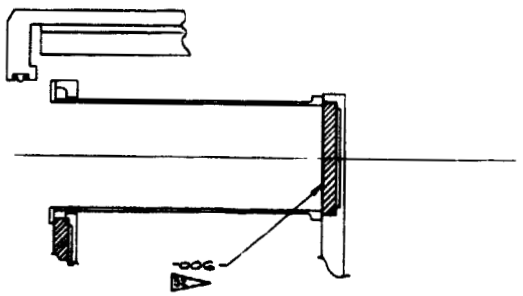
SECTION L-L

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FOLDOUT FRAME 2

8990 0000 124

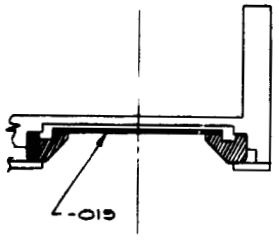
SHEET 6



SECTION W-W 3/C 4

SCALE 2/1

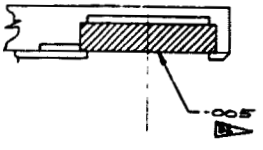
SIMILAR AT SAMPLE LOCATION NO. 35, 37, 41, 42, 43



SECTION S-S 5/B 4

SCALE 4/1

SIMILAR AT SAMPLE LOCATION NO. 100, 123, 82, 59, 72, 220, 227, 208, 67, 7 & 10



SECTION U-U 5/C 4

SCALE 4/1

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REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FOLDOUT FRAME 1

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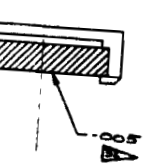

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REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

FOLDOUT FRAME 2

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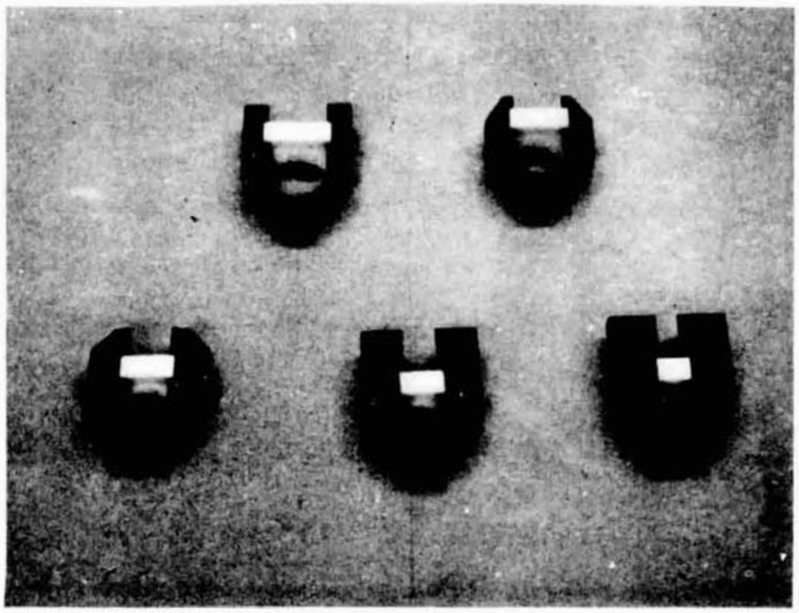

Figure 7. Sample Holders for Various Size Samples

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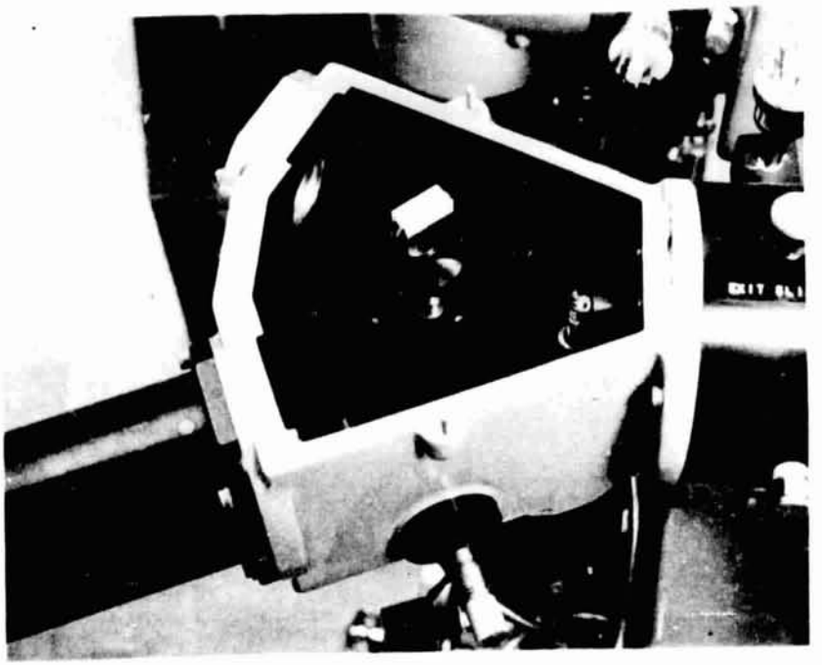

Figure 8. Sample Plus Holder in VUV Double Beam Attachment

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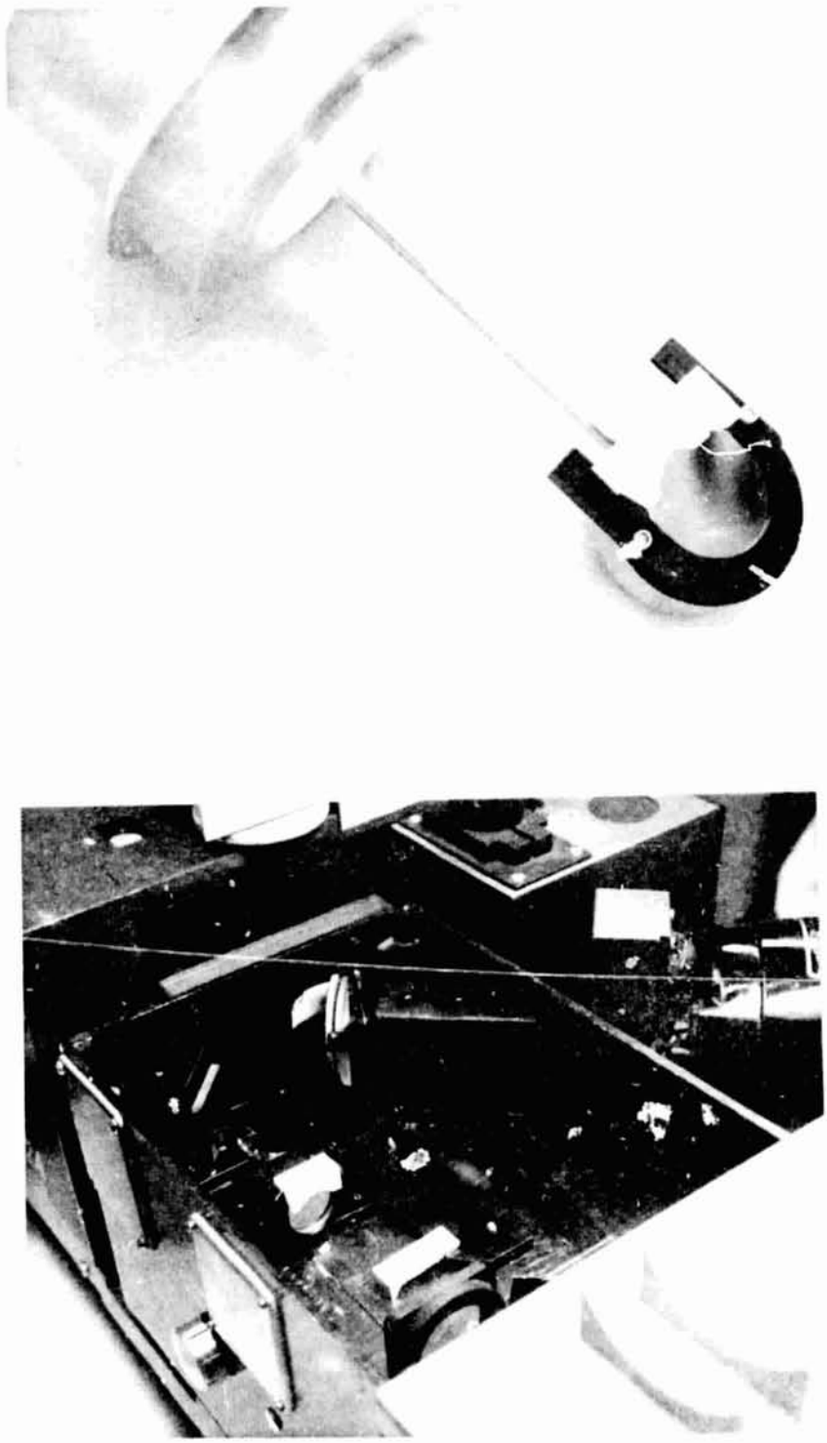

Figure 9. Sample Plus Holder in UV/Visible Reflectance & Transmittance

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR,

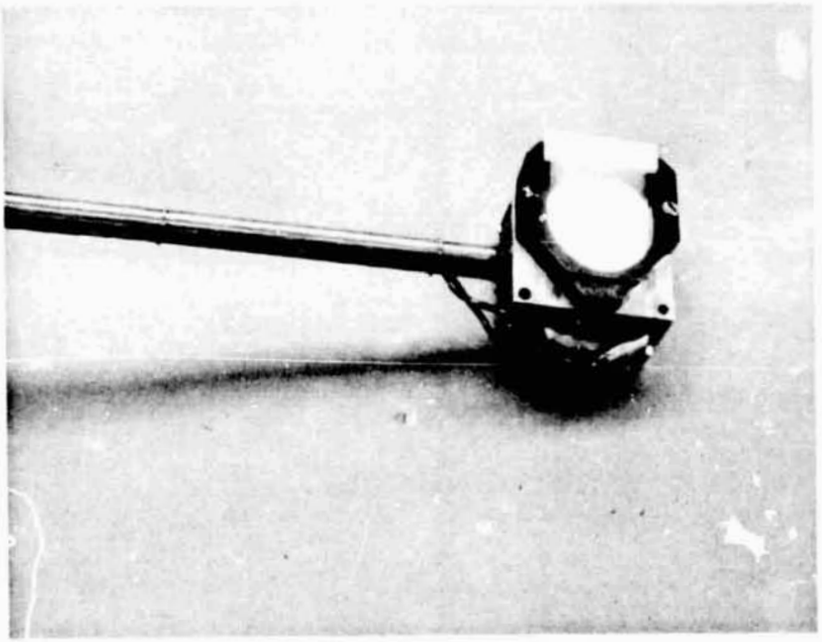

Figure 10. Sample Plus Holder in IR Parabolic Reflectometer

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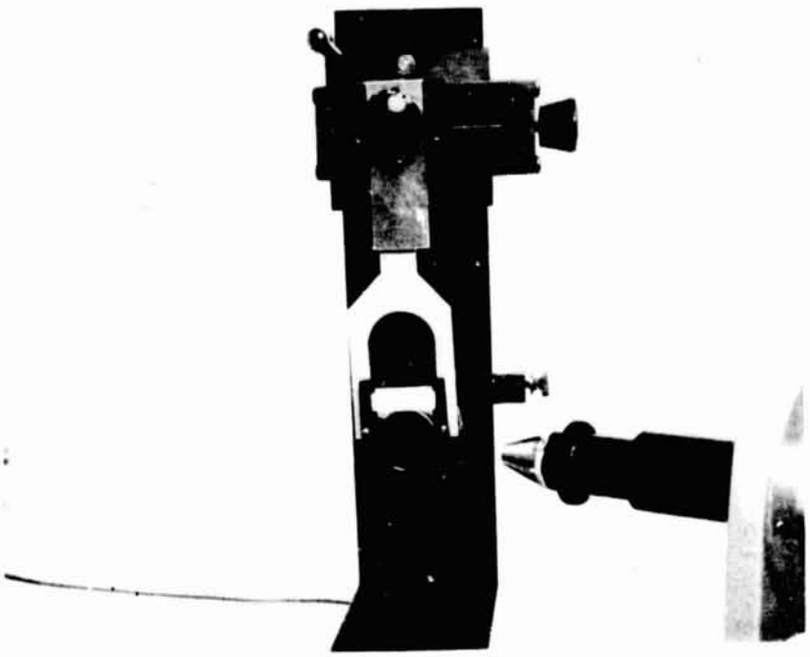

Figure 11. Sample Plus Holder in Ellipsometer

TABLE 1 - TO27 GUEST SCIENTIST SAMPLES

Sample Type	Quantity	Laboratory	Comments
Iridium Coated Cervit Mirrors	7	Harvard College Observatory F. Kasznski 617 - 495-3955	Reflectance at 461Å, 584Å, 735A, 743A, 919A, 932A, 1025A, 1048Å, 1066Å, and 1216A
Four Coated Mirrors in One Holder Pt, Ir, Os, W	1	Harvard College Observatory F. Kasznski 617 - 495-3955	Cervit Substrate Reflectance at same Wavelengths as Iridium
Au & Ni Crystals in One Holder	6	Marshall Space Flight Center P. Peters 205 - 453-5135	Auger Analysis, Type and Thickness of Contaminants
Electret	3	Marshall Space Flight Center E. Shriver 205 - 453-0942	Electrically Charged Teflon Disc
S13G Thermal Paint	2	Illinois Institute of Technology G. Zerlaut 312 - 225-9630	Emittance Changes
Quartz Crystal Microbalance	2	Marshall Space Flight Center R. Naumann 205 - 453-0940	Contaminant Mass Deposition
Optical Black	3	Optical Physics Laboratory J. Wade 303 - 794-5211	Reflectance Changes

arc seconds across the reflected beam and across the incident beam with the sample removed. The angle of incidence for the reflection measurements was 55 arc seconds. Reflection at near grazing incidence is very sensitive to small quantities of contaminant; however, if large amounts of contaminants are found, the beryllium foils will provide important data.

3.3.2 EUV Measurements - Both grazing incidence and normal incidence vacuum ultraviolet monochromators with a double beam attachment were used to measure the reflection and transmission of samples in the extreme ultraviolet, 280Å to 1200Å. Only aluminum foils were measured in wavelengths shorter than 600Å. A uranium anode pulsing light source was used to produce over 30 lines in the region 280Å to 1200Å. The source designed and built by R. Carlson, University of Southern California, was pulsed at a rate of 90 times per second, and compressed air furnished the gas for the discharge region. The double beam attachment consists of an oscillating mirror which deflects the light from the exit slit to the sample detector and then to the reference detector. The detectors are photomultipliers viewing the fluorescent emission from a sodium salicylate screen which is excited by the vacuum UV light. When reflection measurements are necessary, a rotatable light pipe painted with sodium salicylate near the sample is used to bring the reflected beam signal to the sample detector. Incident angles of 10 degrees and 45 degrees were used, and for some samples, additional angles of 30 degrees and 60 degrees were used. Because the signals vary quite rapidly, the ratio of the sample beam to the reference beam was performed by hand calculations. An electronic ratiometer could not follow accurately the signals in this wavelength region. The reflection and transmission of the sample is calculated with and without the sample present by the following equation:

$$\% \text{ Reflection/Transmission} = \frac{\text{Ratio of Detectors with Sample}}{\text{Ratio of Detectors without Sample}} \times 100\% \quad (1)$$

3.3.3 VUV Measurements - A normal incidence vacuum ultraviolet monochromator with a double beam attachment was used to measure the reflection and transmission of samples in the vacuum ultraviolet, 1200Å to 3000Å. A hydrogen gas discharge light source was used to produce a continuum in the region 1200Å to 3000Å. The double beam attachment again produces two beams for ratio recording. The ratio of the sample beam to the reference beam was done electronically. Incident angles of 10 degrees, 30 degrees, 45 degrees, and 60 degrees were used for the mirror samples.

3.3.4 UV/Visible Measurements - The transmission characteristic of the samples were obtained from 2500Å to 2.5 μm using a spectrophotometer. The instrument records the ratio of the sample beam to a reference beam. The percent transmission is calculated from the system output with and without the sample in the beam by the following equation:

$$\% \text{ Transmission} = \frac{\text{Detector Output with Sample}}{\text{Detector Output Without Sample}} \times 100\% \qquad (2)$$

The reflection characteristics of the mirrors were obtained with an integrating sphere attached to the spectrophotometer for the wavelength region 2500Å to 2.5 μm. The sample is placed at the center of the sphere and the reflected and reference beams are collected by the sphere and sensed by a common detector. Incident angles of 10 degrees, 30 degrees, 45 degrees, and 60 degrees were used.

Once again, the detector outputs with and without the samples present were used to calculate the reflection of the samples; namely,

$$\% \text{ Reflection} = \frac{\text{Detector Output with Sample}}{\text{Detector Output Without Sample}} \times 100\% \qquad (3)$$

3.3.5 IR Measurements - The transmission and attenuated total reflection measurements were done with a double beam infrared spectrophotometer. A Nernst glower is used as the source of infrared. Similar to the UV/Visible instrument, the transmission is obtained from a ratio with and without the sample.

The KRS-5 and Ge crystals are used to obtain the infrared spectrum of the contaminants from 2.5 μm to 15 μm using the technique of attenuated total reflection. Because the light interacts with the contaminant at each reflection (over 25 for this sample) this increases the sensitivity of internal reflection spectra over transmission spectra. The strengths and position of the absorption bands are used to determine the composition of the contaminant. Complete details on the procedure used in this technique can be found in a Martin Marietta Report #1610-69-44. "Internal Reflection Spectroscopy as a Technique for the Identification and Monitoring of Spacecraft Contamination Problems".

A parabolic reflectometer was used to measure the mirror samples. A heated cavity source provides the hemispherical incident infrared radiation onto the sample. The reflected radiation at 15 degrees with a field-of-view of 11 degrees is monitored by an infrared monochromator. The reflectance is determined by the ratio of the sample signals to a reference sample. The signals are digitized and processed by the REFLECT computer program. More details on this system can be found in the Martin Marietta Report #1610-68-43, "Parabolic Reflectometer - Description, Evaluation, and Preliminary Measurement Investigation".

3.3.6 Ellipsometry - A standard commercial ellipsometer was used to baseline the reflection effects of the clean mirror on the state of polarization of polarized light. The samples were measured at two angles of incidence; i.e., 50 degrees and 70 degrees. Because the platinum mirrors were partially transparent, additional angles of 35 degrees and 55 degrees were measured to avoid difficulties from second surface reflections. Further details on the technique used can be found in the Martin Marietta report #R-70-48641-005, "Ellipsometry as a Technique for Measuring the Thickness and Refractive Index of Spacecraft Contamination".

3.3.7 Grating Efficiency/Resolution - The gratings were measured for zero and first order diffraction reflection intensity using the ellipsometer fixed collimator arm and rotatable telescope arm. A collimated 3 mm beam from a mercury lamp was incident at 71.25 degrees onto the grating. Two data sets were taken; first, the source was unfiltered and the detector was scanned from zero order until the detector eclipsed the source in 1 degree increments; second, the lamp was filtered to pass 5461Å line and entire line plus zero order were scanned in 1 degree increments. The sodium yellow doublet was expecially scanned to document the resolution of the clean grating. The grating reflectance was measured from 650Å to 1300Å at incident angle of 11 degrees in the normal incidence vacuum ultraviolet monochromator.

3.3.8 Low Scatter Measurements - The nickel mirrors were measured for specular reflectance using the ellipsometer system and a helium gas laser source. The incident light at 67.5 degrees was apertured to 1 mm diameter. The detector was scanned in 1-degree increments from dark current to dark current through the maximum reflection. Five orders of sensitivity were used to map the reflected beam.

3.3.9 IR Absorption Spectra - A catalog of Martin Marietta measured contamination effects from ground simulation tests, laboratory programs, and space exposed surfaces was collected to aid in understanding and assessing the data to be returned from the T027 sample array. This work was funded by Martin Marietta under task number R-72-48641. The IR spectra of the following potential contaminants was measured:

A. Acetone

B. Amyl Alcohol

C. Benzene

D. Carbon Tetrachloride

E. Chloroform

F. Cooling Oil (Dow-Corning)

G. Cyclohexane

H. Dimethylamine

I. Dust

J. Ethanol

K. Formamide

L. Freon Solvents

M. High Vacuum Silicone Grease

N. Kapton

O. Methanol

P. Methylethylketone

Q. Monomethylhydrazine Nitrate

R. Mylar

S. Neoprene

T. Nitrobenzene

U. Polyethylene

V. Potting Epoxies

W. RTV Silicones

X. Silicone Potting Compounds

Y. Teflon

Z. Thermalac Coatings

AA. Tygon

BB. Urine

CC. Urine (Dried)

DD. Water (Distilled)

EE. Water (Salt)

FF. Water (Tap)

GG. Xylene

The spectra were obtained using the technique developed earlier and reported in the previous 48641 report #1610-69-44, "Internal Reflection Spectroscopy as a Technique for the Identification and Monitoring of Spacecraft Contamination Problems". Under the current task, methods of taking spectra were developed which allowed the spectra to be rapidly standardized with a minimum of corrections for background effects. Measurements have been added from the Skylab Ground Test Program, Lewis Research Center Rocket Test, and current laboratory studies.

3.3.10 Photography - Preflight black and white photographs were taken of all the 248 flight samples a few days before they were shipped to KSC for installation into the sample array. In addition, dark field photographs were taken of all the samples except the HCO mirrors, diffraction gratings, probe, and any replacement samples. The dark field photographs highlight surface conditions and imperfections by collecting the scattered light from the surface. Photographs of the installed samples in the array were taken at KSC.

3.4 Flight Sample Listing - Table 2 lists each of the 250 flight samples and the preflight measurements performed. Not listed in the table are the photographs of each sample taken at Martin Marietta and KSC. As can be seen from the table, the guest samples are listed for completeness but no information was available on what preflight measurements were performed.

3.5 Preflight Data Processing - The data from each of the measuring instruments (the data is in the form of chart recordings) was placed on computer punch cards for computer processing. Points are selected along the continuous chart recording to represent the spectral curve. A computer program, The T027 Optical Properties Analysis, was developed to process all of the reflectance and transmittance data obtained from the T027 samples. The program has five separate options; namely,

a. Multi Plots - Percent reflectance/transmittance versus wavelength for up to 15 curves;

b. Initial Test Ratio - Computes ratio of test curve to initial curve and plots this ratio versus wavelength;

c. Multi Spectrum Mean - Sums all values of any number of curves; divides sum by the number of curves; and generates a mean value versus wavelength, and plots it;

d. Deviation From Mean - In histogram form, shows the differences between the test and initial; test mean and initial mean; test and initial mean; and finally, test mean and initial;

e. Deviation and Editing Algorithm - Defines a boundary around the behavior of a like set of samples; shows the standard spread of variations. The editing algorithm flags unusual points which may be discarded as invalid.

The output of this program is a tabulated printout, hard copy plate, and microfilm. As examples of some preflight data, Fig. 12 shows a multi plot of reflectance versus wavelength for six Al + MgF_2 mirrors and the generated mean value shown by the dollar symbol. The legend can be read as follows for the

TABLE 2. PREFLIGHT SAMPLE MEASUREMENTS
(Sheet 1 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
1	QCM						MSFC
2	Al + MgF_2		1-3-73	8-21-72	10-26-72		3-19-73 Cleaned
3	Fused Quartz Flat				7-18-72 2-2-73		
4	OPL-Optical Black						Serial #001
5	Al + MgF_2		1-6-73	8-21-72	10-19-72 10-26-72		
6	Fused Quartz Flat				7-18-72 12-1-72		
7	Al Foil						Not Measured
8	Al + MgF_2		1-16-73	8-21-72	10-19-72 7-18-72		
9	Fused Quartz Flat				7-18-72		
10	Al Foil						Not Measured
11	Al + MgF_2		1-4-73	8-21-72 2-14-73	10-19-72 2-1-73		
12	Fused Quarts Flat				7-18-72		
13	Al Foil						Not Measured
14	Al + MgF_2		1-16-73	11-15-72 8-23-72	10-20-72		1-27-73 Cleaned

TABLE 2. (Continued)
(Sheet 2 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
15	Fused Quartz Flat				7-13-72		
16	Al Foil						Not Measured
17	Al + MgF_2		1-4-73	8-23-72 11-15-72	10-20-72		
18	Fused Quartz Flat				7-17-72		
19	HCO - Iridium						Serial #72
20	MgF_2			9-22-72	7-13-72		
21	Pt		1-3-72	8-23-72 10-18-72	10-30-72		1-17-73 Ellipsometry 3-19-73 Cleaned
22	MgF_2			9-22-72	7-13-72 12-1-72		
23	Pt		1-3-72	8-23-72 10-18-72	10-30-72 2-1-73		1-17-73 Ellipsometry
24	MgF_2			9-22-72	7-13-72		
25	Pt		1-3-72	8-23-72 10-18-72	10-30-72		1-26-73 Cleaned
26	MgF_2			9-22-72	7-13-72		
27	Pt		1-17-73	8-23-72 10-18-72	10-30-72		

TABLE 2. (Continued)
(Sheet 3 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
28	MgF_2		1-17-73	9-22-72	7-13-72 2-2-73		
29	Pt		1-17-73	8-23-72 10-18-72	10-30-72		
30	MgF_2			9-22-72	7-13-72		
31	Pt		1-17-73	8-23-72 10-18-72	10-30-72		
32	MSFC-H						Au and Ni Crystals
33	Au		1-15-73	8-7-72	8-21-72 8-28-72 10-18-72	8-31-72 2-6-73	1-26-73 Cleaned
34	Al + MgF_2		1-19-73 12-29-73	8-9-72 12-13-72	10-26-72		
35	Al + MgF_2		1-4-73	9-7-72	10-31-72 12-7-72 2-1-73		1-26-73 Cleaned
36	Al + MgF_2		1-2-73	7-19-72	9-20-72 11-7-72 1-29-73 1-29-73		1-26-73 Cleaned
37	MgF_2		1-4-73	10-2-72	10-31-72 12-8-72		1-26-73 Cleaned

TABLE 2. (Continued)
(Sheet 4 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
38	Al		1-19-73	8-9-72 12-29-72	11-16-72 12-18-72		1-12-73 Ellipsometry 2-13-73 Ellipsometry
39	Al + LiF		1-17-73	8-10-72 8-18-72 12-22-72 2-13-73	11-15-72 1-30-73		1-26-73 Cleaned
40	Al + MgF_2		1-2-73	9-29-72 10-16-72	10-26-72 11-13-72		
41	Al + MgF_2		12-29-72	8-9-72	10-26-72 12-7-72		
42	Al + MgF_2		1-2-73	8-8-72 2-13-73	10-26-72 1-29-73		1-26-73 Cleaned
43	Al + MgF_2		1-4-73	10-2-72	10-31-72		1-26-73 Cleaned
44	Au		1-18-73	8-7-72 12-28-72	8-28-72	2-9-73	1-16-73 Ellipsometry
45	Fused Quartz				7-10-72		
46	HCO-Composite Mirror						Pt Ir, Os, W
47	Al + MgF_2			7-19-72 12-22-72	9-20-72 11-7-72		
48	Fused Quartz Flat	10-11-72			6-30-72 2-2-73		1-26-73 Cleaned 1-26-73 Ellipsometry

TABLE 2. (Continued)
(Sheet 5 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
49	Sapphire				6-16-72 7-12-72		
50	Fused Quartz				7-10-72		
51	Pt		1-9-73	8-3-72 12-22-72	8-10-72 12-6-72		1-17-73 Ellipsometry 1-26-73 Cleaned
52	MgF_2			9-21-72	6-22-72 12-20-72		
53	MgF_2			9-20-72	6-22-72 10-16-72 2-2-73		
54	QCM						MSFC
55	Grating		1-22-73				1-23-73 Hg Lines
56	Pt		1-9-73	12-27-72	8-7-72 12-6-72		1-18-73 Ellipsometry 1-26-73 Cleaned 2-13-73 Ellipsometry
57	Al + MgF_2			7-20-72 1-2-73	9-20-72 11-7-72		
58	Au		12-28-72 1-18-73	8-8-72	8-28-72 9-6-72	2-9-73	1-16-73 Ellipsometry
59	Al Foil		9-9-72 2-7-73				

TABLE 2. (Continued)
(Sheet 6 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
60	Pt		1-9-73	7-25-72 12-27-72	8-8-72 12-5-72		1-15-73 Ellipsometry 1-26-73 Cleaned
61	Fused Quartz Flat	10-11-72			6-30-72		
62	Au		1-18-73	8-8-72 12-27-72 2-13-73	9-6-72 1-31-73	2-9-73	1-16-73 Ellipsometry 1-26-73 Cleaned
63	MSFC-E						Au and Ni Crystals
64	Ge/ATR						10-25-72 IR Baseline
65	KRS5/ATR						9-29-72 IR Baseline 10-25-72 IR Baseline
66	Grating		1-19-73				1-23-73 Hg Lines
67	Al Foil		2-6-73				
68	Ge					2-14-73	2-13-73 Ellipsometry
69	Al + MgF_2		1-10-73	7-20-72 2-13-73	10-26-72 11-13-72 1-30-73		
70	Pt		1-10-73	7-24-72 10-17-72	8-14-72		
71	Al + MgF_2		1-10-73	7-20-72	10-26-72 11-8-72 12-20-72 12-21-72		

TABLE 2. (Continued)
(Sheet 7 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
72	Al Foil		2-7-73				
73	Al + MgF_2		1-10-73	7-20-72	10-26-72 11-13-72		1-26-73 Cleaned
74	Fused Quartz Flat	10-11-72			7-5-72		
75	Al + MgF_2		1-10-73	7-20-72	10-27-72 11-08-72		
76	MgF_2			9-20-72	6-27-72		
77	Fused Quartz				7-7-72		
78	LiF			9-22-72	10-24-72 11-28-72		
79	Fused Quartz				7-7-72 2-2-73		
80	MSFC-K						Au and Ni Crystals
81	Fused Quartz				7-10-72		
82	Al Foil		2-8-73				
83	Fused Quartz				7-10-72		
84	Ge				1-29-73	2-14-73	UV/VIS ge mirror
85	LiF				10-25-72 11-28-72 2-2-73		

TABLE 2. (Continued)
(Sheet 8 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
86	Pt		1-10-73	7-25-72	8-8-72		
87	Sapphire				7-12-72 2-2-73		
88	Pt		1-10-73	7-25-72 2-14-73	8-8-72 1-3-73 1-31-73		2-13-73 Ellipsometry
89	MSFC-M						Au and Ni Crystals
90	Pt		1-11-73	8-2-72	8-9-72		
91	Ge					2-14-73	
92	Pt		1-13-73	8-2-72	8-9-72		
93	Ge/ATR					10-26-72	
94	Fised Quartz Flat	10-11-72			7-5-72		
95	Pt		1-11-73	8-3-72	8-14-72		
96	MgF_2			9-20-72	6-21-72		
97	Al + MgF_2		1-11-73	7-21-72	10-30-72 11-8-72		
98	KRS5/ATR					9-29-73 10-25-73	
99	Probe						Not Measured

TABLE 2. (Continued)
(Sheet 9 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
100	Be Foil	6-2-72 6-23-72	2-9-73				
101	HCO-Iridium						Serial #82
102	HCO - Iridium						Serial #81
103	HCO - Iridium						Serial #83
104	Probe						Not Measured
105	Al + MgF_2		1-3-73	7-12-72 7-18-72 10-17-72	8-3-72 12-7-72 12-13-72		1-26-73 Cleaned
106	Al + MgF_2		1-12-73	7-19-72	10-27-72 11-7-72		7-19-72 Cleaned
107	Al + MgF_2			1-3-73 2-13-73	8-3-72 8-14-72 12-7-72 12-13-72 1-30-73		
108	Ni		12-28-72 1-18-72	9-28-72 10-16-72 2-14-73	9-18-72 11-14-72 12-4-72 1-3-73 1-31-73		1-16-73 Ellipsometry 1-24-73 Ellipsometry 2-12-73 Ellipsometry
109	Chromium		1-22-73		12-6-72 1-31-73		

TABLE 2. (Continued)
(Sheet 10 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
110	IIT S-13G						Thermal Control Paint
111	Probe						Not Measured.
112	OPL-Optical Black				12-5-72		Serial MB-001
113	Chromium				1-22-73		
114	Chromium				1-23-73		2-12-73 Ellipsometry
115	Al Foil		2-8-73				
116	Probe						Not Measured.
117	MSFC-A1						Electret, Positive Charge
118	MSFC-B1						Electret,Negative Charge
119	MSFC-N1						Electret, Neutral
120	MgF_2			9-21-72	6-21-72		
121	Pt		1-11-73	8-3-72	8-14-72		
122	Fused Quartz Flat				7-5-72		
123	Be Foil	6-14-72					
124	IIT S-13G						Thermal Control Paint
125	Au		1-15-73	9-29-73	9-19-72	2-9-73	1-16-73 Ellipsometry
126	HCO - Iridium						Serial #80

TABLE 2. (Continued)
(Sheet 11 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
127	Ni		1-18-73	9-29-72 12-28-72	9-20-72 10-18-72 11-14-72		1-15-73 Ellipsometry 1-25-73 Ellipsometry 3-21-73 Cleaned
128	Al + MgF_2		1-4-73	8-24-72 9-29-72	9-7-72		1-26-73 Cleaned
129	Al + MgF_2			8-24-72 9-29-72	9-7-72 11-17-72		1-26-73 Cleaned
130	Al + MgF_2			8-24-72 9-29-72	9-7-72 11-17-72		1-26-73 Cleaned
131	Al + MgF_2			8-24-72 10-2-72	9-7-72 11-17-72		
132	Al + MgF_2		1-5-73	8-24-72 10-2-72	9-7-72		
133	Al + MgF_2			8-24-72 10-6-72	9-7-72		
134	Al + MgF_2			8-24-72 10-6-72	9-7-72		
135	Al + MgF_2			8-25-72 10-6-72 11-22-72	9-7-72		
136	Al + MgF_2		1-5-73	8-25-72 10-6-72 11-17-72	9-7-72		

TABLE 2. (Continued)
(Sheet 12 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
137	Al + MgF_2			8-25-72 10-9-72 11-17-72	9-7-72		
138	Al + MgF_2			10-9-72 11-22-72	8-25-72 9-11-72		
139	Al + MgF_2			8-25-72 10-9-72 11-21-72	9-11-72		
140	Al + MgF_2		1-5-73	8-25-72 10-9-72 11-21-72	9-11-72		
141	Al + MgF_2			8-25-72 10-4-72 10-5-72 11-22-72	9-11-72		10-5-72 Cleaned 1-26-72 Cleaned
142	Al + MgF_2			8-28-72 10-4-72 11-16-72	9-11-72		
143	Al + MgF_2			8-28-72 10-4-72 11-16-72	9-11-72		
144	Al + MgF_2		1-8-73	8-28-72 10-10-72 11-16-72	9-11-72		

TABLE 2. (Continued)
(Sheet 13 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
145	Al + MgF_2		1-8-73	8-28-72 10-10-72 11-16-72	9-11-72		
146	Al + MgF_2		1-8-73	8-28-72 10-12-72 11-15-72	9-11-72		1-26-73 Cleaned
147	Al + MgF_2		1-8-73	8-29-72 10-12-72	9-11-72 11-21-72		
148	Al + MgF_2		1-5-73	8-29-72 10-12-72	9-12-72		
149	Al + MgF_2		1-8-73	8-30-72 10-11-72	9-12-72		
150	Al + MgF_2		1-8-73	8-30-72 10-11-72	9-12-72		
151	Al + MgF_2		1-8-73	8-30-72 10-12-72	9-12-72		
152	Al + MgF_2		1-5-73	9-6-72 10-12-72	9-12-72		
153	Al + MgF_2		1-8-73	9-6-72 10-12-72	9-13-72		1-26-73 Cleaned
154	MgF_2			9-22-72	7-19-72		
155	MgF_2			9-22-72	7-19-72		

TABLE 2. (Continued)
(Sheet 14 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
156	MgF_2			9-25-72	7-19-72 12-1-72		
157	MgF_2			9-25-72	7-19-72		
158	MgF_2			9-25-72	7-19-72		
159	MgF_2			9-25-72	7-19-72		
160	MgF_2			9-25-72	7-20-72 2-2-73		
161	MgF_2			9-25-72	7-20-72		
162	MgF_2*				2-14-72		*Sample Cracked; Replaced at KSC by Backup Sample #268, 3-9-73.
163	MgF_2			9-25-72 10-19-72	7-20-72		
164	MgF_2			9-25-72	7-20-72		
165	MgF_2			9-25-72	7-20-72		
166	MgF_2			9-25-72	7-20-72		
167	MgF_2			9-25-72 10-19-72	7-21-72		
168	MgF_2		9-25-72 10-19-72	7-21-72 12-1-72			

TABLE 2. (Continued)
(Sheet 15 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
169	MgF_2			9-26-72	9-21-72		
170	MgF_2			9-26-72	7-21-72		
171	MgF_2			9-26-72	7-24-72		
172	MgF_2			9-26-72	7-24-72		
173	MgF_2			9-26-72	7-24-72 12-1-72		
174	MgF_2			9-26-72	7-24-72		
175	MgF_2			9-26-72	7-24-72		
176	MgF_2			9-26-72	7-24-72		
177	MgF_2			9-26-72	7-24-72		
178	MgF_2			9-26-72	7-24-72		
179	MgF_2			9-26-72	7-24-72 12-1-72		
180	Fused Quartz				7-25-72 7-28-72		
181	Fused Quartz				7-25-72 7-28-72		
182	Fused Quartz				7-25-72 7-28-72 2-2-73		

TABLE 2. (Continued)
(Sheet 16 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
183	Fused Quartz				7-25-72 7-28-72 10-23-72		
184	Fused Quartz				7-25-72 7-28-72 7-31-72 10-23-72		
185	Fused Quartz				7-25-72 7-28-72 7-31-72 10-23-72		
186	Fused Quartz				7-26-72 7-28-72		
187	Fused Quartz				7-26-72 7-28-72		
188	Fused Quartz				7-26-72 7-31-72		
189	Fused Quartz				7-26-72 7-31-72		
190	Fused Quartz				7-26-72 7-31-72		
191	Fused Quartz				7-26-72 7-31-72		

TABLE 2. (Continued)
(Sheet 17 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
192	Fused Quartz				7-27-72 7-27-72		
193	Fused Quartz				7-27-72		
194	Fused Quartz				8-1-72		
195	Fused Quartz				8-1-72		
196	Fused Quartz				8-1-72		
197	Fused Quartz				8-1-72		
198	Fused Quartz				8-1-72		
199	Fused Quartz				8-1-72		
200	Fused Quartz				2-21-73		Previous Sample Broken 2-20-73
201	Fused Quartz				8-1-72		
202	Fused Quartz				2-21-73		Previous Sample Broken 2-20-73
203	Fused Quartz				8-1-72		
204	Fused Quartz				8-1-72		
205	Fused Quartz				8-1-72		
206	Ni		1-18-73	8-21-72 12-28-72	8-2-72 11-14-72		1-15-73 Ellipsometry

TABLE 2. (Continued)
(Sheet 18 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
207	Probe						Not Measured.
208	Al Foil		?-8-73				
209	Pt		1-12-73	8-4-72	8-7-72		
210	LiF		1-17-73	7-18-72 10-16-72 12-27-72	11-15-72 12-13-72		
211	MSFC-N						Au and Ni Crystals
212	OPL - Optical Black				12-5-72		Serial #MB-002
213	Fused Quartz Flat	7-19-72			7-19-72		
214	Al + MgF_2		1-12-73	7-24-72 10-16-72	10-27-72 11-8-72 11-16-72		
215	MgF_2			9-21-72	6-21-72		
216	MSFC-D						Au and Ni Crystals
217	Fused Quartz				7-10-72 11-28-72		
218	Pt		1-12-73	8-7-72	8-11-72		
219	Al		1-16-73	8-10-72 8-18-72	11-16-72		1-12-73 Ellipsometry
220	Al Foil		2-8-73				

TABLE 2. (Continued)
(Sheet 19 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
221	MgF_2			9-21-72	6-20-72		
222	Au		1-15-73	8-8-72	8-23-72 10-30-72 11-13-72 12-14-72	2-7-73	1-26-73 Cleaned
223	LiF			9-22-72	10-18-72 10-25-72 11-28-72		
224	LiF			9-22-72	11-28-72		
225	Ge					2-14-73	
226	Fused Quartz				6-30-72		
227	Be Foil	6-31-6-23, 1972					
228	Al + MgF_2		1-12-73	7-24-72 10-16-72	10-27-72 11-8-72		
229	Al + LiF		1-17-73	7-18-72 10-17-72 12-27-72	11-15-72		
230	Al + MgF_2		1-12-73	7-21-72	10-30-72		
231	MgF_2			9-8-72 9-21-72	6-21-72		
232	Grating		1-19-73				1-24-73 Hg Lines

TABLE 2. (Continued)
(Sheet 20 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
233	Pt		1-12-73	8-7-72	8-11-72		
234	Fused Quartz Flat	7-19-72			6-30-72		
235	Ge					2-14-73	3-19-73 Cleaned
236	Be Foil	6-14-72					
237	KRS5/ATR					9-29-72 10-25-72	3-21-73 Cleaned
238	Ge/ATR				7-10-72		
239	Fused Quartz				11-30-72		
240	Sapphire				6-19-72 7-12-72		1-26-73 Cleaned 3-19-73 Cleaned
241	Fused Quartz Flat	7-19-72			6-30-72		1-26-73 Cleaned
242	Al + MgF_2		1-15-73	7-24-72 10-19-72	10-27-72 11-7-72		1-26-73 Cleaned 3-19-73 Cleaned
243	Pt		1-15-73	8-3-72	8-7-72		1-26-73 Cleaned
244	MgF_2			9-21-72	6-27-72		
245	HCO-Iridium						Serial #88
246	Ni				1-23-73		Replacement Sample
247	Ni						Replacement Sample

TABLE 2. (Concluded)
(Sheet 21 of 21)

SAMPLE NUMBER	SAMPLE TYPE	MEASUREMENT (DATE)					MISCELLANEOUS
		X-RAY	EUV	VUV	UV/VISIBLE	IR	
248	Chromium				1-22-73		Replacement Sample
249	Au		1-18-73	8-9-72 12-28-72	10-30-72 12-7-72 1-31-73	2-9-73	1-16-73 Ellipsometry
250	HCO-Iridium						Serial #91

diamond symbol:

> Sample Number 11 Case 1, sample type -003 listed in drawing #8900000124, aluminum mirror overcoated with magnesium fluoride, 7/8 in. diameter, measured by the DK2A spectrophotometer, chart #1458, measured on October 20, 1972, incident angle of 10 degrees.

Figure 13 shows the ratio of the reflectance for sample #8 to the computed mean for all six samples versus wavelength. Figure 14 shows one of the six similar pages of tabulated data for these six samples; in this case, the data for sample #8. Figure 15 shows the mean and three sigma plots for these same samples. Figure 16 is the tabulated three sigma value. Figure 17 shows the spread in reflectance for some Al + MgF_2 mirrors in the VUV region. Figures 18 and 19 illustrate the reflectance and three sigma values for samples in the EUV region.

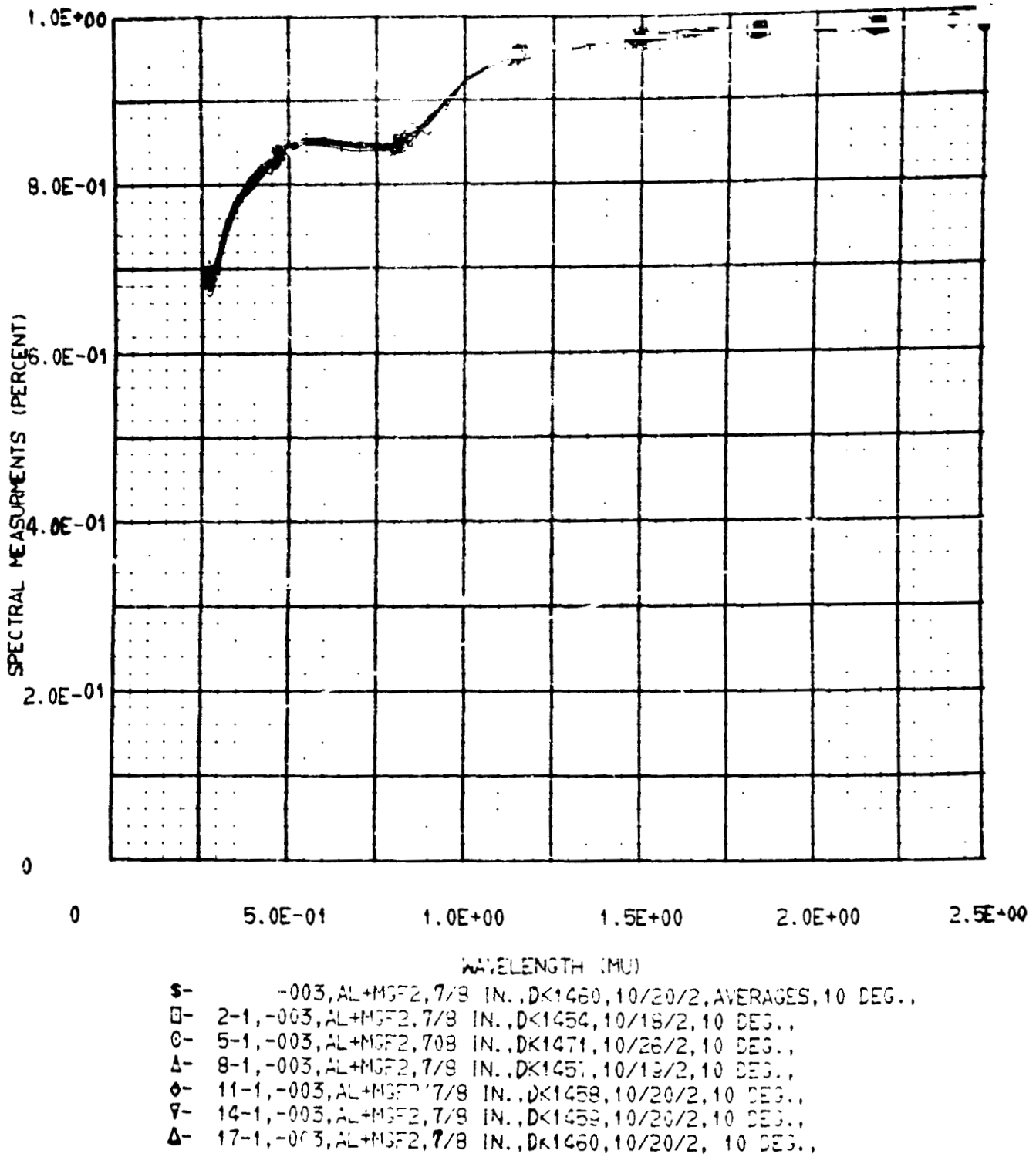

Figure 12. Multi Plots of Reflectance Versus Wavelength for 6 Al+MgF_2 Mirrors

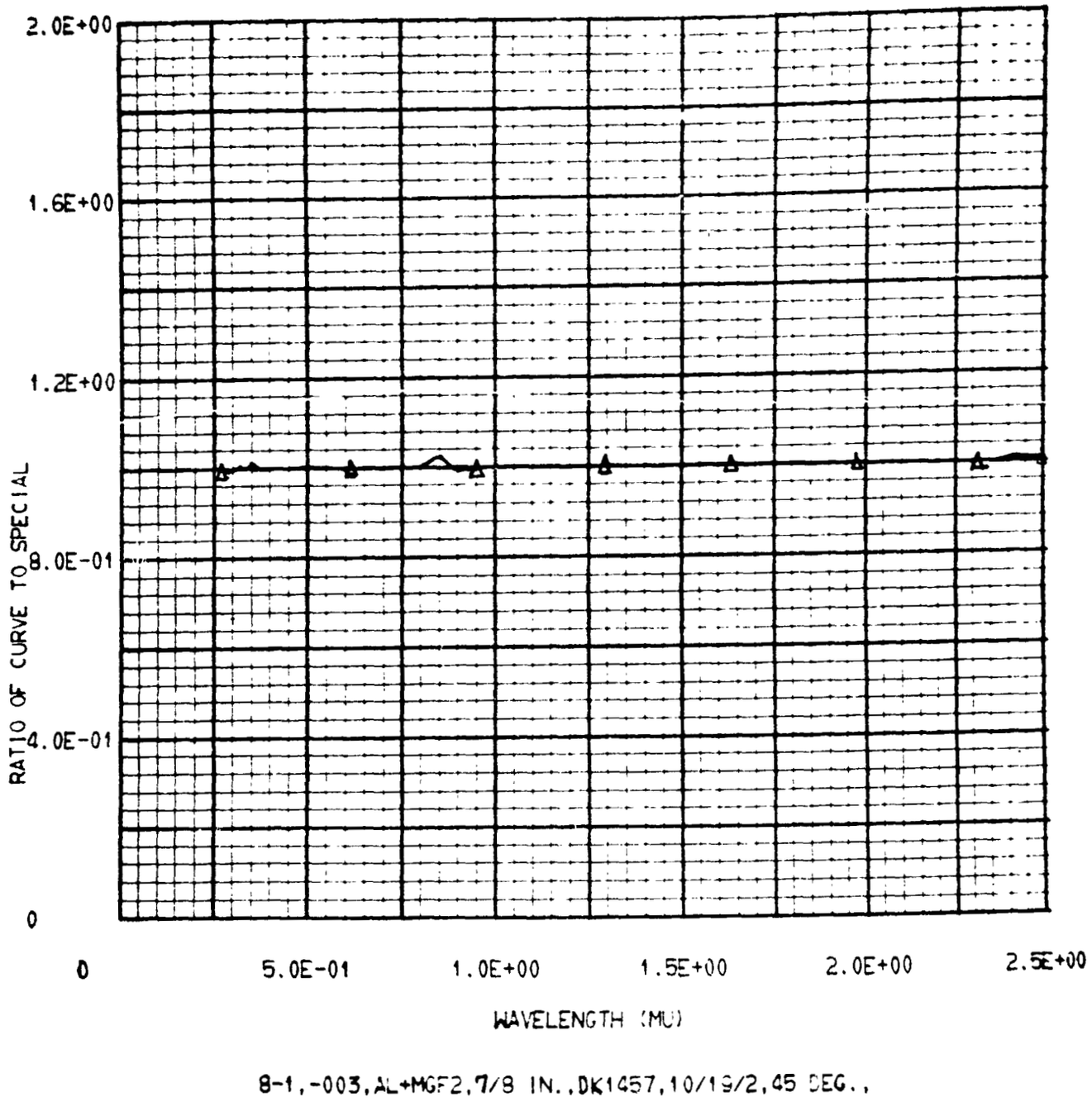

Figure 13. Ratio of Sample 8 Curve to Mean of All Six Mirrors

WAVELENGTH (MICRONS)		BAND	MEAN TEST REFLECTANCE CURVE	MEAN TEST ABSORBTANCE (1. - REF.)	RATIO OF TEST CURVE TO SPECIAL (CURVE/SPECIAL.)	MEAN SPECIAL REFLECTANCE CURVE	VARIANCE FROM SPECIAL (SPECIAL-CURVE)
.270TO	.300	UV	.698442	.301558	1.00	.696667	-.001775
.300TO	.400	UV	.775898	.224102	1.01	.770200	-.005698
.400TO	.400	UV	.810235	.189765	1.01	.805000	-.005235
.400TO	.500	VISIBLE	.830001	.169999	1.00	.826625	-.003376
.500TO	.600	VISIBLE	.849976	.150024	1.00	.849500	-.000476
.600TO	.700	VISIBLE	.849560	.150440	1.00	.848500	-.001060
.700TO	.700	VISIBLE	.847826	.152174	1.00	.845000	-.002826
.700TO	.800	NEAR IR	.846413	.153587	1.00	.845000	-.001413
.800TO	.900	NEAR IR	.862708	.137292	1.01	.855500	-.007208
.900TO	1.000	NEAR IR	.890110	.109890	.993	.896500	.006390
1.000TO	1.000	NEAR IR	.923077	.076923	1.00	.922000	-.001077
1.000TO	1.100	NEAR IR	.935008	.064992	1.00	.935000	-.000008
1.100TO	1.100	NEAR IR	.946939	.053061	.999	.948000	.001061
1.100TO	1.200	IR	.952084	.047916	.999	.953000	.000916
1.200TO	1.300	IR	.960849	.039151	.100E+01	.961000	.000151
1.300TO	1.400	IR	.965482	.034518	.999	.966500	.001018
1.400TO	1.500	IR	.968020	.031980	.997	.970500	.002480
1.500TO	1.600	IR	.972081	.027919	.999	.973500	.001419
1.600TO	1.700	IR	.975635	.024365	.100E+01	.976000	.000365
1.700TO	1.800	IR	.976685	.023315	.999	.977500	.000815
1.800TO	1.900	IR	.978208	.021792	.100E+01	.978500	.000292
1.900TO	2.000	IR	.978208	.021792	.999	.979000	.000792
2.000TO	2.100	IR	.978239	.021761	.999	.979000	.000761
2.100TO	2.200	IR	.979778	.020222	.100E+01	.980000	.000222
2.200TO	2.300	IR	.979798	.020202	.998	.982000	.002202
2.300TO	2.400	IR	.985859	.014141	1.00	.983500	-.002359
2.400TO	2.499	IR	.986869	.013131	1.00	.984500	-.002369

-003,AL+MGF2,7/8 IN.,DK1460,10/20/2,AVERAGES,10 DEG.;
8-1,-003,AL+MGF2,7/8 IN.,DK1457,10/19/2,10 DEG.,

Figure 14. Tabulated Form of Reflectance Vs Wavelength for Sample 8 and the Mean of All Six Mirrors

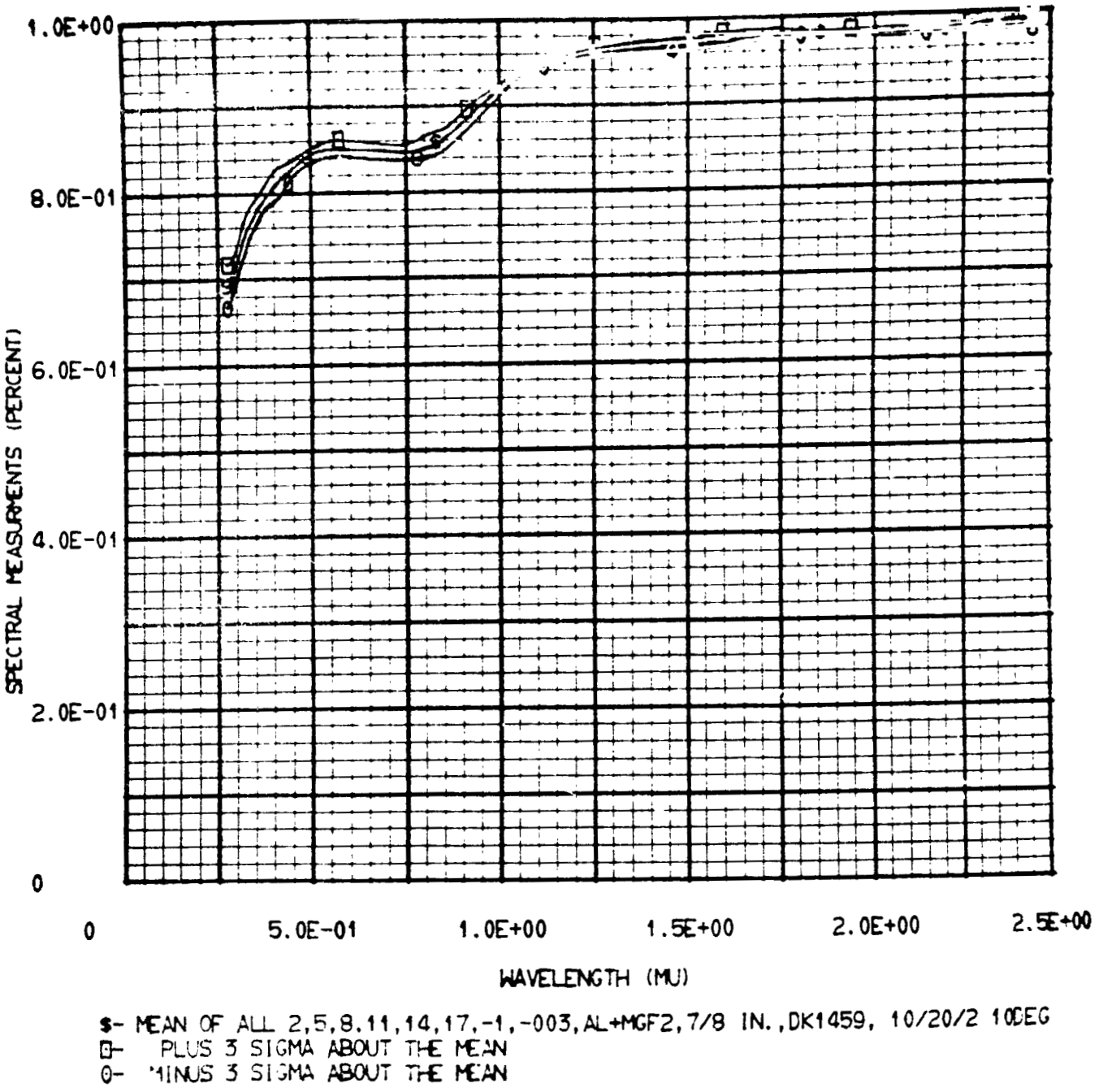

Figure 15. Plot of 3 Sigma About the Mean of Reflectance Vs Wavelength

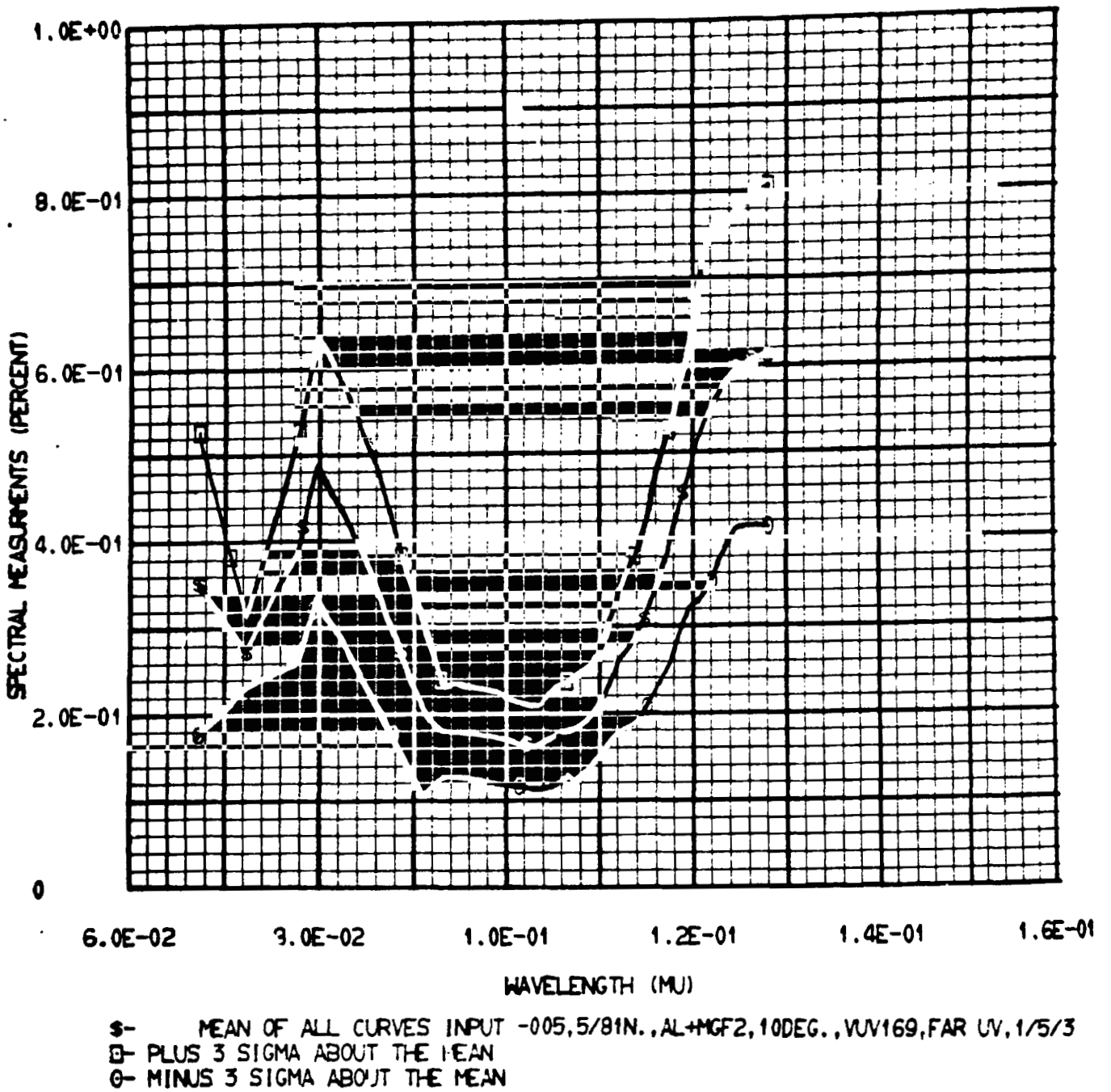

Figure 16. Plot of 3 Sigma About the Mean of Reflectance Versus Wavelength for the 14 Al+MgF_2 Mirrors

OPTICAL COMPUTATIONS CASE 6

WAVELENGTH (MICRONS)	MEAN VALUE OF ALL CURVES	3 SIGMA (STANDARD DEVIATION)	MINIMUM MEASUREMENT	MAXIMUM MEASUREMENT
.27500	.691551	.02524	.67929	.70291
.28500	.697225	.02376	.68545	.70736
.29500	.706368	.02085	.69575	.71550
.30500	.722180	.01930	.71314	.72972
.31500	.740707	.01995	.73146	.74592
.32500	.754108	.02007	.74490	.75947
.33500	.764403	.01761	.75656	.76843
.34500	.773792	.01553	.76698	.77919
.35500	.781456	.01365	.77467	.78640
.36500	.788535	.01215	.78213	.79278
.37500	.794500	.01359	.78761	.79872
.38500	.799519	.01668	.79110	.80611
.39500	.804162	.01692	.79650	.81096
.41250	.812783	.01821	.80492	.81882
.43750	.822819	.01260	.81771	.82688
.46250	.832052	.00719	.82867	.83442
.48750	.840810	.00899	.83718	.84475
.52500	.848077	.00910	.84455	.85259
.57500	.852037	.00914	.84785	.85529
.65000	.848768	.01010	.84309	.85157
.73000	.845534	.00852	.84094	.84808
.85000	.859060	.01278	.85107	.86246
.95000	.897780	.01173	.89011	.90055
1.05000	.935664	.00304	.93418	.93717
1.15000	.953487	.00427	.95188	.95565
1.25000	.961575	.00597	.95831	.96390
1.35000	.967029	.00730	.96294	.96942
1.45000	.970649	.00819	.96802	.97360
1.55000	.973407	.00860	.96911	.97716
1.65000	.976547	.00760	.97367	.98122
1.75000	.978537	.00552	.97665	.98125
1.85000	.979244	.00261	.97817	.98028
1.95000	.979269	.00323	.97821	.98095
2.05000	.978944	.00540	.97573	.98095
2.15000	.979893	.00419	.97727	.98098
2.25000	.981532	.00486	.97980	.98333
2.35000	.984083	.00641	.98081	.98636
2.44950	.985385	.00882	.98081	.98859

-003,AL+MGF2,7/8 IN.,DK1454,10/18/2,10 DEG.,

Figure 17. Tabulated Form of 3 Sigma About the Mean of Reflectance Versus Wavelength

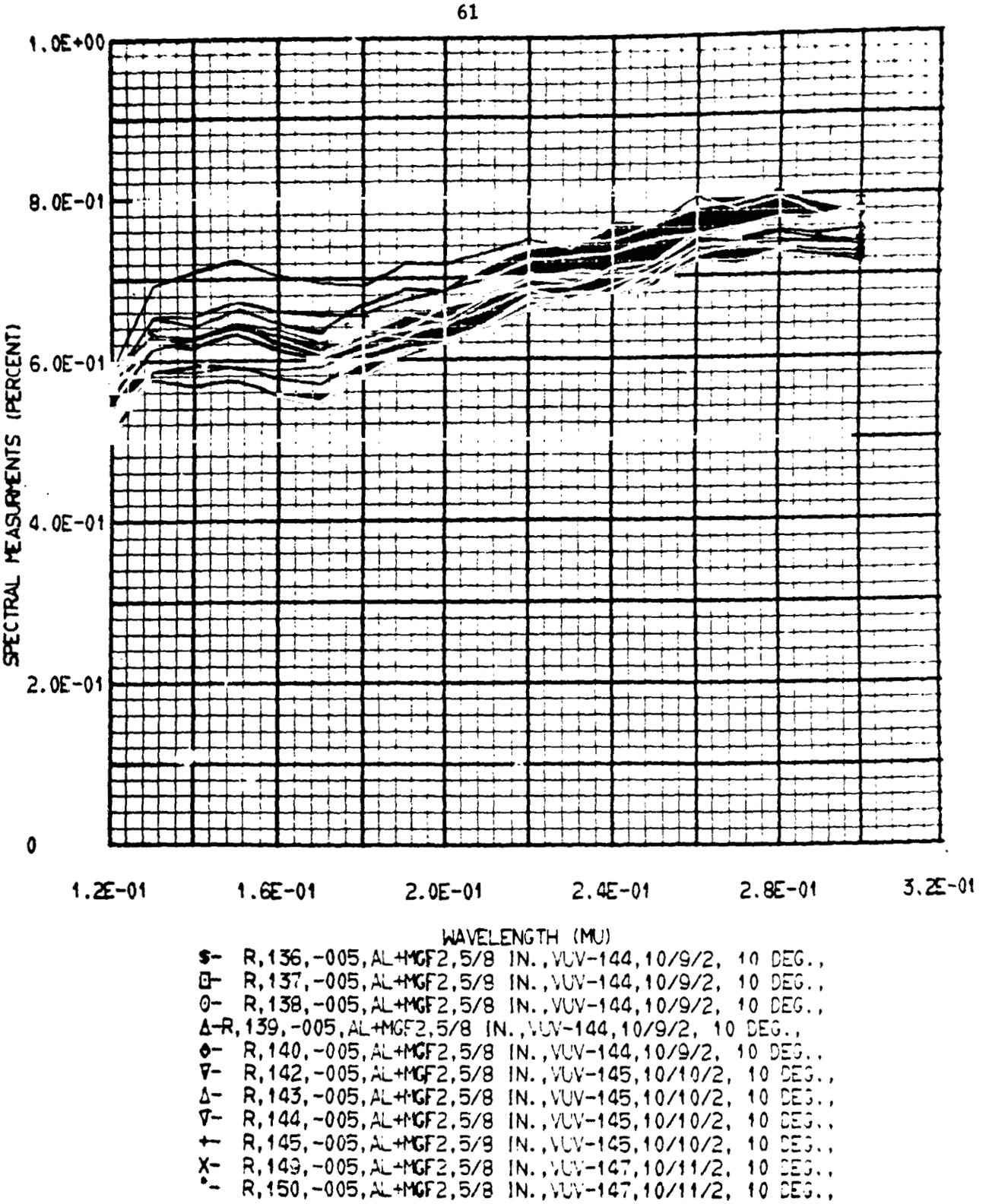

Figure 18. Multi Plots of Reflectance Versus Wavelength for 11 Al+MgF_2 Mirrors

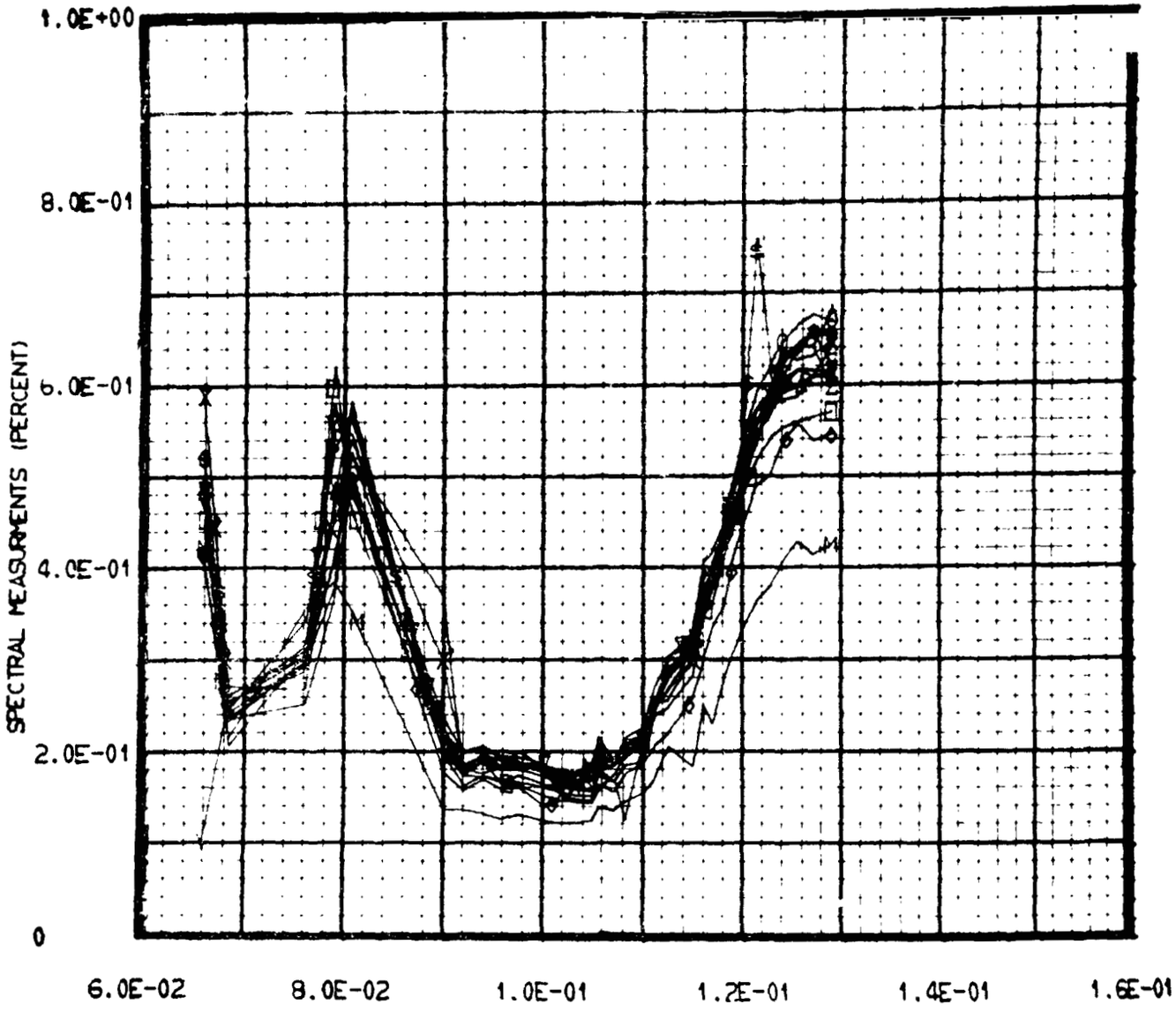

Figure 19. Multi Plots of Reflectance Versus Wavelength for 14 Al+MgF_2 Mirrors

4. PERFORMANCE ON SKYLAB 1/2

The array was placed on the anti-solar scientific airlock (ASAL) by astronaut P. Conrad on mission day 24 (June 17, 1973) at about GMT 18:30. No difficulties were experienced in the installation, deployment, and activation of the power and start switches. The array was removed on day 26 at about GMT 17:00 (exposure time 46 hours and 30 minutes). The following table lists scheduled spacecraft events which could add to the deposition of contaminants on the samples.

Table 3 Skylab 1/2 Events During T027 Array Exposure

EVENT	DOY/MISSION DAY/GMT HOUR/MIN
M092 Vent	168:24:16
M171 Vent	168:24:17
Installation of Array	168:24:18:30
HK 3A TAL Vent	168:24:22
M092 Vent	169:25:11
M171 Vent	169:25:12
M092 Vent	169:25:16
M171 Vent	169:25:16
TAL Vent	169:25:22
EVA by Crew	170:26:12
Removal of Array	170:26:17

The orientation of the array in the ASAL was normal, namely samples 53 - 61 faced the CSM (+x axis) and samples 62 - 68 faced toward increasing +y axis (missing OWS solar panel). Several unforeseenevents greatly effected the performance of the sample array, the following list describes them.

A. ASAL Exposure - The array was designed and tested for performance out of the solar scientific airlock (SCAL). This airlock was not useable during S1 1/2 because the contingency

heat shield parasol was extended through the SSAL (using the backup T027 photometer canister system). Deposition models predicted two orders of magnitude less contaminants on the anti-solar side of the OA. Also the lack of solar radiation prevented studying the effects of photopolymerization of surface contaminants.

B. No Rotation - The upper carrousel did not rotate and expose the subsequent set of samples after the first 24 hours. Low temperatures were experienced out of the ASAL, however these temperatures were obtained during the qualification tests for short periods of time. It is unknown at this time whether the lower carrousel operated.

C. No Telemetry - The telemetry connections for the ASAL outlet pins corresponding to the sample array connector were not wired in. Therefore no real time information was obtained on contaminant deposition by the two quartz crystal microbalances, nor verification that the carrousels rotated.

D. Late Exposure - The array was preflight scheduled for exposure four days after the launch of SL 1. Problems with the SL 1 vehicle delayed the launch of SL 2 and the low priority of the array delayed the performance until 35 days after SL 1 launch. The exponential character of material outgassing gives an estimated quasi steady state condition within 25 to 1000 hours. Assuming an average time for exponential decay of 20 days, about 17% of the initial contaminants from SL 1 were present during the sample array deployment.

E. Reduced Length of Exposure - Only 46.5 hours of exposure was obtained out of the 120 planned hours. Once again the degree of contamination was reduced, low levels of contaminants makes the measurement and analysis program more difficult.

F. Non-sealing of the Sample Area - In removing the array from the airlock, Conrad noticed the upper carrousel valve was not closed (about 3mm open) and frost had formed over the top of the upper carrousel plate. This area was cold from vacuum exposure and then exposed to the warm moist OWS atmosphere.

5. POSTFLIGHT MEASUREMENTS AND RESULTS

Final maintenance and calibration of each measuring instrument was performed in preparation for receipt of the exposed samples and the postflight measurement program. In addition, data from Skylab QCM's, and the T027 photometer system was studied to give some indication of the magnitude of deposited contaminants. This information influenced how the samples were first studied.

5.1 Residual Gas Analysis - The first postflight measurement and analysis performed on the sample array was a measurement of the gas content within the sample array. The gas samples were taken through the Seaton-Wilson valves on the end cover plates and measured by a CEC 21-614 magnetic sector mass spectrometer. Figure 20 is a schematic view of the gas analysis inlet system.

The CEC 21-614 Mass Spectrometer uses a 180-degree flight path through a magnetic field to resolve the mass particles. A liquid nitrogen trapped diffusion pump maintained the spectrometer at a fixed low pressure. The inlet system used a 3μm gold leak to maintain the pressure drop at the entry. The remainder of the entry system consists of a mechanical roughing pump, VAC ION pump, valves, pressure gauges including a capacitance monometer, a nitroget inlet, a lcc chamber and a 1 ℓ ballast chamber. Pure gas samples were used to calibrate the spectrometer. The resolution at 90 percent valley was 1.50 AMU. A connection line which coupled the sample array to the inlet system is shown in Fig. 21. The line has a Varian mini conflat flange welded to approximately 23 cm of 0.63 cm O. D. stainless tube with an 0.63 cm stainless bellows connected to a Seaton-Wilson mating plug.

The following sequence of gas samples was used:

1. Background mass spectra and pressure of spectrometer inlet system;

2. Sealed ground stowage container, at this point power was applied to the array to reach the four telemetry channels associated with the two quartz crystal microbalances;

3. Area under the control panel cover plate;

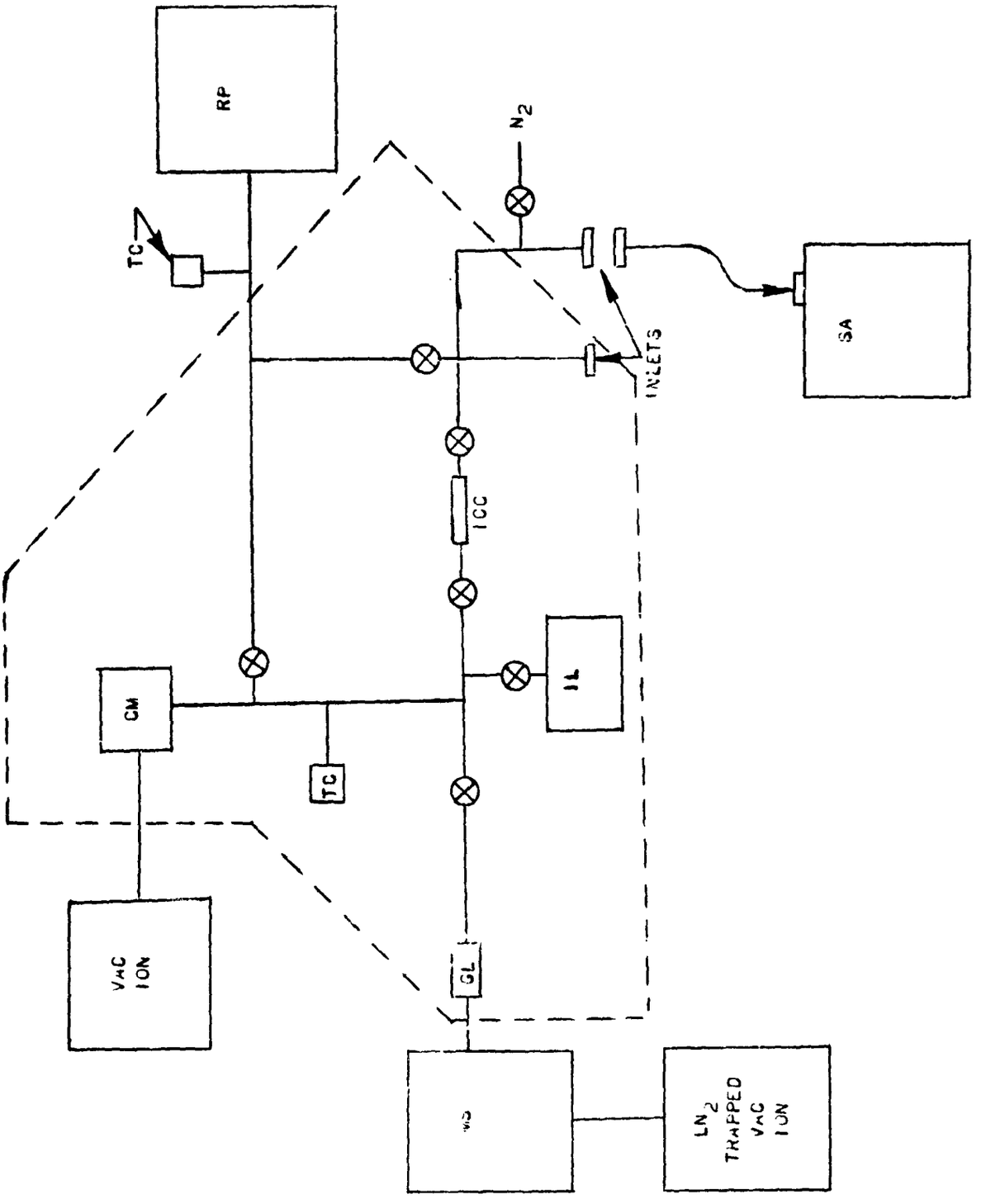

Figure 20. Schematic View of the Gas Analysis Inlet System

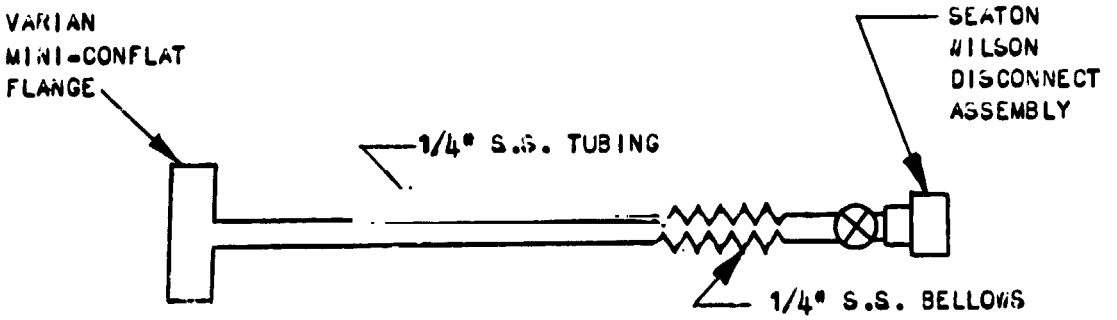

Figure 21. Connection Line for the Sample Array to the Inlet System

4. Area under sample cover plate;

5. Upper carrousel air space; and

6. Sample area by extending sample array to break the inner seal.

Each gas sample followed this procedure:

a. Pump down the entire inlet system.

b. Verify that the background spectrum is clean.

c. Mate the connection line to the sample array and plate.

d. Measure the pressure in the inlet system.

e. If the pressure is 100 μm or above, proceed to step g.

f. If the pressure is below 100 μm, back-fill the inlet with dry, pure N_2 until 100 μs is reached; then proceed.

g. Seal a gas sample in the lcc chamber.

h. Pump down the remainder of the inlet system including the 1ℓ ballast tank.

i. Release the gas from the lcc chamber.

j. Initiate the mass spectrometer scan.

k. After spectra have been taken from all sample array chambers, calibration samples will be run at appropriate mass ranges as seen in the sample array spectra.

The following table summarizes the results.

Table 4 Residual Gas Analysis T027 Sample Array System

SAMPLING AREA	PRESSURE	MAJOR CONSTITUENT
Ground Stowage Container	Above 600 Torr	High Nitrogen Low in Water & Oxygen
Electronic Control Panel Cover Plate	About 40 Torr	Oxygen 20% of Nitrogen Peak
Sample Cover Plate	About 270 Torr	High Nitrogen & Water Low Oxygen
Upper Carrousel/All Samples	Estimate 270 Torr	High Nitrogen & Water Low Oxygen, No Outstanding Contaminant Peaks

The two quartz crystal microbalances were turned on before the array was opened to compare their frequency to the preflight baseline measured at KSC at the conclusion of the sample installation. Table 4 shows that the results, the Space Sciences Laboratory at MSFC has not announced the meaning of the results at this time.

Table 5 QCM Outputs at KSC and Postflight at Martin Marietta

Channel	KSC Voltage (V)	MMC Voltage (V)	(V)	(V)	(V)	(V)
QCM #1 Temperature	0.30	.27	.25	.24	.23	.23
QCM #2 Temperature	2.1	1.67	1.58	1.56	1.55	1.55
QCM #1 Frequency	0.75	.71	.71	.70	.70	.70
QCM #2 Frequency	0.85	1.31	1.31	1.32	1.33	1.33
Pressure (Torr)	Ambient	4	4	4	0.7	0.7

5.2 Sample Removal and Observations - After the RGA analysis, the sealed array was returned to the class 100 clean bench in the optics laboratory for removal of the samples. Photographs were taken of the samples installed in the array and selected samples were also photographed after removal using a dark field technique. Except for the upper carrousel samples which were spotted in flight during the removal

of the array from the scientific airlock, none of the photographs show any significant visual evidence of contaminants. Each sample was placed in its numbered position (identical to flight designation) in the laboratory storage container.

During the removal of the samples it was determined that the upper carrousel samples were still in the same position as set at KSC. This should not have been the locations for a 46 hour operation. The lower carrousel samples were also in the KSC setting, however, the normal operation of the array for 26 hours would reposition the lower carrousel back to its starting position. The lack of telemetry connections at the anti-solar SAL prevented recording the carrousel driver signals.

After the samples were all removed the array was reassembled and operated, Appendix D contains the table of contents for this test. Both carrousels showed normal rotation at the appropriate times. Because the array was operated from the anti-solar SAL rather than from the planned solar SAL, it was subjected to much colder operating temperatures than expected. Temperatures measured on the T027 photometer system operated from the same airlock indicate that the array probably cooled down to -45°F. This could have caused low temperature mechanism seizure of both carrousel mechanisms. However, the lower carrousel should have indexed at least once because the initial and first few index times occurred prior to significant cool down of the mechanisms from cabin temperature (about 70°F). It is possible that the lower carrousel indexed properly inflight, however, both carrousels index together at the start of the 25th hour. Thus, for some unknown reason it would be necessary for only the upper carrousel to not rotate at this time and the lower carrousel to rotate its last time one hour later. As described in section 2.2, both carrousel mechanisms were at one time cooler than -100°F and still rotated properly during the thermal vacuum flight qualification test.

To further test the postflight reassembled sample array system, the unit was placed in a vacuum chamber and cooled down to -80°F. This was a worst case prediction for the array by thermal modeling analysis. The hourly carrousel functioned properly; however the upper carrousel seized at the 24 hour of operation after partially indexing (about 30%) into position. Inspection of the drive mechanism showed no obvious sign of jamming or interference. Report T027-SA-1-74 details the procedure and results of this test, see appendix R.

Discounting thermally induced mechanism seizure, two non-normal crew operations could explain the carrousels not indexing. If the circuit breaker supplying 28 VDC power to the anit-solar SAL power outlet was open or the array power switch was not placed to the ON position prior to initiating the automatic sequence, either reason would explain the non-indexing.

5.3 Reflectance and Transmittance Measurements - The primary set of samples in the following table were measured optically for changes in reflectance and transmittance from 2.75A to 20 μm. No significant changes in the postflight values compared to the preflight values has been seen. To illustrate the type of data obtained, a gold mirror was selected to show the reflectance values from 0.12-2.5 μm at a 10^{o} angle of incidence. Similar plots were determined for 30^{o}, 45^{o}, and 60^{o} angles of incidence and for all of the primary samples. Figures 22 and 23 illustrate the preflight and postflight measurements processed and plotted by the T027 Optical Properties Analysis computer program for sample 62. As can be seen from the data for wavelengths 0.12-0.30 μm, some difficulty was experienced in that the postflight values were higher than the preflight measurements. This has been shown to be an instrument configuration change after the preflight values were obtained. Selected laboratory control samples were rerun and show this increased reflectance and transmittance. Using this change as a normalization factor the flight samples show no significant difference from their preflight condition. Figures 24 and 25 show the ratio of the postflight values to the preflight. The preflight and postflight mean of all the primary gold samples is shown in Figs. 26 and 27; the ratio of the postflight mean to the preflight mean is shown in Figs. 28 and 29. The three sigma deviation about the preflight and postflight mean is shown in Figs. 30 - 33. Three sigma deviation means 99.74% of the curves will fall inside the three sigma boundaries. Three sigma deviations for the primary Pt samples is shown in Figs. 34 - 37, for Al + MgF_2 samples in Figs. 38 - 41, for MgF_2 in Figs. 42 - 45, and for quartz in Figs. 46 and 47.

The beryllium foil filters (100, 123, 227, 236, and back-up samples 123-2 and 227-2) transmittance values were determined and again no significant change was obtained. Figure 48 shows the x-ray transmission for sample 100.

A parabolic reflectometer was used to determine any

Table 6. Postflight Optical Measurements Primary & Secondary Samples

PRIMARY SAMPLES

SAMPLE	NO.	WAVELENGTH 0.12-0.30 μm	WAVELENGTH 0.25-2.5 μm	ATR	ELLIPSOMETRY
Au	33	X	X		X
	44	X	X		X
	58	X	X		X
	62	X	X		X
	125	X	X		X
	222	X	X		
Al+MgF_2	2	X	X		
	14	X	X		
	17	X	X		
	47	X	X		
	57	X	X		
	75	X	X		
	97	X	X		
	107	X	X		
	128	X	X		
	129	X	X		
	130	X	X		
	153	X	X		
	214	X	X		
	228	X	X		
	230	X	X		
	242	X	X		
KRS-5 ATR	65			X	
	98			X	
	237			X	
Ge ATR	64			X	
	93			X	
	238			X	
Pt	21	X	X		
	29	X	X		
	31	X	X		
	51	X	X		
	56	X	X		
	70	X	X		
	95	X	X		
	121	X	X		
	209	X	X		

Table 6. Continued

SAMPLE	NO.	WAVELENGTH 0.12-0.30 μm	WAVELENGTH 0.25-2.5 μm	ATR	ELLIPSOMETRY
Pt	218	X	X		
	233	X	X		
	243	X	X		
Quartz	3	X			
	15	X			
	18	X			
	48	X			
	61	X			
	74	X			
	94	X			
	122	X			
Ge	68				X
	84				X
	91				X
MgF_2	20	X	X		
	28	X	X		
	30	X	X		
	52	X	X		
	53	X	X		
	76	X	X		
	96	X	X		
	120	X	X		
	154	X	X		
	155	X	X		
	179	X	X		
	215	X	X		
	221	X	X		
	231	X	X		
	244	X	X		
		SECONDARY SAMPLES			
Au	62-2	X			
	222-2	X			
Al+MgF_2	36	X			
	40	X			
	69	X			
	88	X			
	90	X			
	92	X			
	228-2	X			

Table 6. Continued

SAMPLE	NO.	WAVELENGTH 0.12-0.30 μm	WAVELENGTH 0.25-2.5 μm	ELLIPSOMETER	PARABOLIC 1.2-20 μm
Pt	233-2	X			
Quartz	23	X			
	25	X			
	27	X			
	60	X			
	86	X			
Ge	225			X	
	235			X	
MgF_2	22	X			
	24	X			
	26	X			
Nickel	108	X			
	127	X			
	206	X			
Al+LiF	39	X			
	210	X			
	229	X			
Al	38	X			X
	58				X
	219	X			X
Sapphire	49	X			
LiF	78	X			
	89	X			
	223	X			
	224	X			
Au	33				X
	44				X
	58				X
	62				X
	222				X
	249				X
	255-1				X

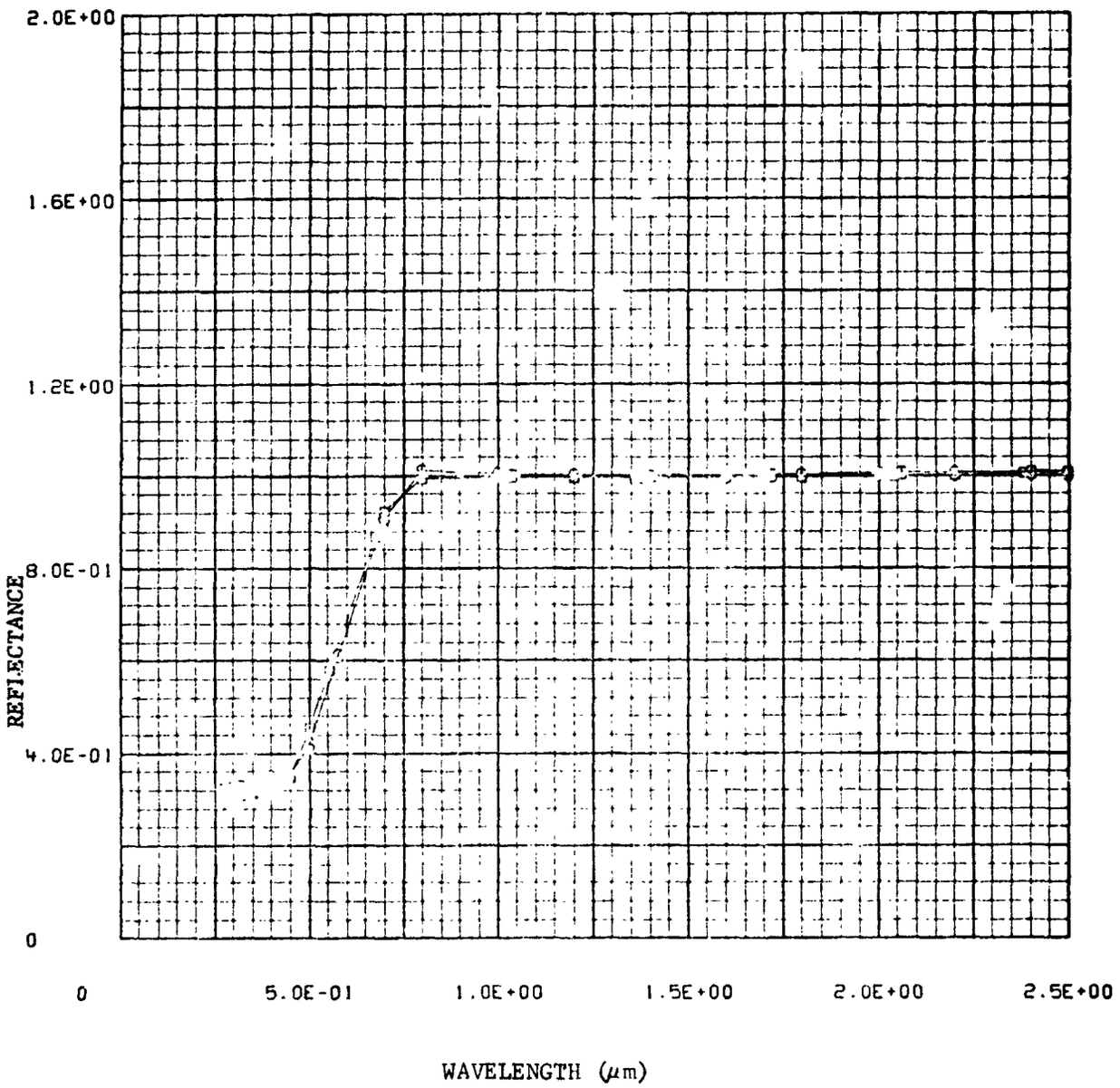

Figure 22. Reflectance Versus Wavelength
- Preflight 62, Gold Mirror, 10 Deg, DK 1419, 9/6/72
- Postflight 62, Gold Mirror, 10 Deg, PODK-04, 7/5/73

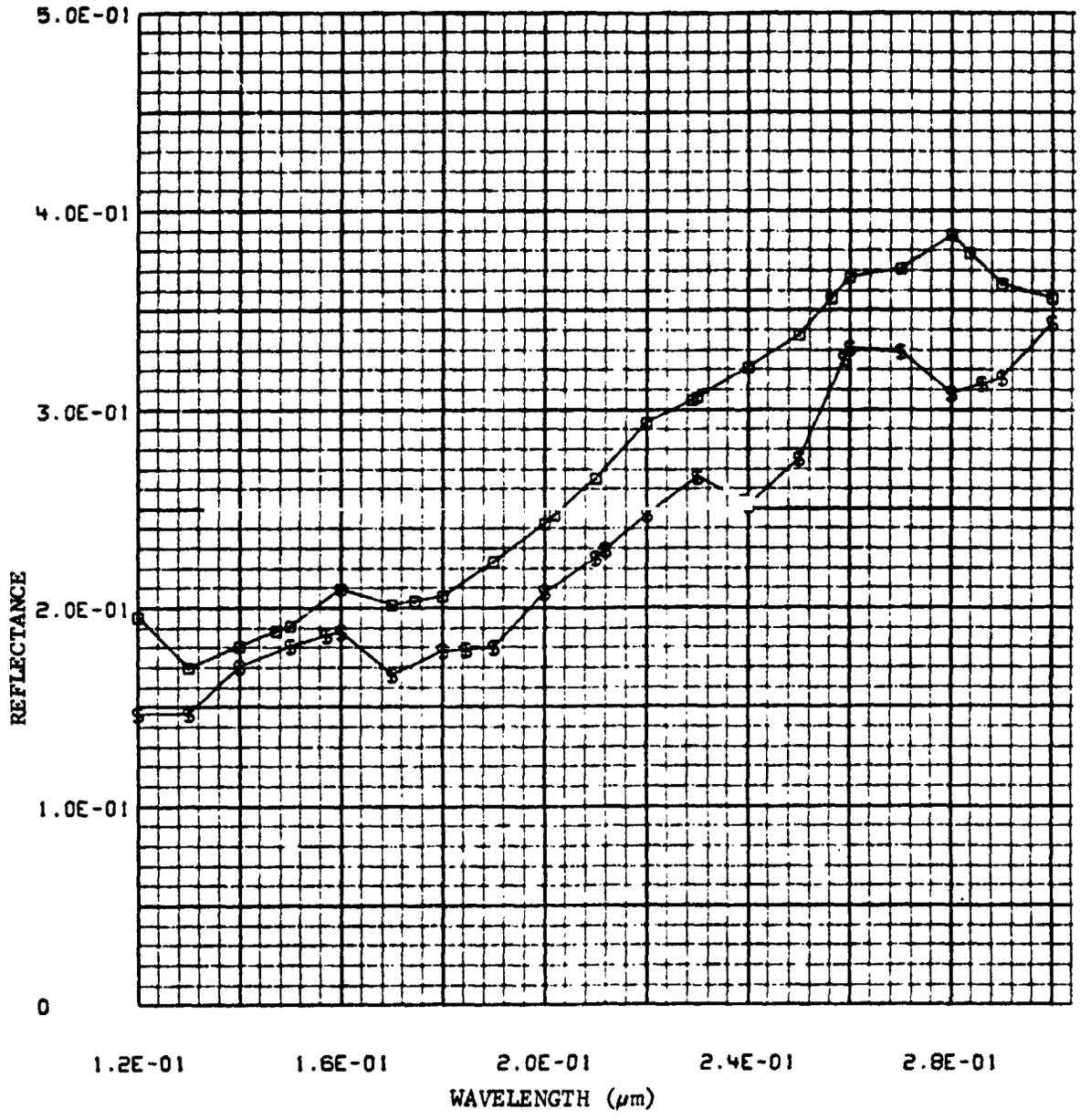

Figure 23. Reflectance Versus Wavelength
$ Preflight 62, Gold Mirror, 10 Deg, VUV 115, 8/8/72
□ Postflight 62, Gold Mirror, 10 Deg, VUV 502, 7/7/73

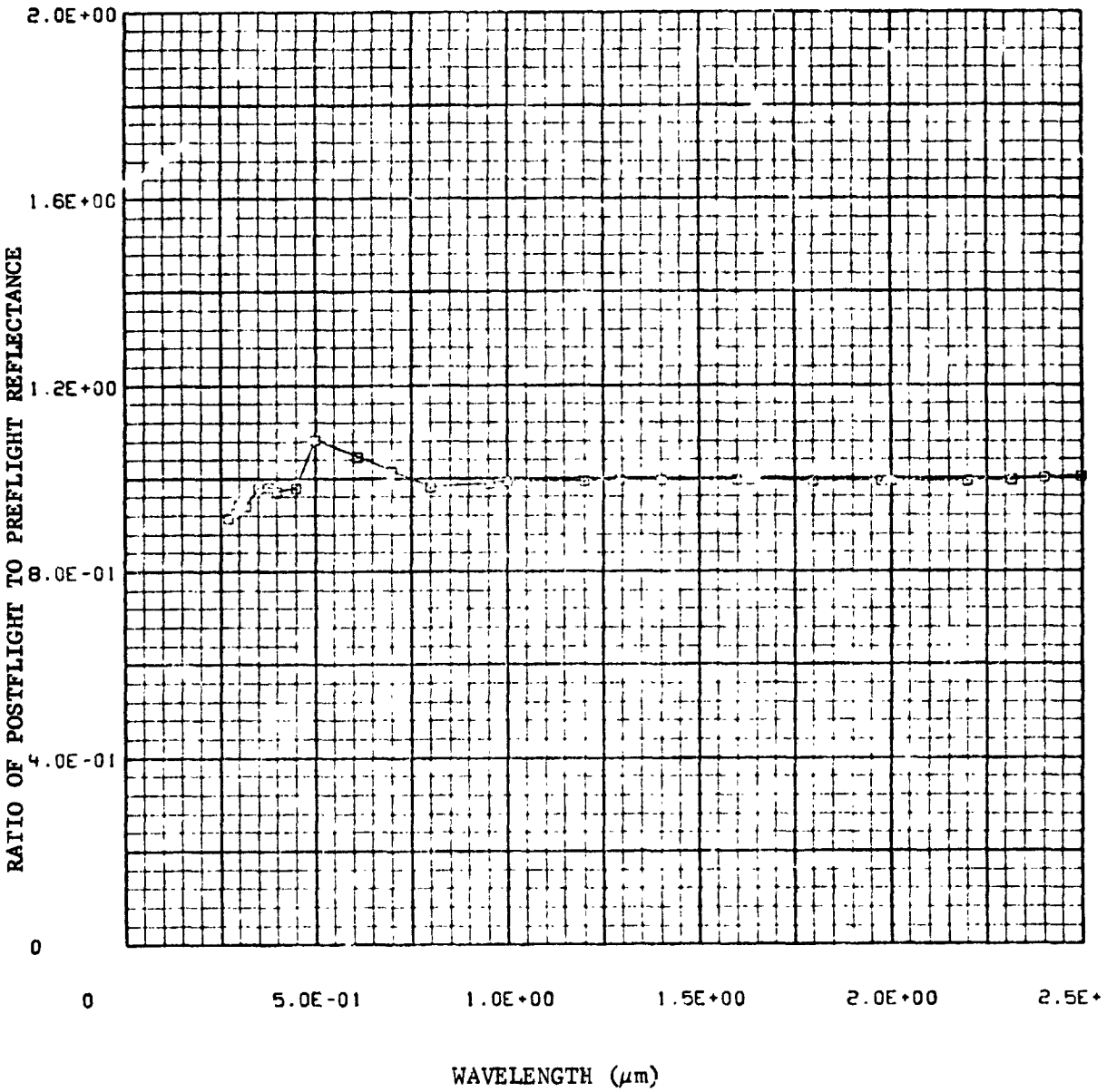

Figure24. Ratio Of Postflight To Preflight Reflectance Vs Wavelength
62 Gold Mirror, PODK-04, 10 Deg, 7/5/73

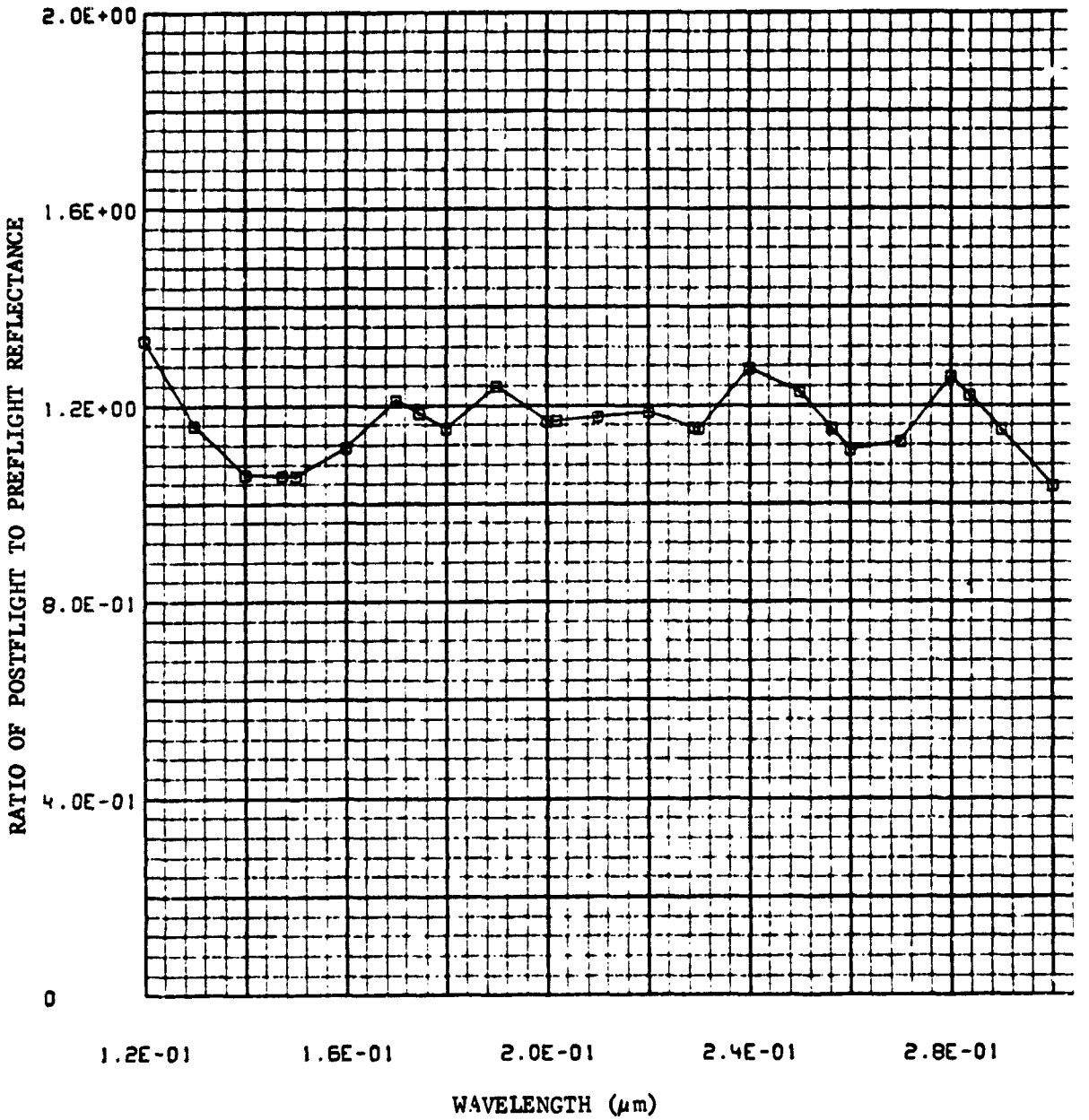

Figure 25. Ratio Of Postflight To Preflight Reflectance Vs. Wavelength
62 Gold Mirror, 10 Deg, VUV 502, 7/7/73

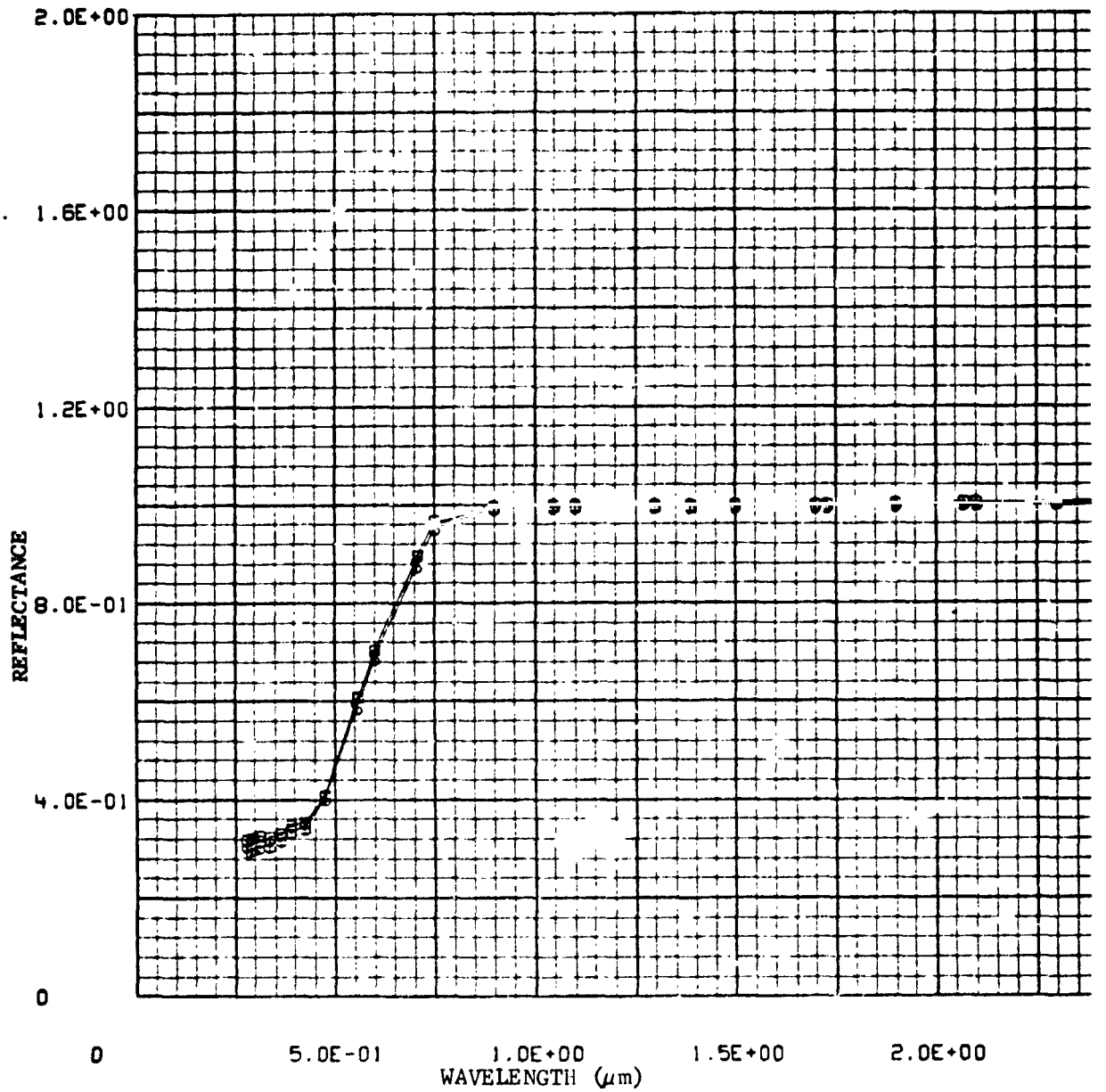

Figure 26. Preflight And Postflight Mean Reflectance Versus Wavelength
$ Mean Of All Primary Gold Mirrors Preflight, 10 Deg, DK, 9/26/73
⊡ Mean Of All Primary Gold Mirrors Postflight, 10 Deg, DK, 9/26/73

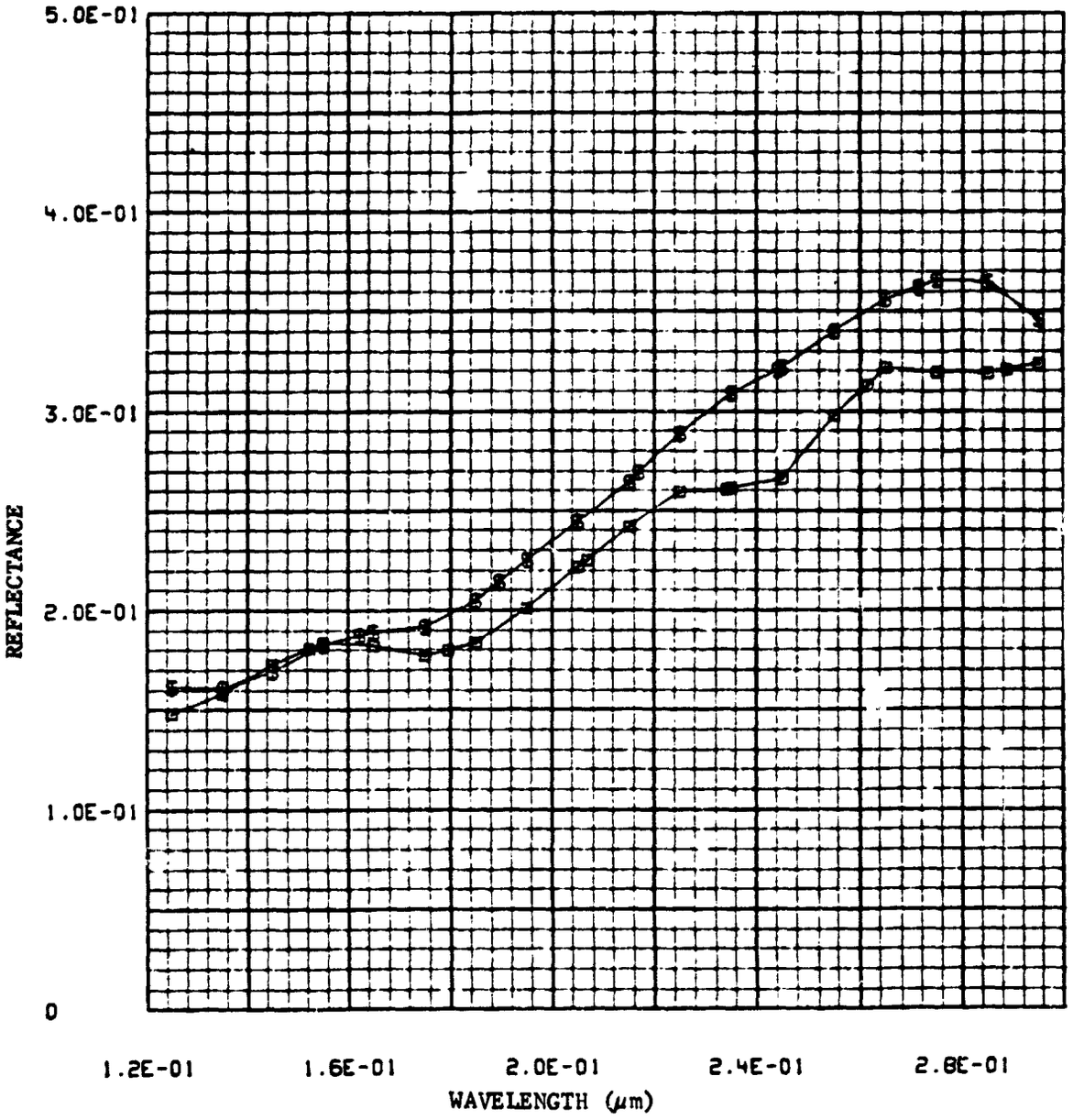

Figure 27. Preflight And Postflight Mean Reflectance Versus Wavelength
$ Preflight Mean All Primary Gold Mirrors, 10 Deg, VUV, 9/26/73
Ω Postflight Mean All Primary Gold Mirrors, 10 Deg, VUV, 9/26/73

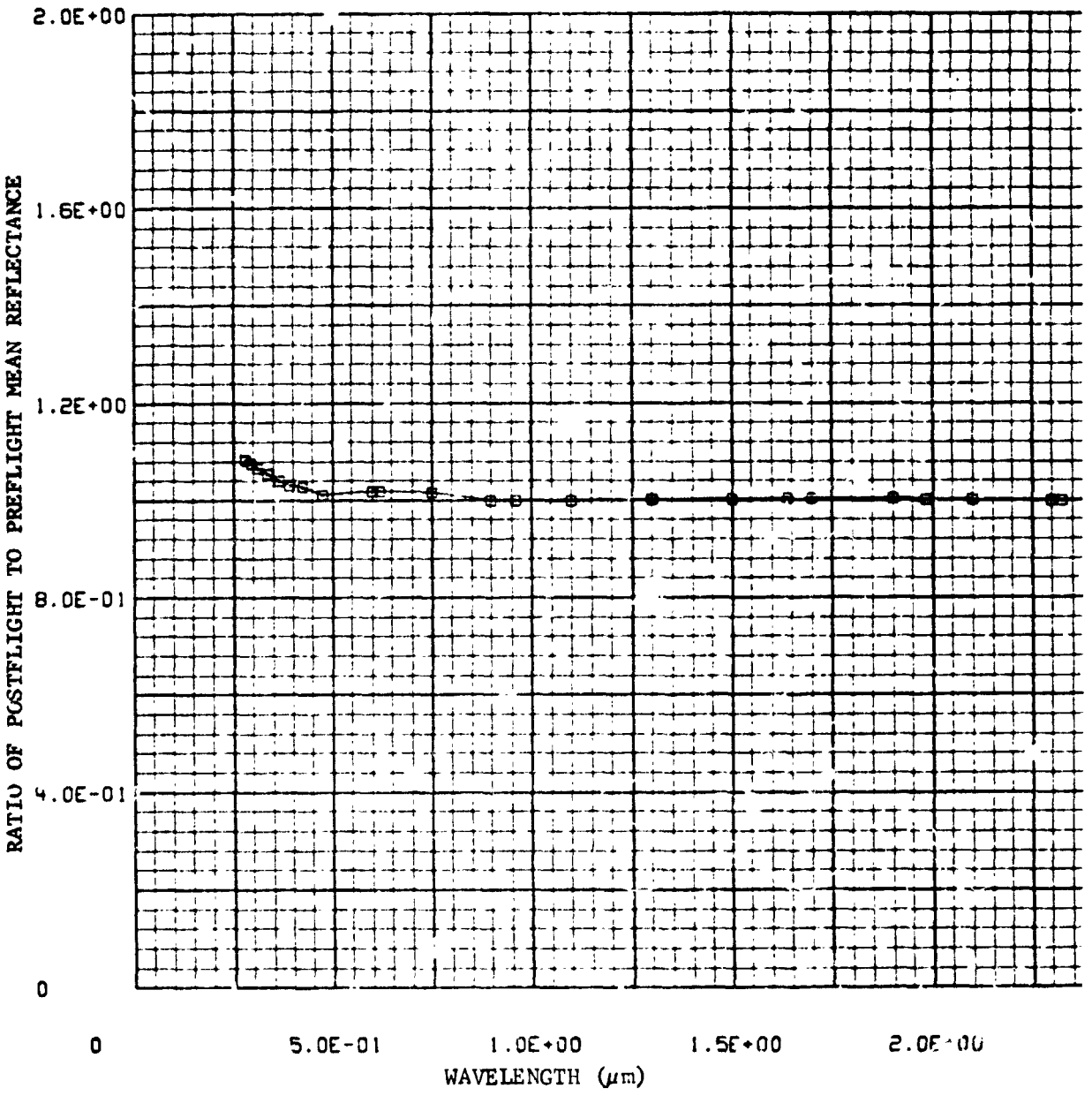

Figure 28. Ratio Of Postflight To Preflight Mean Reflectance Vs. Wavelength All Gold Primary Mirrors, 10 Deg, DK, 9/26/73

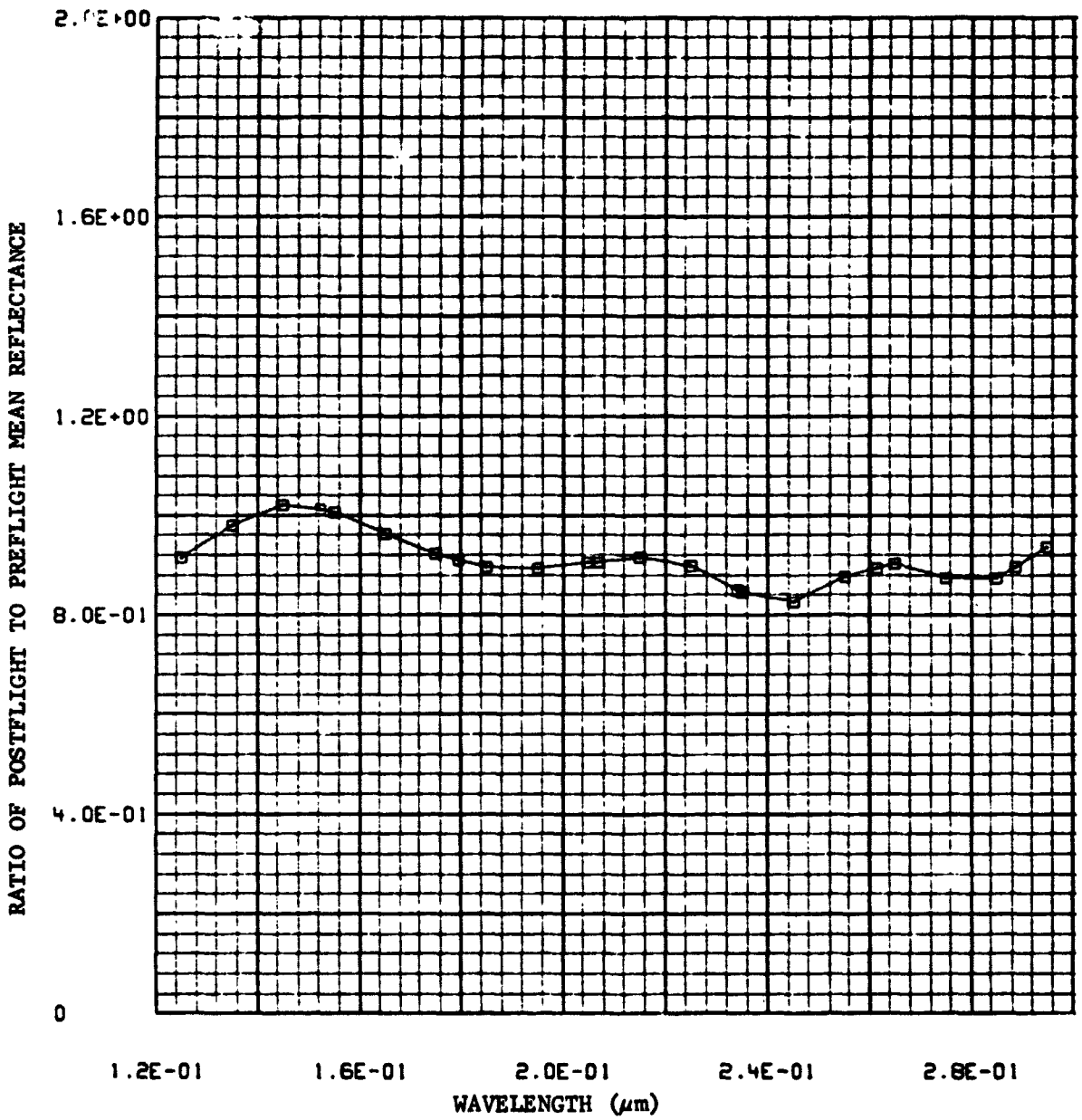

Figure 29. Ratio Of Postflight To Preflight Mean Reflectance Vs. Wavelength All Primary Gold Mirrors, 10 Deg, VUV, 9/26/73

C-2

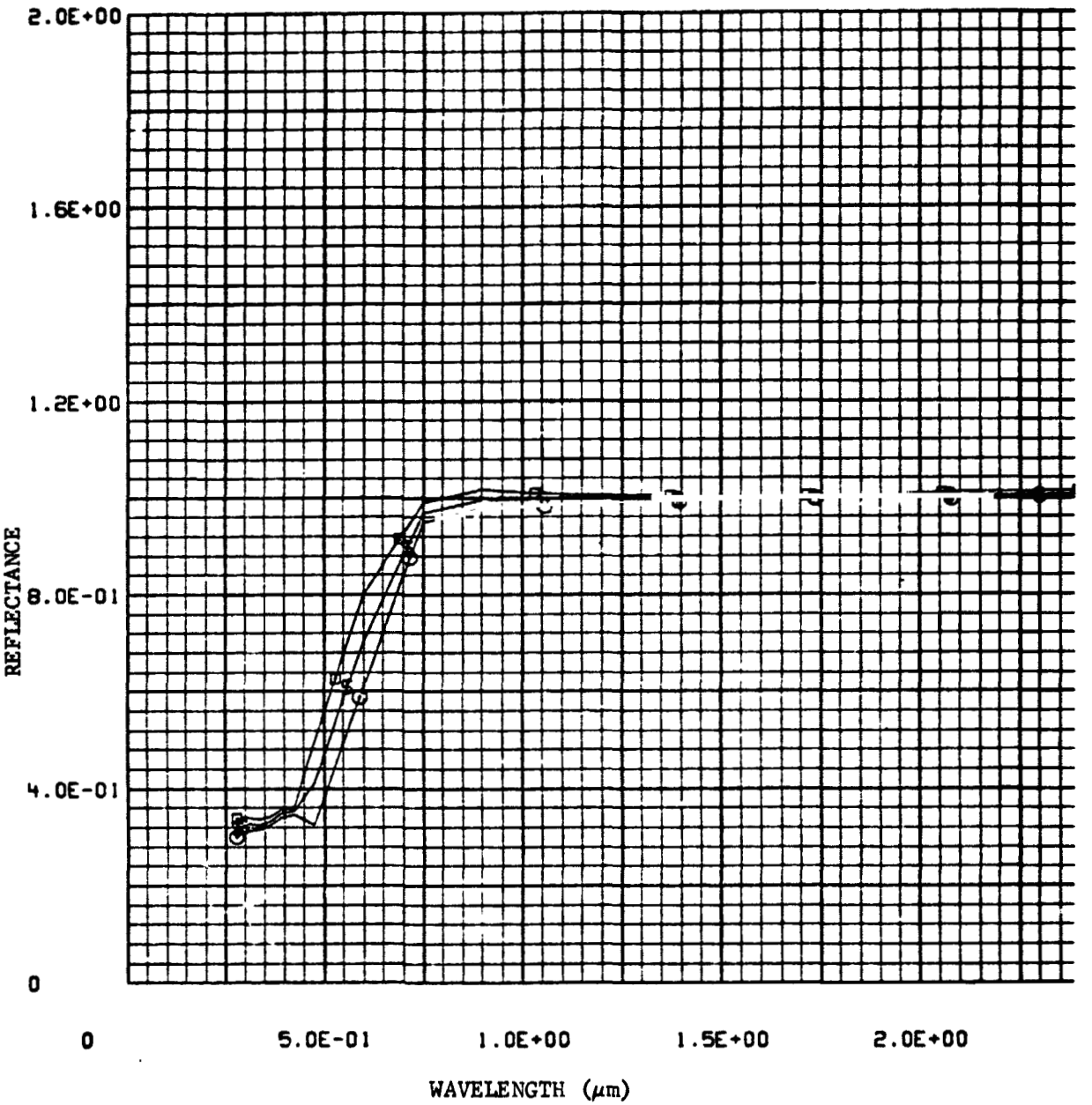

Figure 30. Three Sigma Deviation About Mean Reflectance Versus Wavelength
All Preflight Primary Gold Mirrors, 10 Deg, DK, 9/25/73
$ Mean Reflectance, □ Plus Three Sigma, ⊙ Minus Three Sigma

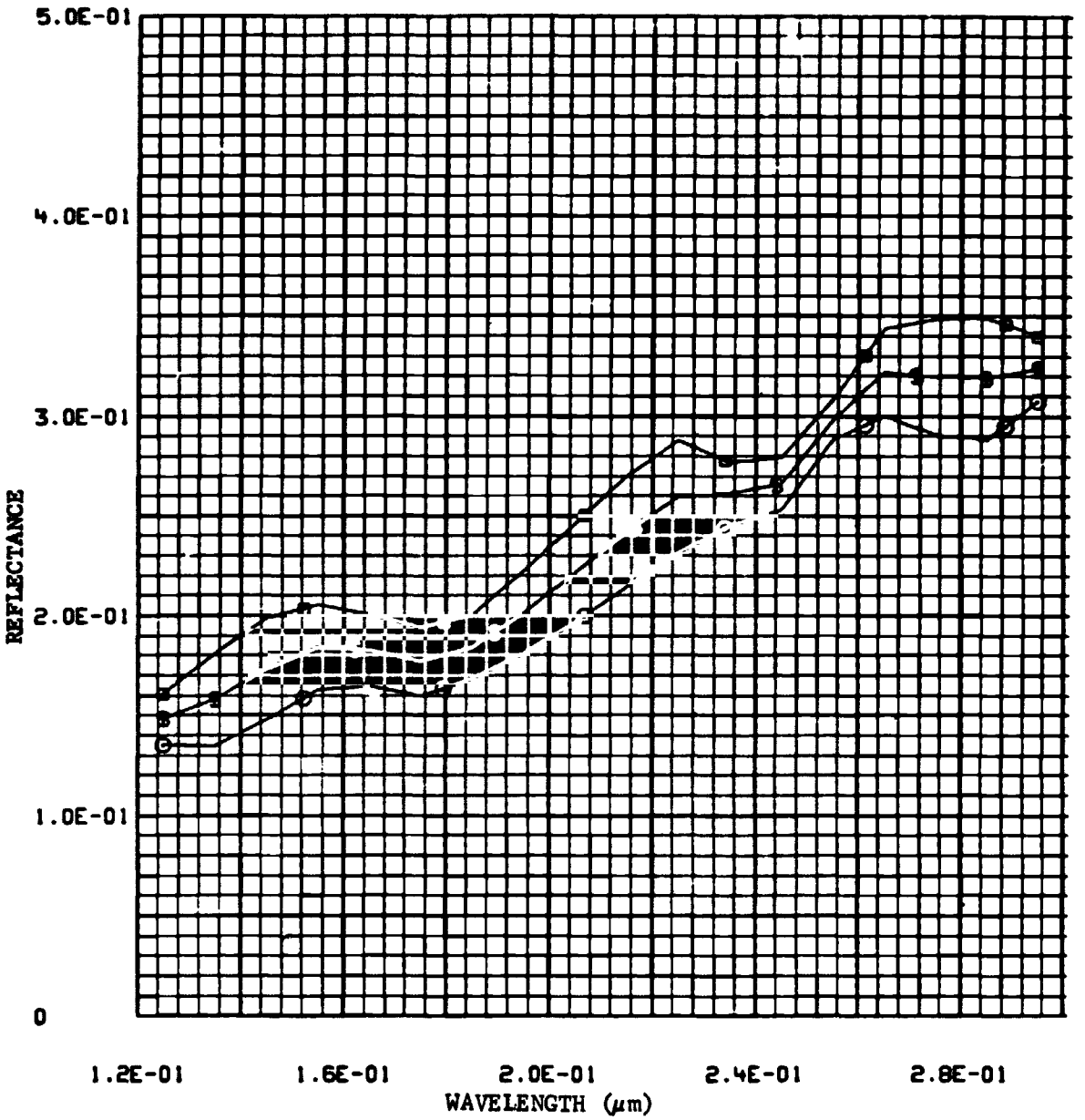

Figure 31. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Preflight Primary Gold Mirrors, 10 Deg, VUV, 9/22/73

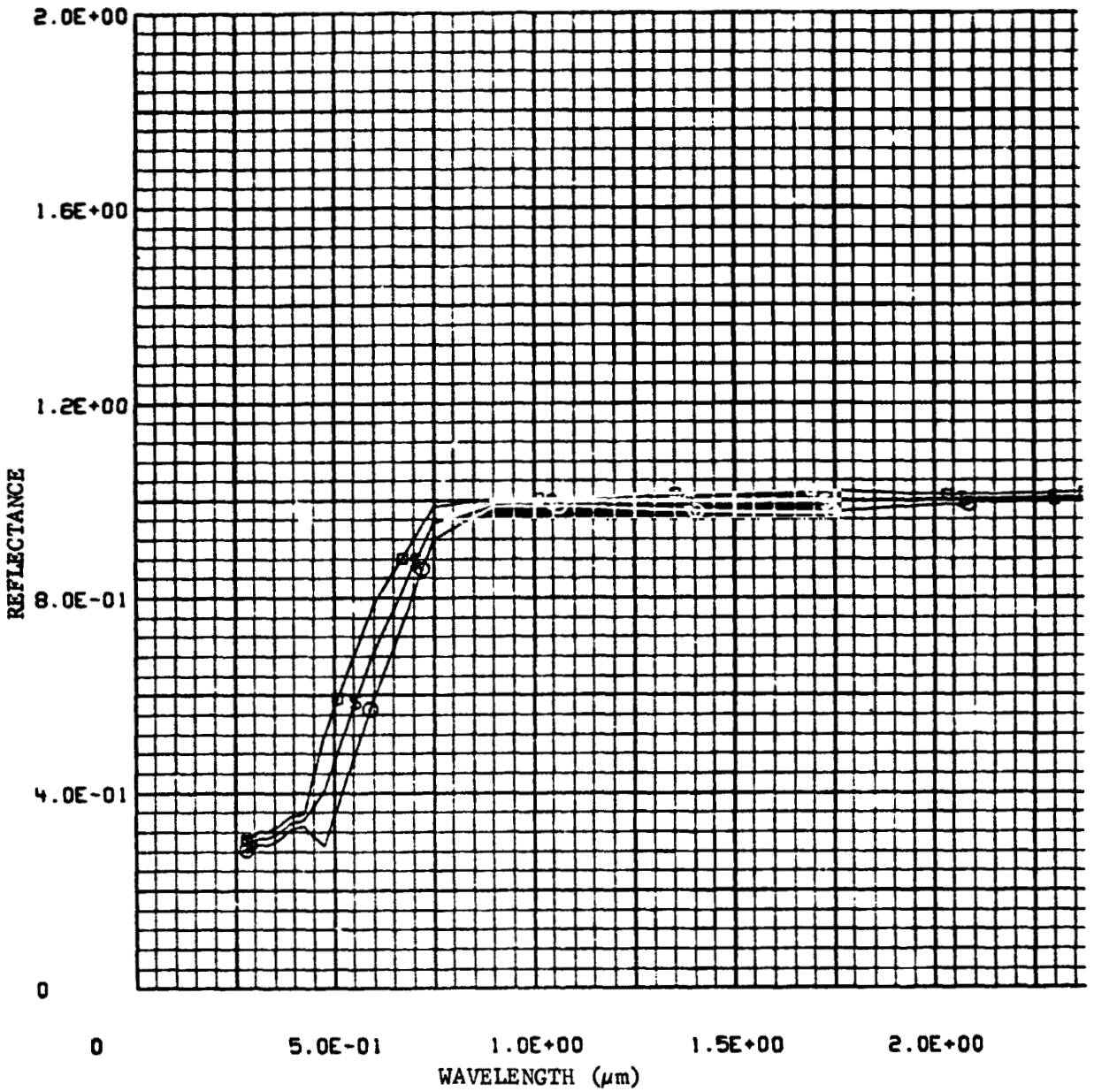

Figure 32. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Gold Mirrors, 10 Deg, DK, 9/25/73

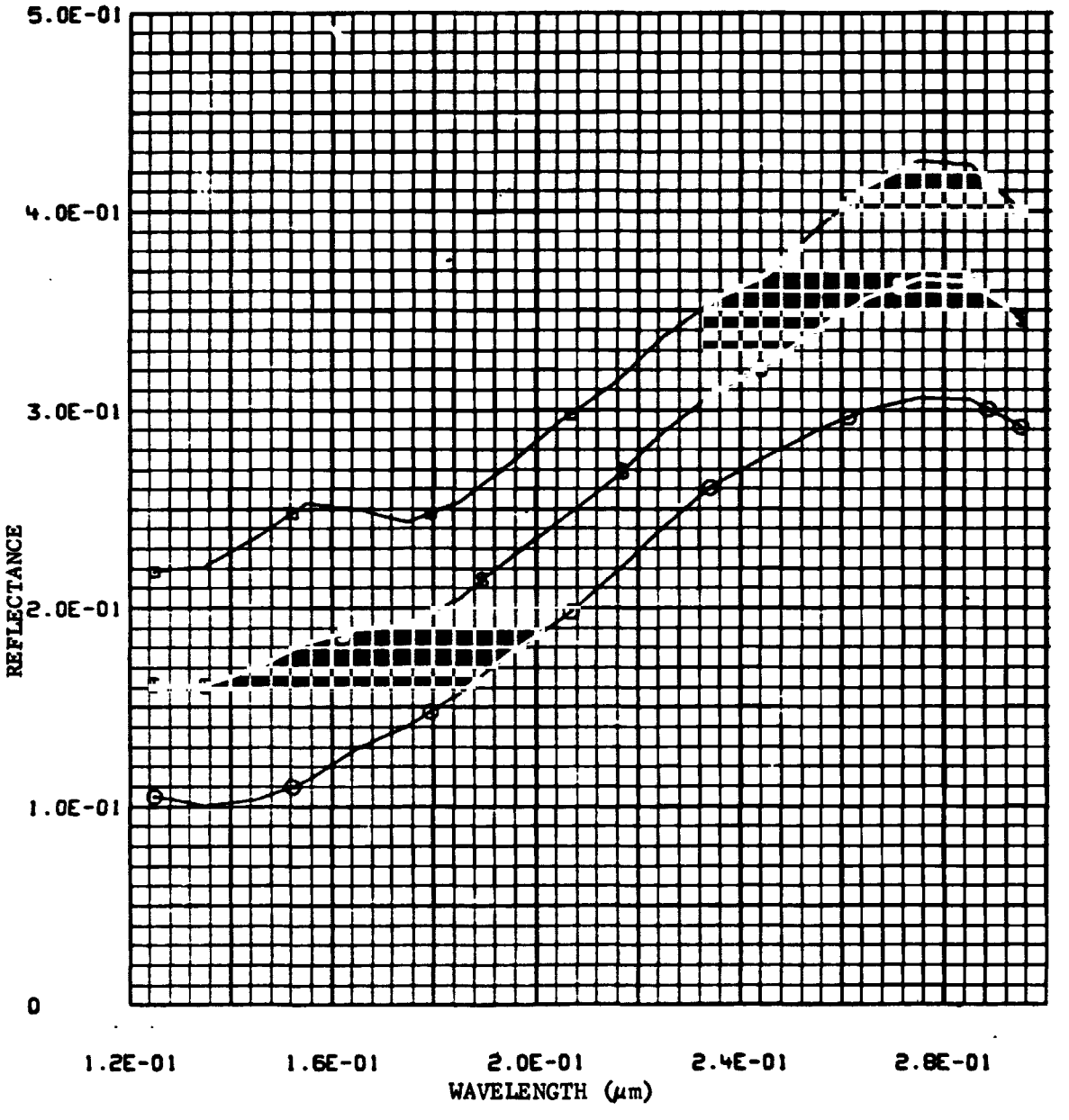

Figure 33. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Gold Mirrors, 10 Deg, VUV, 9/22/73

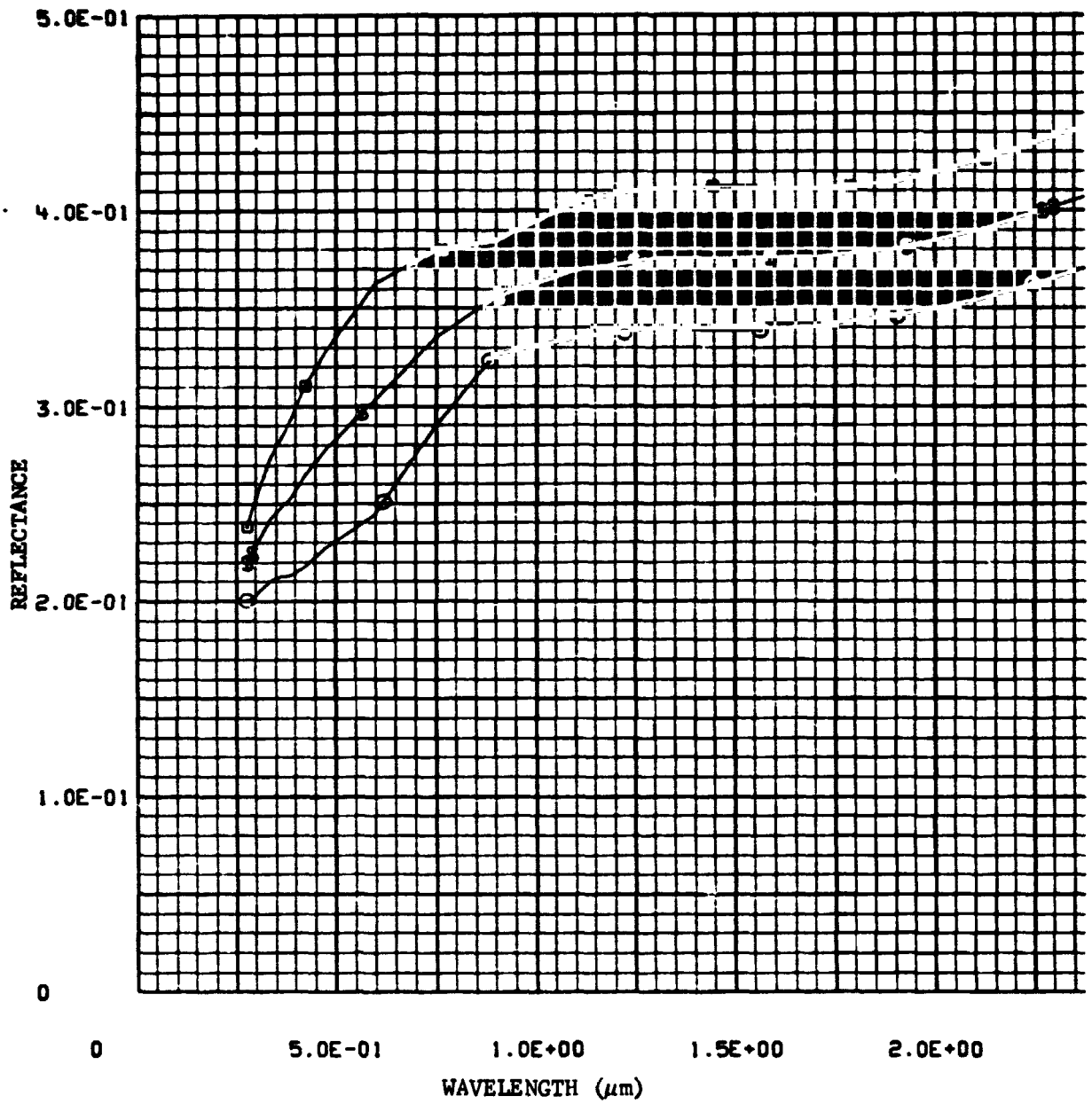

Figure 34. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Preflight Primary Platinum Mirrors, 10 Deg, DK, 9/25/73

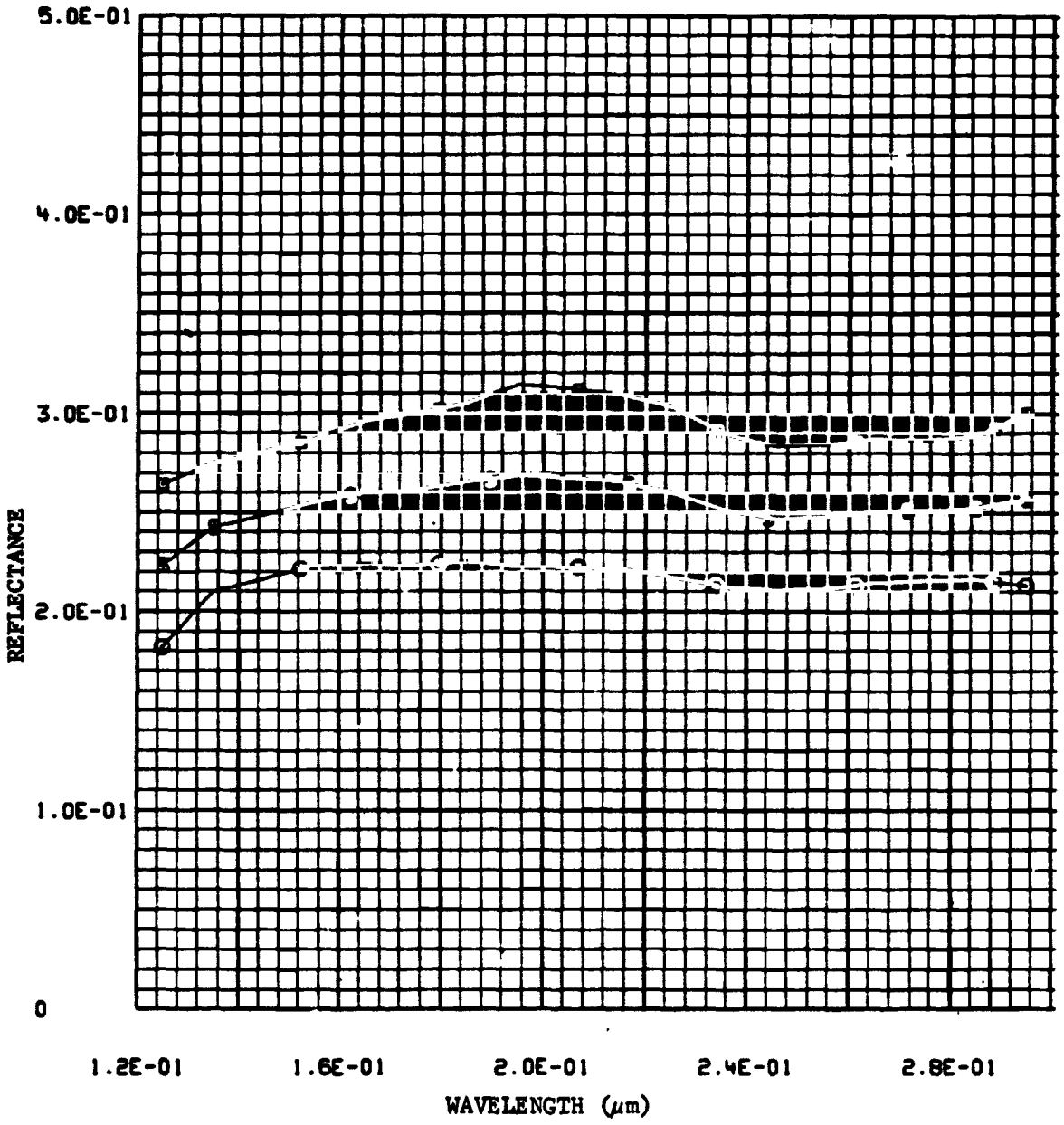

Figure 35. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Primary Preflight Platinum Mirrors, 10 Deg, VUV, 9/22/73

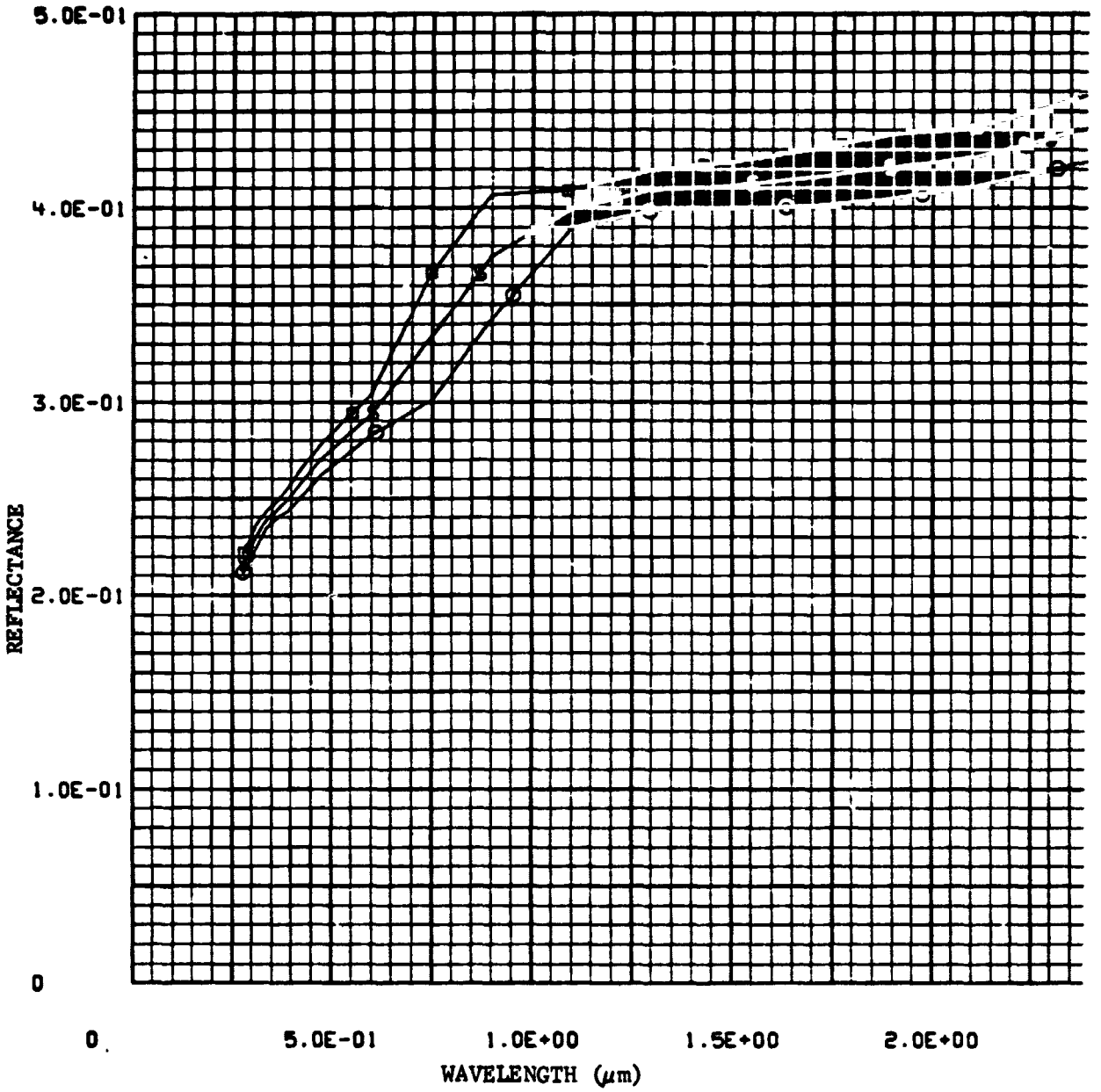

Figure 36. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Platinum Mirrors, 10 Deg, DK, 9/25/73

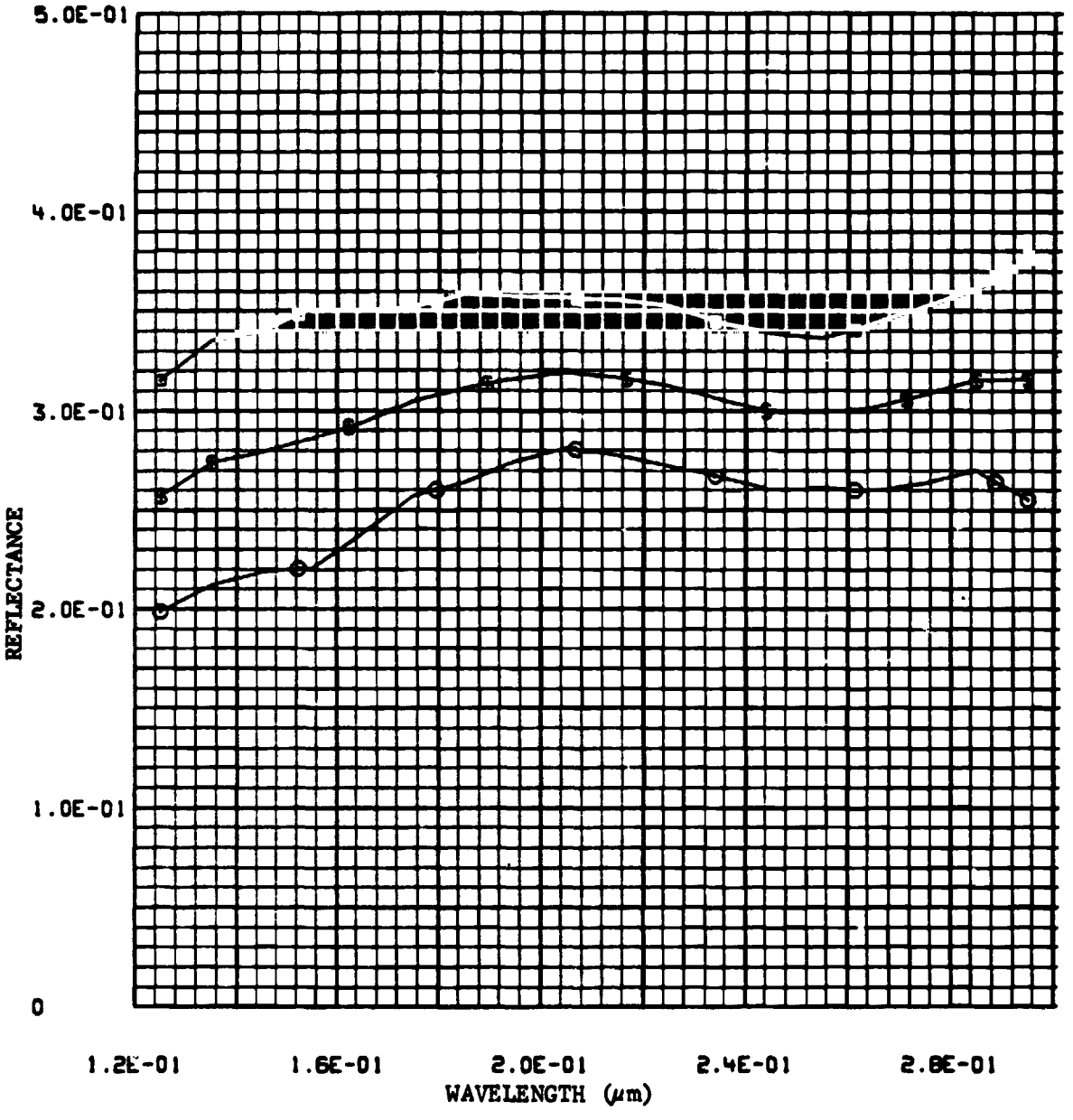

Figure 37. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Platinum Mirrors, 10 Deg, VUV, 9/22/73

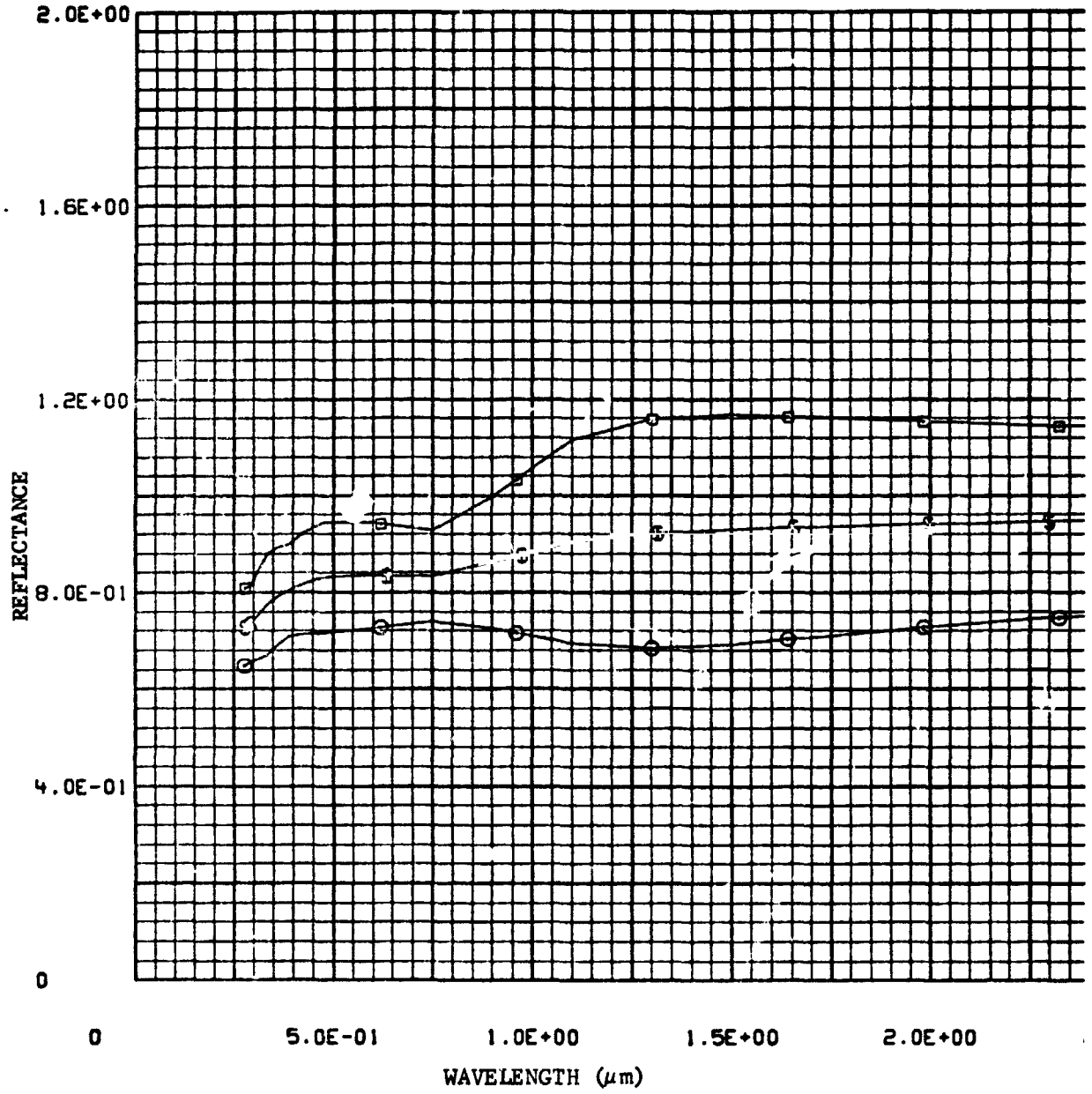

Figure 38. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Preflight Primary Al+MgF_2 Mirrors, 10 Deg, DK, 9/25/73

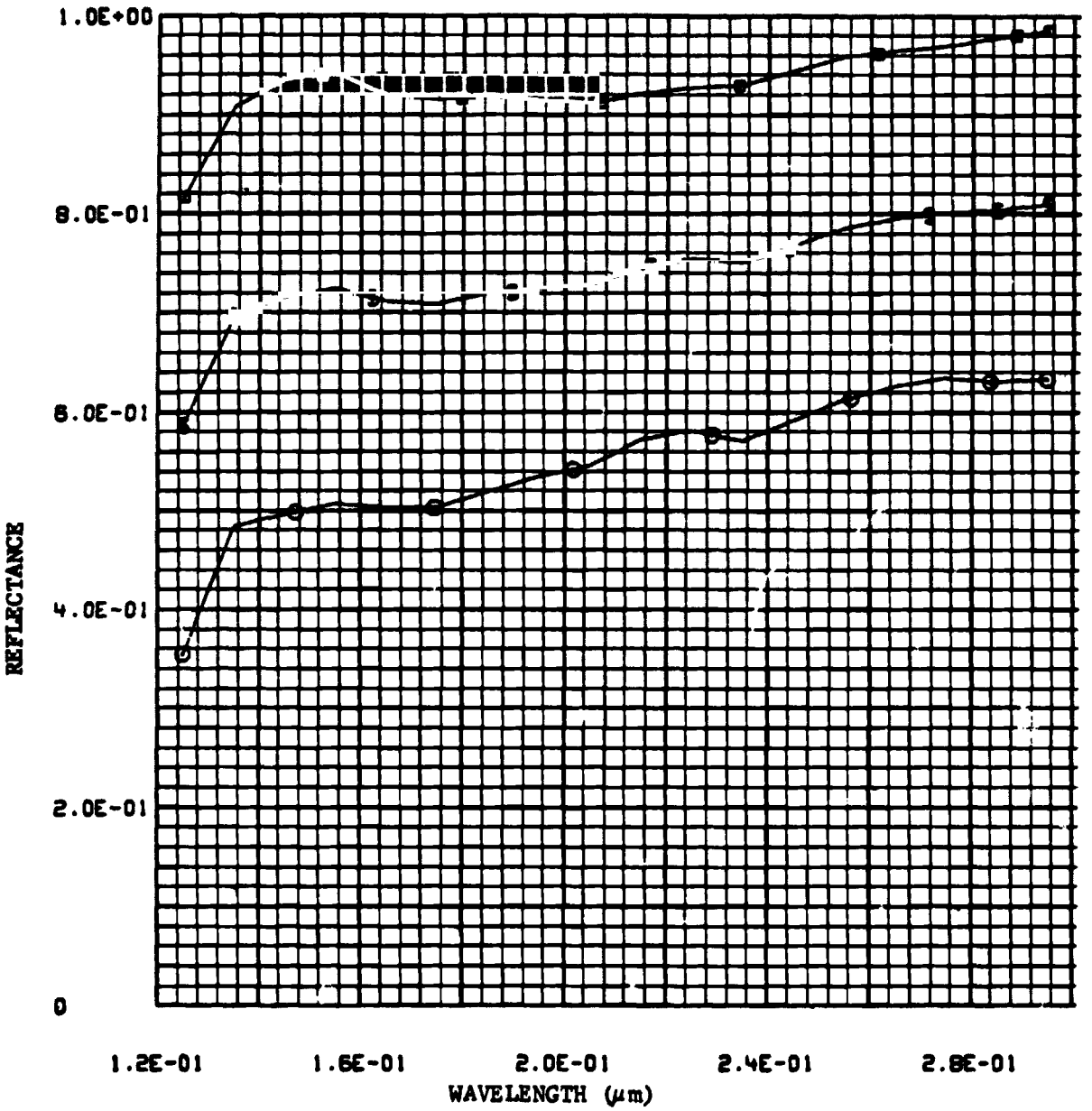

Figure 39. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Preflight Primary Al+MgF_2 Mirrors, 10 Deg, VUV, 9/24/73

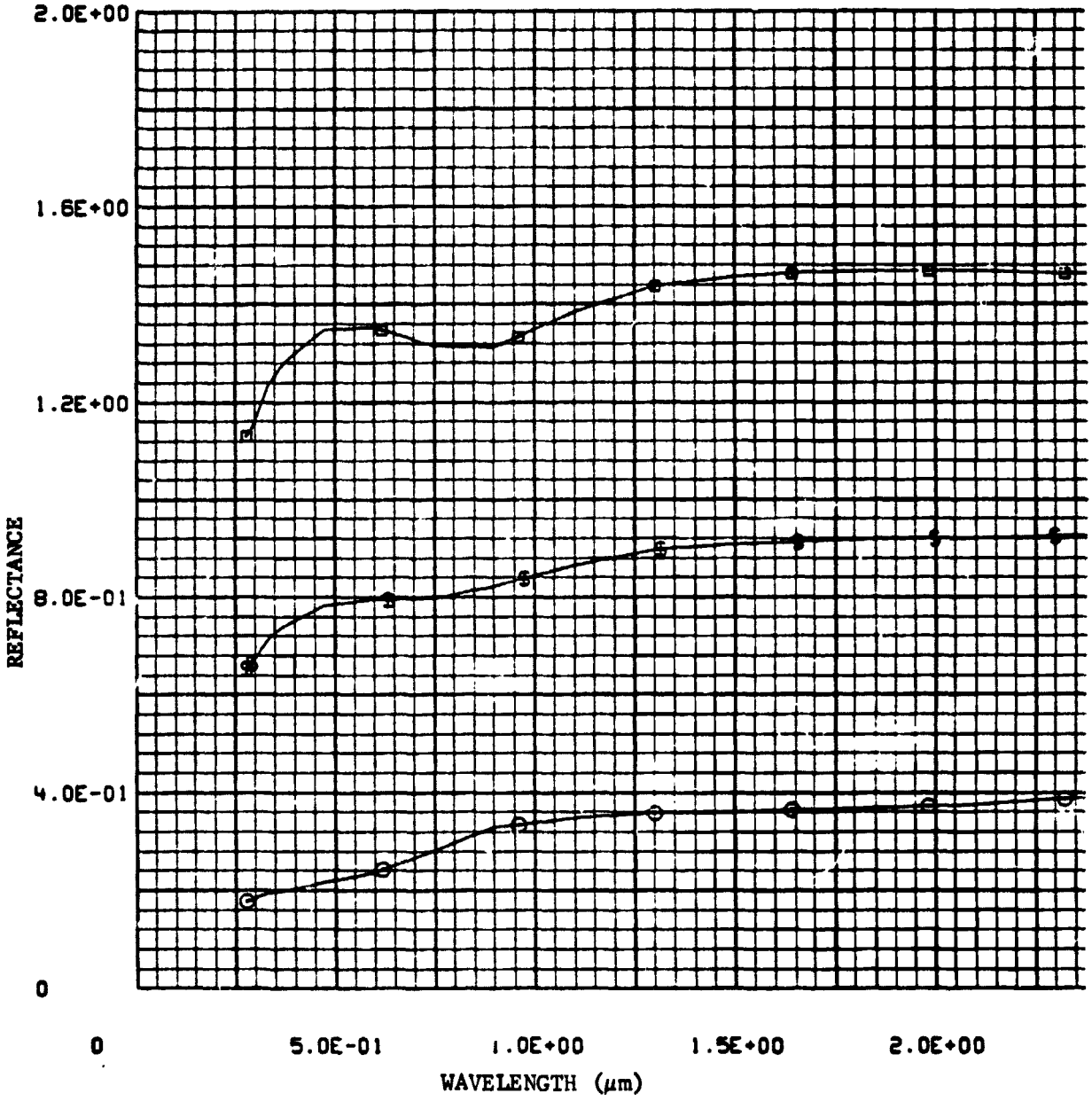

Figure 40. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Al+MgF_2 Mirrors, 10 Deg, DK, 9/25/73

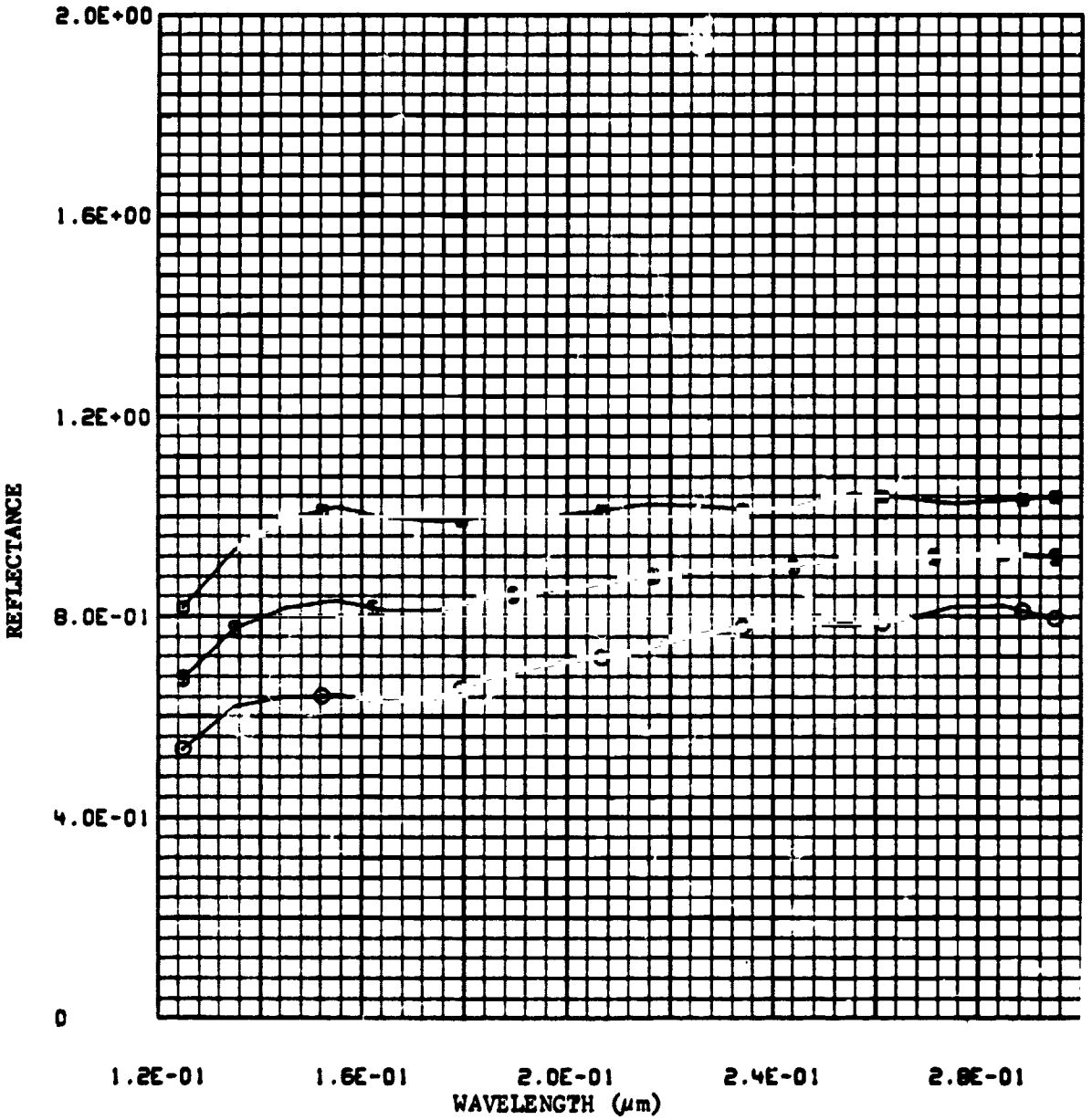

Figure 41. Three Sigma Deviation About Mean Reflectance Versus Wavelength All Postflight Primary Al+MgF_2 Mirrors, 10 Deg, VUV, 9/24/73

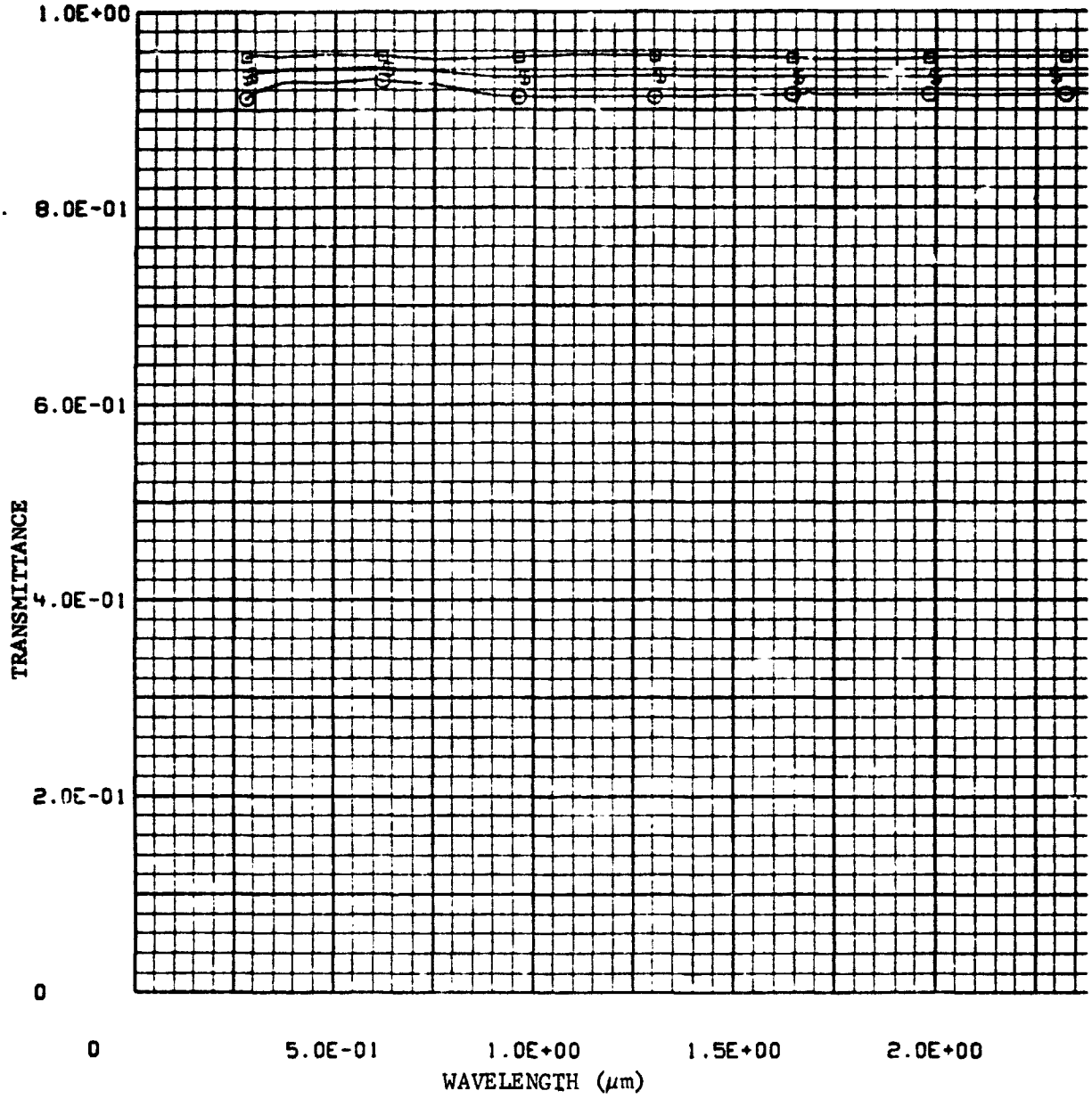

Figure 42. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Preflight Primary MgF_2 Windows, DK, 9/25/73

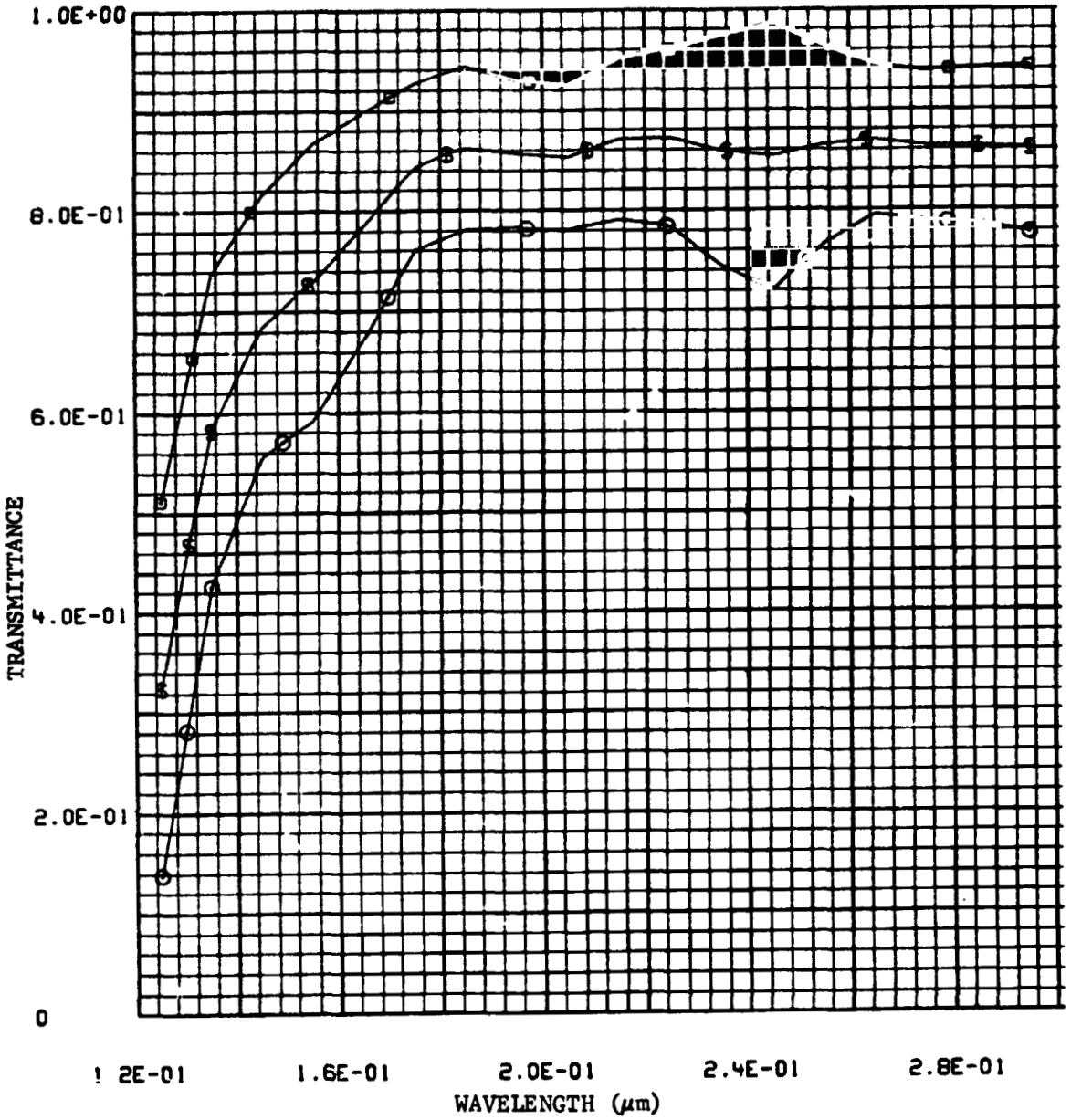

Figure 43. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Preflight Primary MgF_2 Windows, VUV, 9/24/73

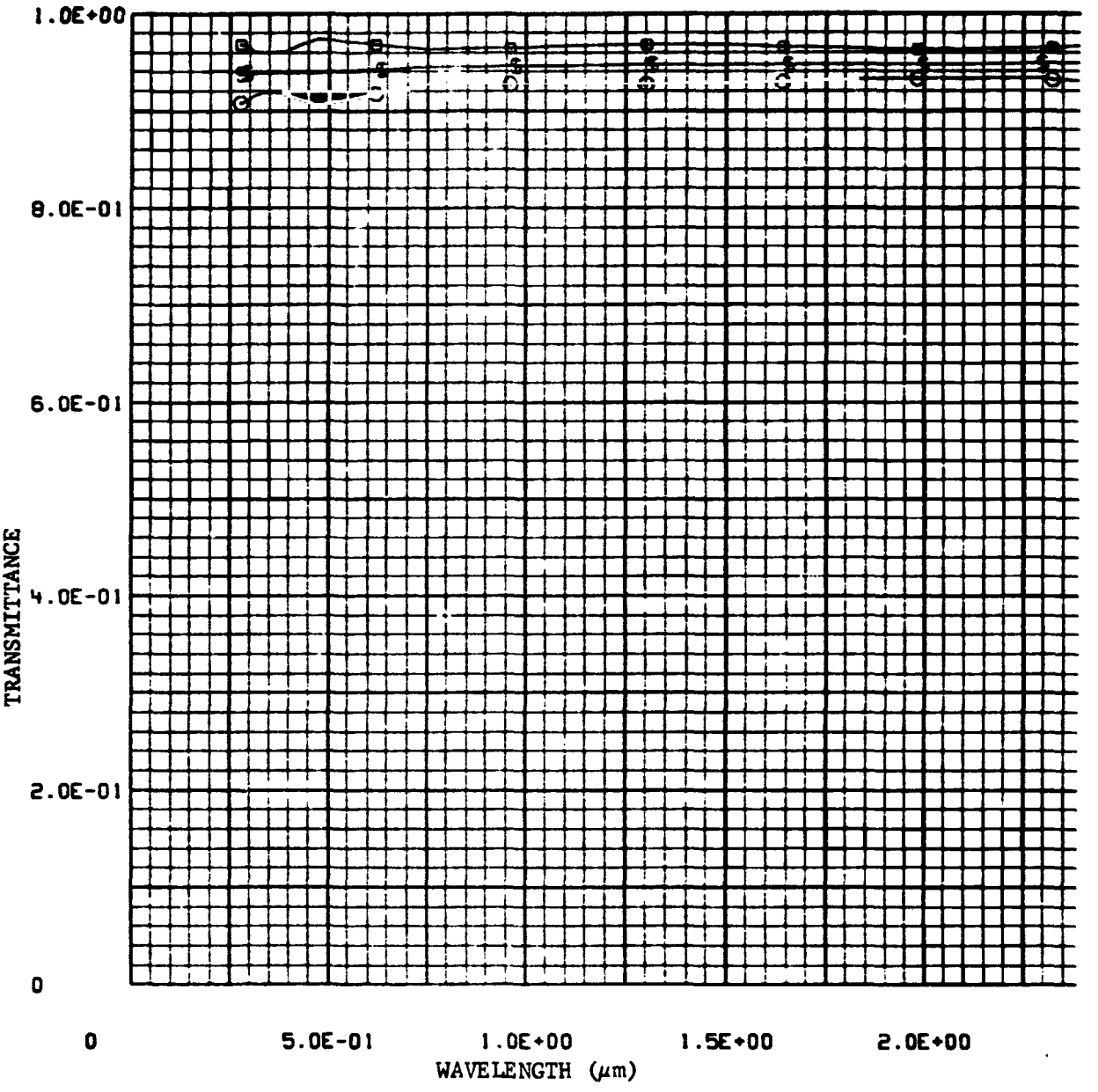

Figure 44. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Postflight Primary MgF_2 Windows, DK, 9/25/73

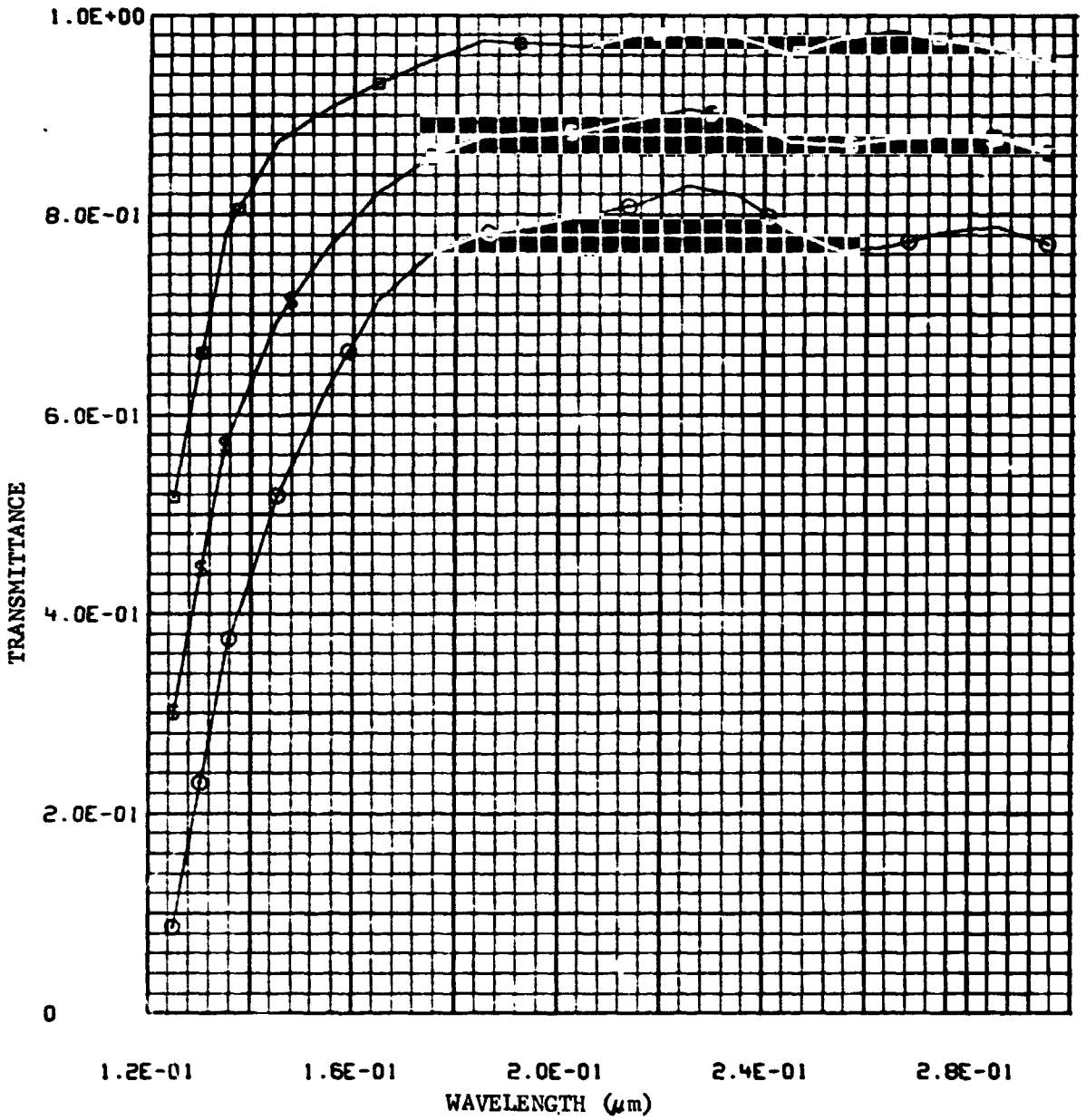

Figure 45. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Postflight Primary MgF_2 Windows, VUV, 9/24/73

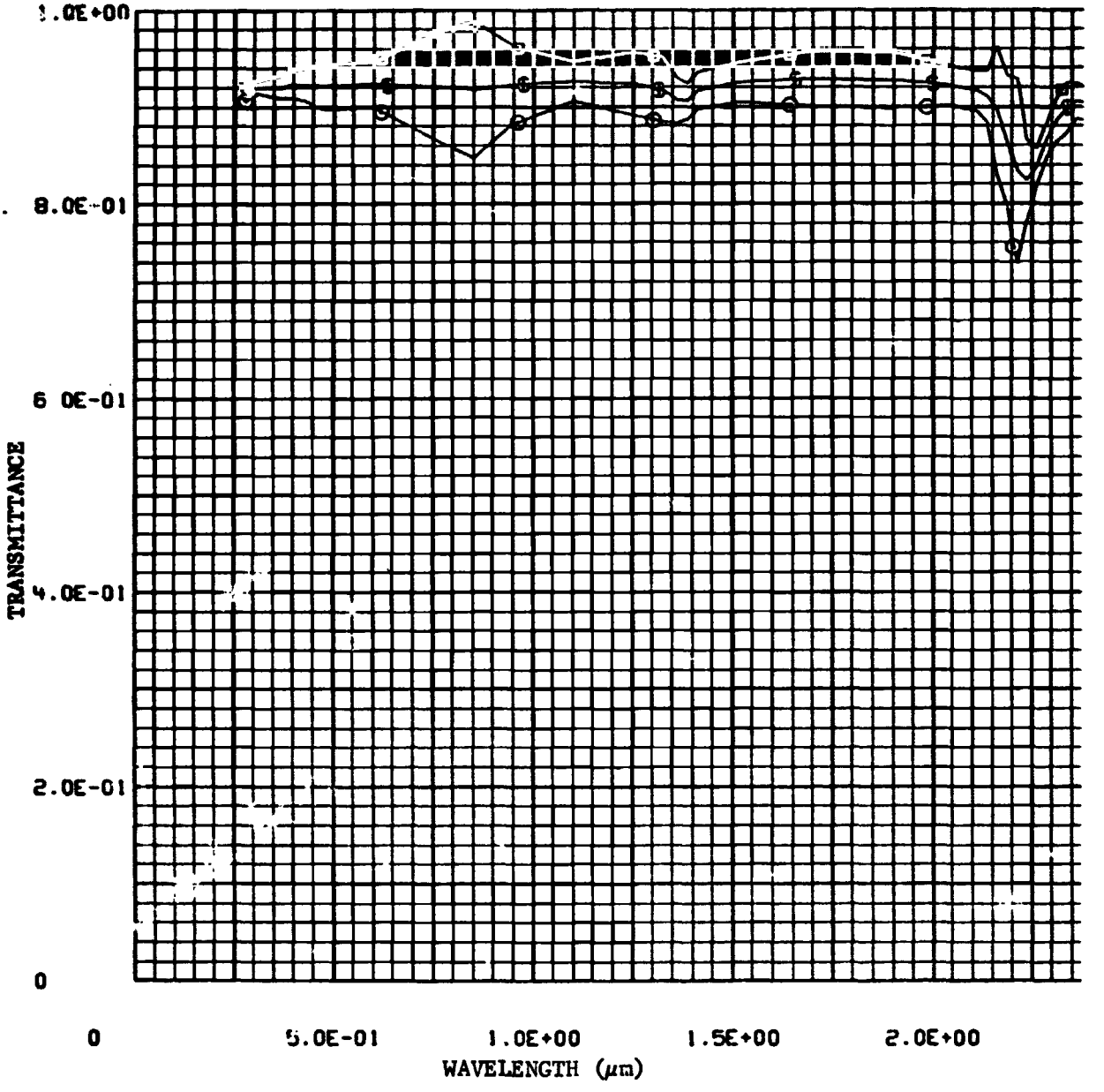

Figure 46. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Preflight Primary Quartz Windows, DK, 9/26/73

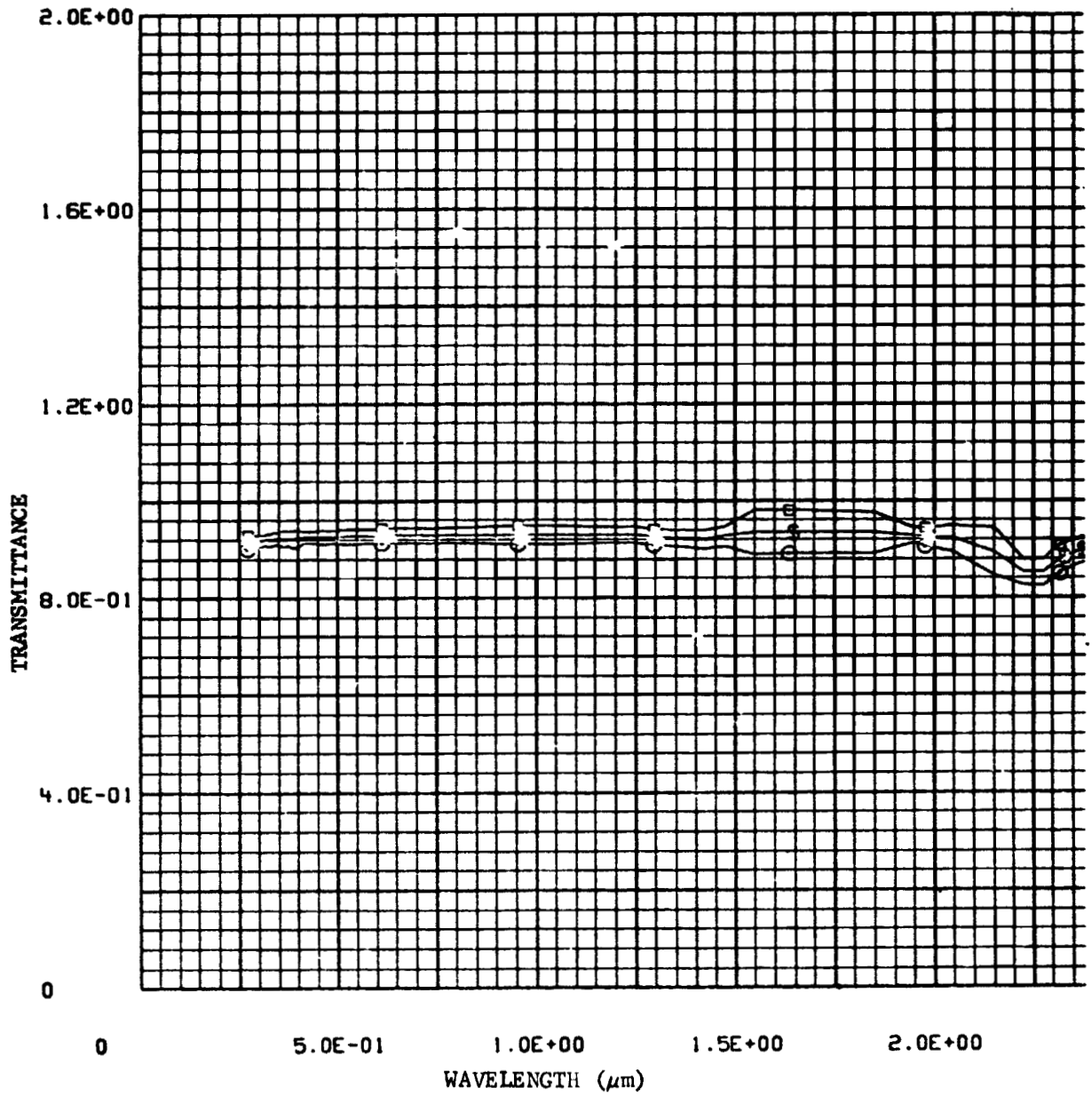

Figure 47. Three Sigma Deviation About Mean Transmittance Vs. Wavelength All Postflight Primary Quartz Windows, DK, 9/26/73

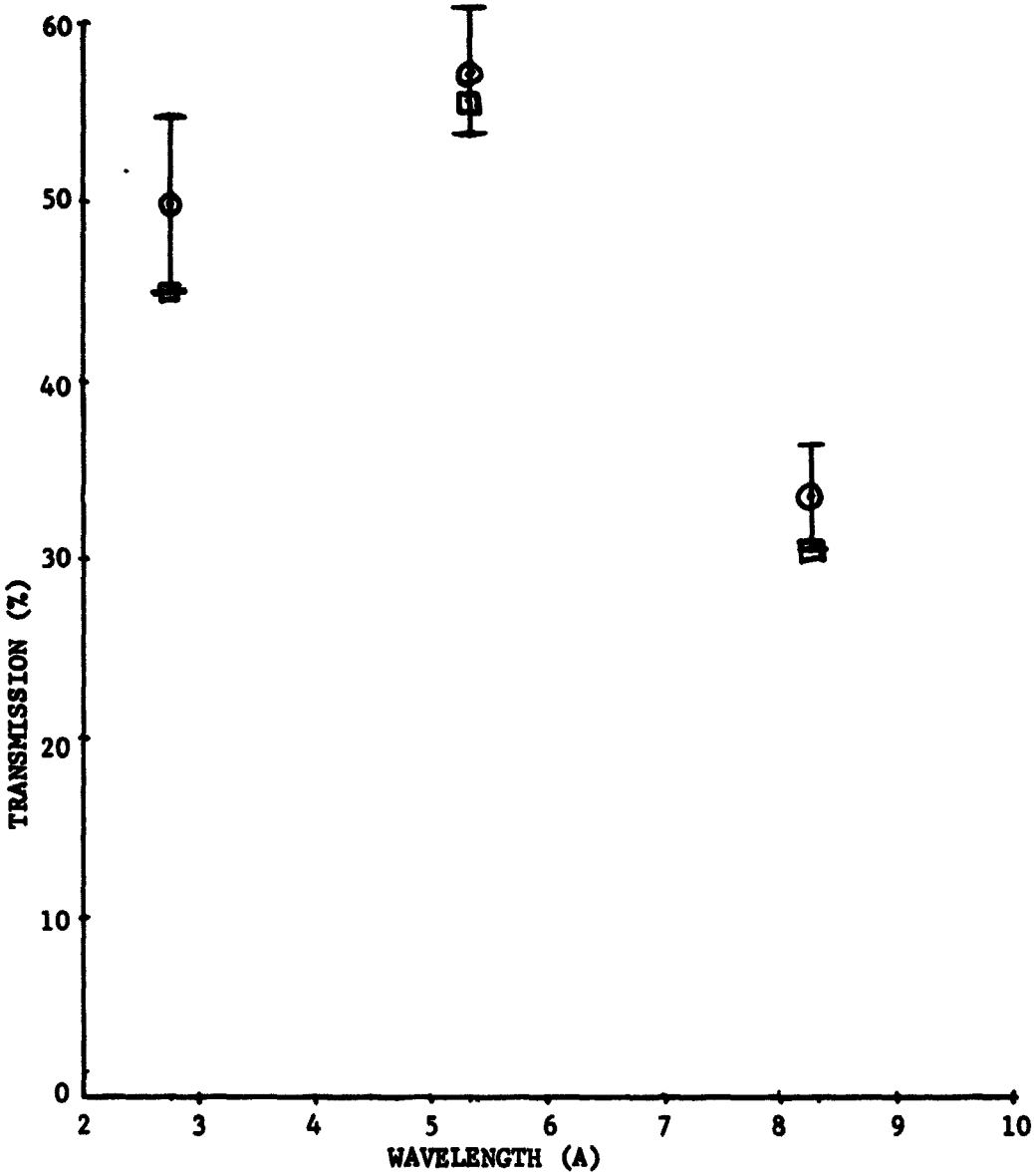

Figure 48. X-Ray Transmission Of Beryllium Foil Number 100. Preflight ⊙, Postflight ⊞, Reproducibility Bars On Preflight Data.

changes in infrared (1.2-20 μm) reflectance or detect any absorption bands for the gold samples (33, 44, 58, 62, 222, 249, and backup 255) and aluminum mirrors (38, 58, and 219). Within the precision of the instrument, no significant changes were detected.

5.4 Thickness Measurements - Selected samples of gold and germanium (see table 6) were studied for contaminant thickness using ellipsometry. Values were reported in the 30 Day Status Report of contaminant thicknesses ranging from 3 to 24A. These values are not correct, further work found systematic calculation errors in the preflight measurements giving no significant contaminant thicknesses.

5.5 Diffraction Gratings - The three diffraction gratings (55, 66, and 232) were measured for changes in zero and first order diffraction reflection intensity. Neither the efficiency nor resolution had changed from the preflight values.

5.6 Low Scatter Measurements - Three nickel mirrors (108, 127, and 206) were measured for specular reflectance in 1^{o} increments through five orders of sensitivity to detect scattering of the incident helium (6328A) laser beam by any surface contaminant. No significant change in scattering was detected; Fig. 49 shows the normalized preflight and postflight scattering values for sample 127, the points fall within the thickness of the line.

The quartz flats (6, 12, 48, 61, 74, and 94) were used to determine changes in x-ray (8.34A) scattering, the reduction in data from this test is still in progress. However, no obvious change in the scattering has been seen.

5.7 Infrared Absorption - The six ATR samples (64, 65, 93, 98, 237, and 238) were used to obtain the infrared absorption spectra of the contaminants. Only the two exposed KRS-5 crystals (65 and 98) showed any new absorption bands. Bands were found at 9.45 μm and 13.79 μm, however there is a lack of sufficient key bands to positively identify the contaminant composition by infrared spectra alone. Although the 9.45 μm band is typical of silicones, other equally strong silicone bands are missing. Figure 50 shows the absorption spectra for sample 65.

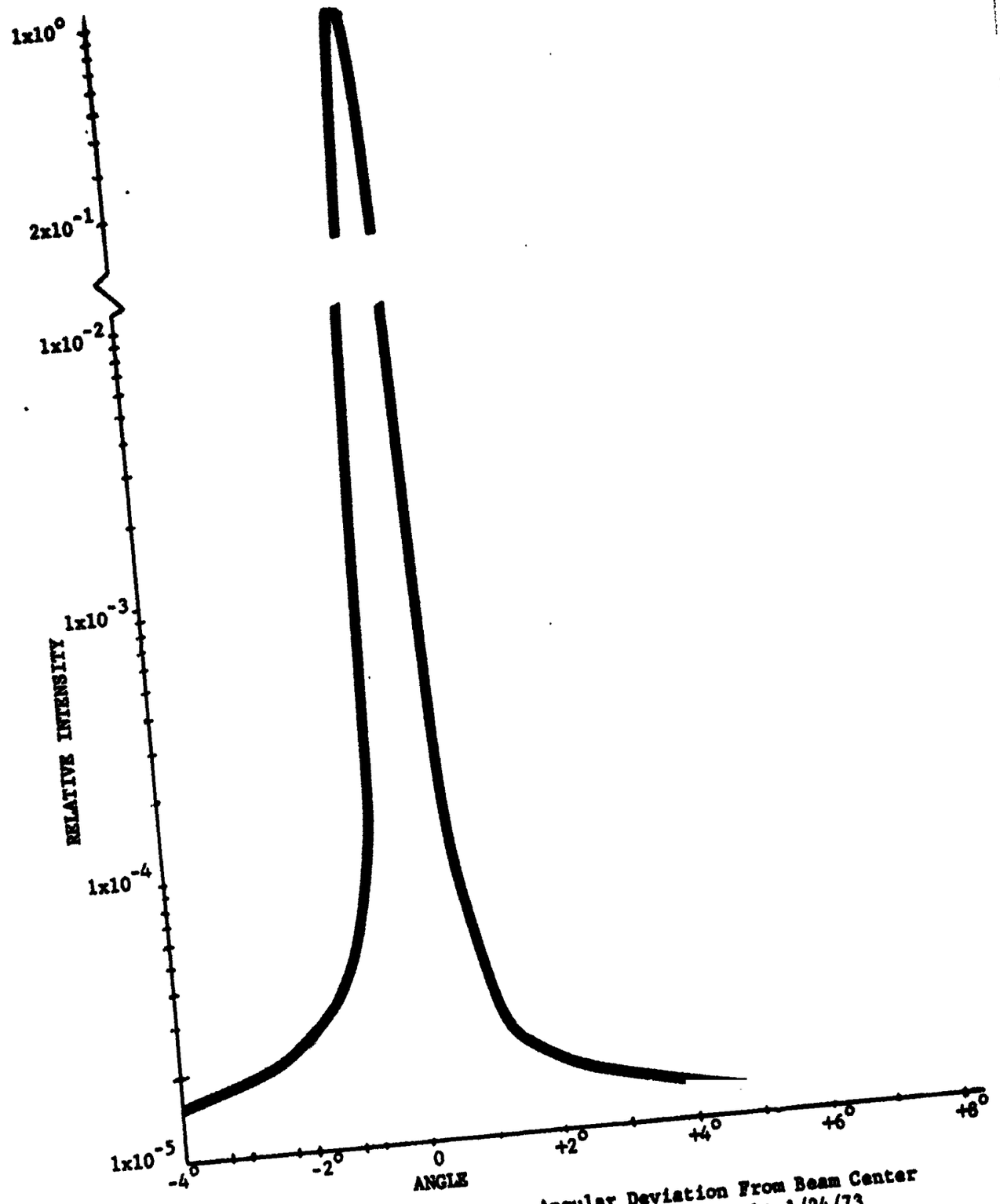

Figure 49. Specular Reflection Versus Angular Deviation From Beam Center
Nickel Mirror 127, Postflight 8/15/73, Preflight 1/24/73

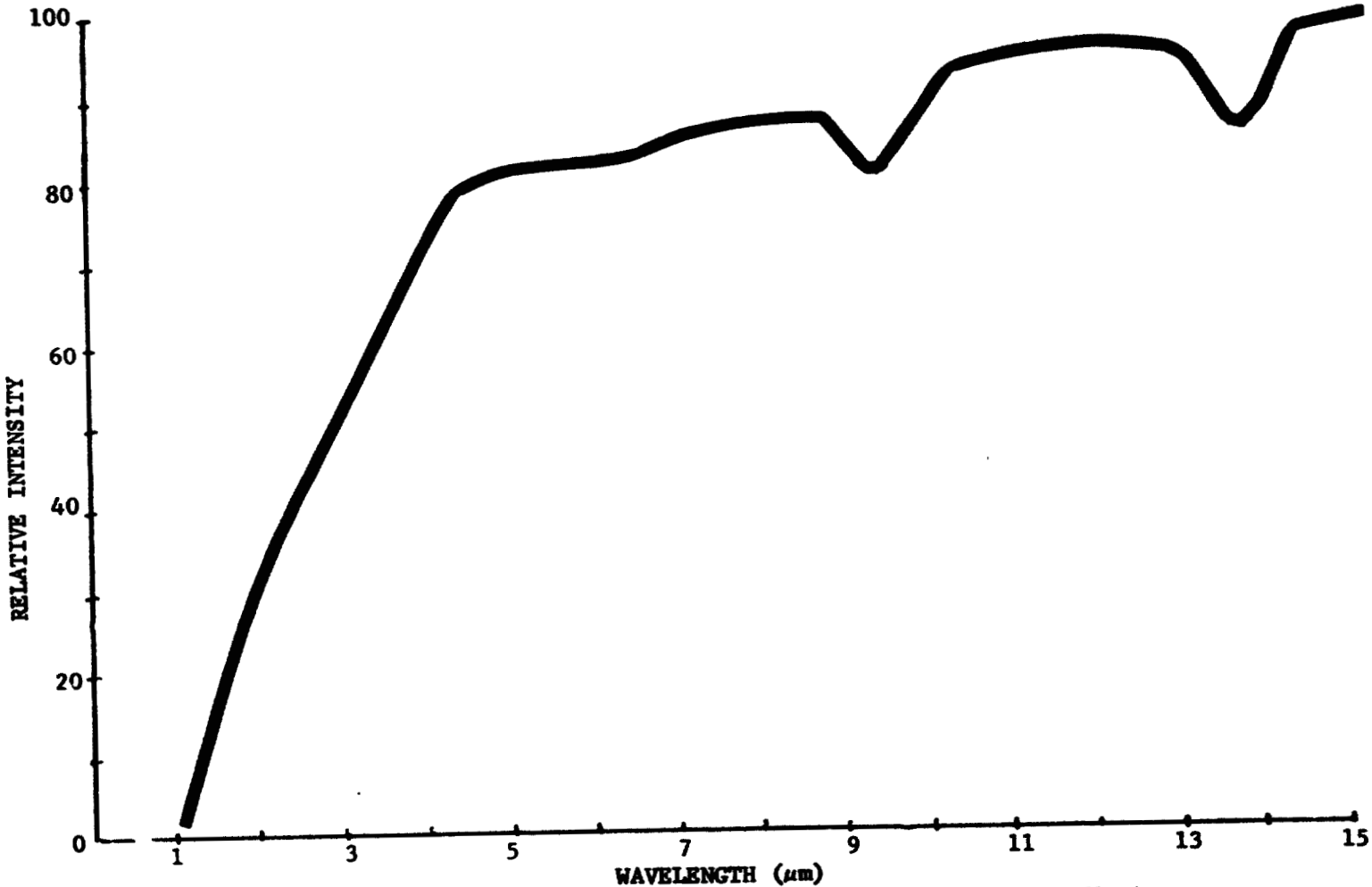

Figure 50. Infrared Absorption Spectra Versus Wavelength, KRS-5/ATR 65, Postflight

5.8 Mass Spectrometer Analysis - Three sample retention plates were analysed for contaminant composition by mass spectroscopy. The plates covered samples 53-61, 77-84, and 206-217. Leaching solvents hexane, benzene, methylethylketone, and methanol were used to concentrate the contaminants. Background spectra were taken for each solvent in the same manner as the sample spectra. The concentrated solutions were used for the mass spectrometer and in addition portions of the hexane and methanol solutions underwent ultraviolet spectroscopic analysis.

All three plates released their contaminants to the hexane in much greater proportion than any of the other solvents. The second solvent, benzene had the second largest peak intensities. No differentiation in peak intensity ratios as a function of solvent was observed. For this reason, all the needed information can be obtained by discussing the hexane solvent mass spectra.

All the ultraviolet spectra have increasing absorption at shorter wavelengths, shoulders are observed at 0.275 μm and 0.228 μm. The spectra shows that the amount of soluble contaminant on the control plate 206-217 was 15 to 30 times greater than that obtained from the other two plates.

Table 7 shows the prominent mass peaks observed on the three plates. Due to the similarity of the 53-61 and 77-84 plate spectra, their results are listed in one column. The relative abundance column is divided into early and late according to the peak intensity as a function of the time the hexane fraction probe remained in the mass spectrometer inlet. A mass peak whose relative abundance increases with time comes from a compound which has a low volatility.

Table 7 Mass Spectroscopy of Sample Retention Plates

Mass Number	Plates 53-61 & 77-84 Relative Abundance		Plate 206-217 Relative Abundance
	Early	Late	
733	0.2		
667	0.5		
501	10	10	
479	2		
337	3	25	
335	20	25	Present
320		20	

Table 7 (Cont'd)

Mass Number	Plates 53-61 & 77-84 Relative Abundance		Plate 206-217 Relative Abundance
	Early	Late	
313	20		Present
285	20		
279		10	
206		25	18
169	100	25	
167		45	
149	70	100	100
147	50		
105			22
91	100		77
65			24

Although the spectra are quite complex, some specific information can be derived from them. The 149, 167, and 279 peaks are among the most prominent and represent dioctyl phthalate. In many spectra, the 149 peak persists when the 167 peak is in low abundance. This may signify the presence of other rare phthalate esters not commonly classified. The 206-217 control plate in particular has a very large 149 peak with no significant 167 peak. The tropylium ion (mass number 91) is abundant in all spectra and is indicative of aromatic ring and condensed ring compounds. The associated 65 peak and metastable peak at 46.4 which should be present with a 91 peak are observed. Phthalates do not generate the tropylium ion showing that there is a multiplicity of compound types present.

A definite trend of 14 mass unit loss is present in the 53-61 and 77-84 plates which is much less noticeable in the control sample. This indicates the presence of alkanes or alkyl chains in the contaminant present on the plate exposed in space.

No halogenated compounds have been observed; there are no appropriate isotopic ratios nor are there the typical 50, 69, and 100 peaks associated with fluorocarbons. The 73 and 146 peaks typical of silicones are also absent.

The ability to observe the high molecular weight species implies the presence of some very stable compounds, again suggesting the presence of condensed aromatics. The high

molecular weight peaks have not yet been identified using standard mass spectral tables or the National Institute of Health computer files.

Two probes, sample 104 and 207, were attached directly to the mass spectrometer direct introduction probe and heated to 250°C. No contaminants were found on either probe. The lack of contaminant on probe 207 which is within the area of plate 206-217 means the contaminants seen on this control plate probably came from the transportation tray. Although the surface area of the plate is greater, the direct probe technique could easily detect a proportional decrease in the amount of contaminant. Appendix F contains sections from the report submitted by Denver Research Institute who performed the mass spectroscopy work.

Because the contaminants found on the exposed sample plates were also found on the control plate and in both cases only trace amounts were detected, meaningful conclusions on the composition of the space contaminants is difficult. It is concluded that no significant amount of contaminant was deposited and the trace amounts consisted of alkanes or alkyl chains.

5.9 Guest Samples - The twenty one guest samples were returned to the various laboratories on July 10-12, 1973. Verbal discussions with the guest scientists have produced the following preliminary results. A letter from IITRI about their S-13G thermal control paint samples stated there were no visual changes and the diffuse spectral reflectance decreased by 1-2% in the 325 nm to 700 um region. They reported the significance of the decrease is inconclusive. Conversations with E. Shriver, MSFC, revealed the charged electret samples showed some contaminants that the neutral sample did not have. The results on the auger samples are contained in the NASA technical memorandum NASA TM X-64834 Auger Measurements On T027 Samples Exposed During the Skylab 2 Mission, P.N. Peters, MSFC, February, 1974. The abstract states the measurements indicate a low rate of deposition of permanent, continuous-film contamination on the nickel and gold surfaces. The continuous films are less than 5-10 monolayers thick. The HCO tests are still in process and no results are available at this time. The OPL black anoidized surfaces showed no change in reflectance.

6. DATA ANALYSIS

Although the samples were free of contaminants, a brief description of the planned analysis program is included for completeness. The following sections discuss the various portions of the analysis program.

6.1 Optical Property Changes - The preflight and postflight data processed by the developed computer programs was to provide a detailed examination of the effect of space contaminants on transmittance, reflectance, grating efficiency, and polarization. The degree of contamination effects was to be studied and its relation to the instruments on Skylab and future space programs.

Although no exhaustive survey of the optical materials used on Skylab, which will be exposed to external contaminants, has been done, a cursive study of the surfaces planned for Skylab in 1971 resulted in the selection of samples for T027. In many cases, although the exact component is not represented, the critical surface is present. For example, the BK-7 S19CA window material is not on the array, however the MgF_2 coating on that window is present in T027 as a window disc and a dielectric overcoating.

6.2 Variations in Deposition of Contaminants - The T027 Optical Properties Analysis Computer Program will provide the way of comparing a sample and groups of samples to determine the variations in deposition of contaminants due to substrate, solar radiation, period of exposure, and direction of exposure. The nature of the program is to extract the maximum information in a straightforward method. The three sigma capability was developed for sets of like data to handle variations in the curves caused by instrument parameters and not necessarily contamination. The preflight measurements have developed the three sigma curves for the various types of samples. Sigma, the standard deviation of the normal distribution, measures the variation of the individual measurements. Three sigma means 99.74% of the measurements lie within three sigma bands on each side of the mean. In this way differences and abnormal behavior of the postflight measurements can be easily detected.

Table 8 lists the different types of surfaces that were exposed on T027.

Table 8 Types of Sample Surfaces

1.	Au Crystal	9.	Pt Thin Film	17.	LiF Crystal
2.	Au Thin Film	10.	Ni Metal	18.	LiF Thin Film
3.	Al Thin Film	11.	Ni Thin Film	19.	Ge
4.	Al Metal	12.	Be Foil	20.	KRS5
5.	Al Foil	13.	Chromium	21.	Sapphire
6.	Ir Thin Film	14.	Stainless Steel	22.	Fused Quartz
7.	Os Thin Film	15.	MgF_2 Crystal	23.	Optical Black Anodize
8.	W Thin Film	16.	MgF_2 Thin Film	24.	S-13 G Paint
				25.	Teflon

The effects of solar radiation on the deposition of contaminants was to be determined by comparing the samples on the upper carrousel which face the sun with similar samples on the array which are shaded. Orientation changes in the cluster during the array exposure were to be used to determine actual sample solar exposure.

Comparisons between the samples on the upper carrousel, lower carrousel, and other positions would have determined the effects of exposure times and indicate when the contaminants are evolved and lingering time. The upper carrousel consists of six sets of 5 samples. When the start switch on the canister control panel is initiated the counting circuit accumulates pulses until 24 hours have elapsed; at this time the motor is actuated and the next set of 5 samples is rotated under the exposure holes. The first and sixth set of samples will be slightly different in length of exposure because of the astronaut participation. After placing the array on the scientific airlock and venting, he then opens the upper carrousel valve. The astronaut must extend the array, connect the power and telemetry cables, activate the airlock power and telemetry connections, and then initiate the start switch on the array canister control panel. Therefore, the first set of 5 samples will be exposed for 24 hours plus the length of time for the astronaut to perform the operation after opening the carrousel valve. The sixth set will be exposed for 24 hours plus the time until the astronaut retracts the array and closes the carrousel valve. Table 9 shows the expected periods of exposure.

Table 9 Upper Carrousel Sample Times

Set	Sample Numbers	Planned Exposure (hours) Start	Stop
1	14, 15, 16, 28, 29	-0.1	24.0+
2	17, 18, 19, 30, 31	24.0	28.0
3	2, 3, 4, 20, 21	48.0	72.0
4	5, 6, 7, 22, 23	72.0	96.0
5	8, 9, 10, 24, 25	96.0	120.0
6	11, 12, 13, 26, 27	120.0	121.0

+ Assume time zero when switch is initiated.

The lower carrousel consists of 3 rings of 26 samples which rotate under four exposure holes, two adjacent holes in the outer ring and one each for the middle and inner rings. When the start switch is initiated, the carrousel rotates one position and repeats this for each of the next 25 hours, once each hour $\pm$ 2 sec. Table 10 summarizes the exposures of the lower carrousel samples.

Table 10 Lower Carrousel Sample Times

Sample Number	Exposure Period (hours) Start	Stop
128, 154, 180	-0.1	0
129	-0.1	1.1
155, 181	0	1.0
130	0	2.0
156, 182	1.0	2.0
131	1.0	3.0
157, 183	2.0	3.0
132	2.0	4.0
158, 184	3.0	4.0
133	3.0	5.0
159, 185	4.0	5.0
134	4.0	6.0
160, 186	5.0	6.0
135	5.0	7.0
161, 187	6.0	7.0
136	6.0	8.0
162, 188	7.0	8.0
137	7.0	9.0
163, 189	8.0	9.0
138	8.0	10.0
164, 190	9.0	10.0

Table 10(Cont'd)

Sample Number	Exposure Period (hours) Start	Stop
139	9.0	11.0
165, 191	10.0	11.0
140	10.0	12.0
166, 192	11.0	13.0
141	11.0	13.0
167, 193	12.0	13.0
142	12.0	14.0
168, 194	13.0	14.0
143	13.0	15.0
169, 195	14.0	15.0
144	14.0	16.0
170, 196	15.0	16.0
145	15.0	17.0
171, 197	16.0	17.0
146	16.0	18.0
172, 198	17.0	18.0
147	17.0	19.0
173, 199	18.0	19.0
148	18.0	20.0
174, 200	19.0	20.0
149	19.0	21.0
175, 201	20.0	21.0
150	20.0	22.0
176, 202	21.0	22.0
151	21.0	23.0
177, 203	22.0	23.0
152	22.0	24.0
178, 204	23.0	24.0
153	23.0	25.0
179, 205	24.0	25.0
128	24.0	121.0
154, 180, 129	25.0	121.0

Figure 51 shows the samples that will be used to obtain the effects of direction on contaminant deposition and thus indicate where the contaminants are coming from. The samples listed by each axis face that direction. Note, in all cases the control samples were to be used to normalize the data from any handling or storage effects. Also, information gained from the control samples which are covered during the space exposure period was to be used to assess the effects of contaminant mobility and the cleanliness of the scientific air-

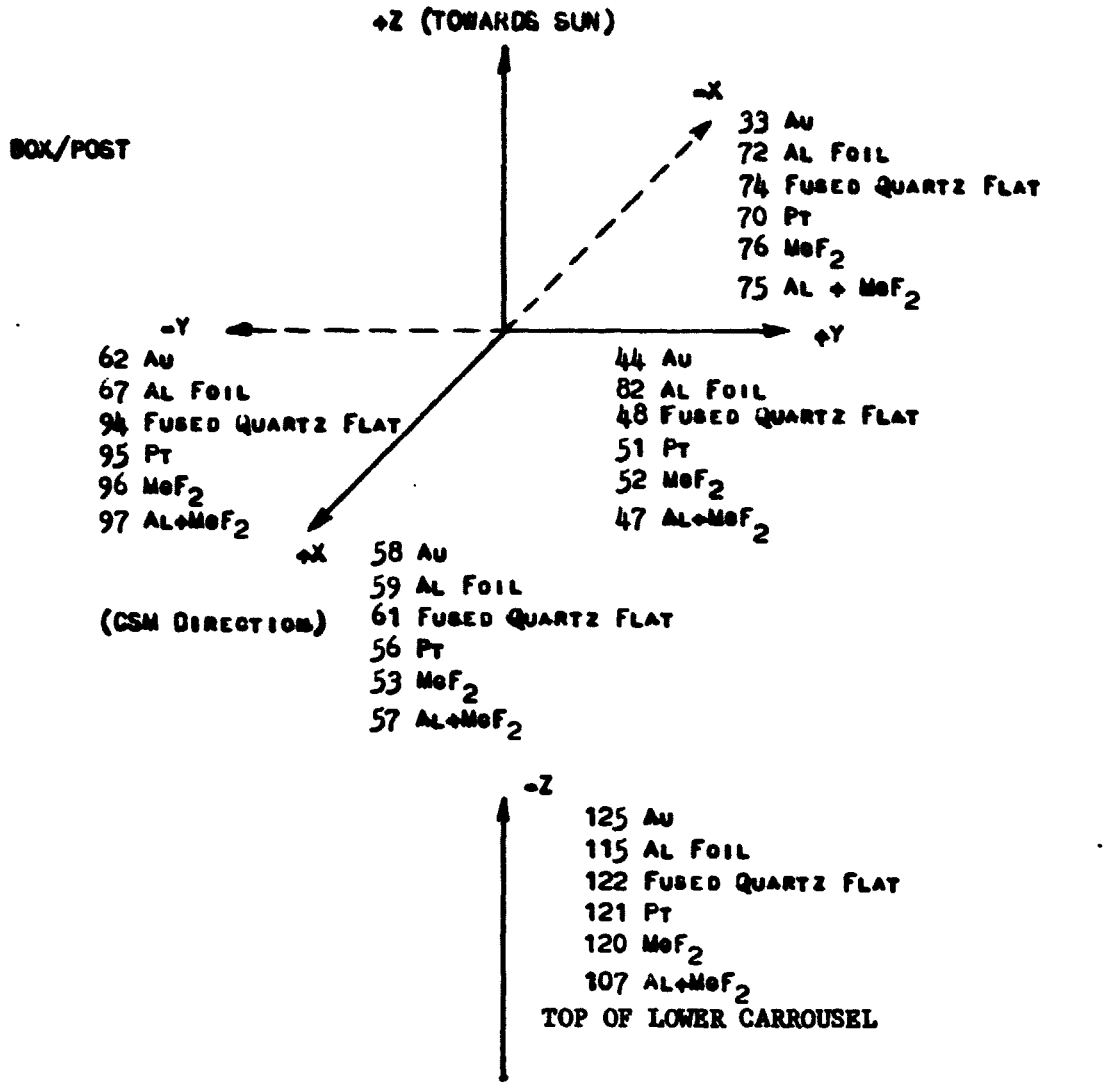

Figure 51. Samples for Directional Information

lock area.

Nine Al + MgF_2 mirrors will be used to study the effects of exposure diameters and path lengths on contaminant deposition. The samples are positioned at the backs of tubes whose length and diameter varies. One of the tubes has a 100 μm slit through which the contaminant must pass. The condition of this slit will also indicate the ability of space contaminants to clog an instrument's entrance slit. Table 11 lists the important characteristics of these sets of samples.

Table 11 Samples for Geometry Effects

Sample No.	Sample Type	Tube Length (cm)	Tube Diameter (cm)	Comments
33	Al + MgF_2	-	-	
34	Al + MgF_2	6.19	2.54	
35	Al + MgF_2	2.20	1.91	
36	Al + MgF_2	-	-	
37	Al + MgF_2	2.20	1.27	
40	Al + MgF_2	-	-	
41	Al + MgF_2	2.20	2.54	
42	Al + MgF_2	14.92	2.54	
43	Al + MgF_2	2.20	1.27	100 μm slit

6.3 Identification of Contaminants - The amount of contaminants found on the array and individual samples will directly affect the accuracy in determining the composition of the contaminant. While the X-ray microprobe can analyze very small amounts of contaminants, it can only identify the elemental composition of the contaminant. Mass spectroscopy and infrared absorption spectra can identify mass fragments and chemical grouping. It was expected that all of the combined data would identify the class of contaminants.

For example, silicones, fluorocarbons, hydrocarbons, and ketones are all organic compounds typical of material outgassing products. Both mass spectroscopy and infrared absorption spectra can fully differentiate each of these classes of compounds. Mass range and class complexity was to be derived from the data. The X-ray microprobe would have been especially useful in identifying inorganic and organometallic particles, such as paint pigments, silicones, metal ions, and heavy anions in salts. With the chemical class data, a direct implication of the contaminant source could have been made; such as silicone from RTV, fluorocarbons from teflon,

titanium dioxide from paint, and so forth.

6.4 Source, Time of Evolution, and Lingering Time of Contaminants - A fairly detailed engineering study has been performed on the sources of contaminants, predicted timeline of evolution, and contaminant stay times. The report describing this work is Skylab Orbital Assembly Systems Design Certification Review - Contamination, November 1972. These predictions will be correlated with the T027 measured contaminant composition, directional infromation, and period of exposure to further determine these contamination parameters.

6.5 Guidelines for a Spacecraft Contamination Model - A model entitled Outgassing Deposition Rate Assessment Program (ODRAP) has been developed to predict the Skylab contaminant deposition rates. The report describing this effort is ED-2002-1440 Rev. A, Skylab Program Payload Integration Surface Effects Empirical Model, September 30, 1972. The data from T027 samples was to have provided flight values to test and modify the parameters and assumptions of this model.

7. SUMMARY

The sample array was exposed through the anti-solar scientific airlock on Skylab 1/2 for 46.5 hours of the planned 120 hours. The array did not collect any significant contaminants. No changes in the optical properties of the samples were detected; measurements were taken from the x-ray wavelength region to the infrared. Only trace amounts of contaminants were found using mass spectroscopy and internal reflection spectroscopy. In both cases no definitive conclusion could be drawn from the results. The unfortunate performance compromises due to the Skylab micrometeorite shield problem and the relative cleanliness of the orbital assembly at the anti-solar airlock, placed the amount of available surface contaminants near the limiting sensitivity of the sample array.

However, evidence of contamination on Skylab has been found. Surface deposition of contaminants was very evident in the area of the EVA (extravehicular activity) quadrant of the airlock module. Photographs taken during each of the three missions show a darkening of the white surfaces into a yellow brown color. Several experiments performed in this area were effected by the contaminants. Samples of contaminated surfaces from the S230 principal investigator Dr. D. Lind, D024 principal investigator Dr. W. Lehn, and S020 principal investigator Dr. R. Tousey were studied in our laboratory. Eleven S230 foils were measured for total reflectance from 250 nm to 2500 nm and directional reflectance from 1200 nm to 20500 nm. The foils were visibly contaminated with a film and the reflectance was significantly lower than the backup foils which remained on the ground. The reflectance was used to calculate the solar absorptance of the foils and the observed interference bands throughout the visible wavelength region were used to calculate the thickness of the contaminant. The thicknesses ranged from 280 nm to 1400 nm and the solar absorptance increased up to 2.4 times the clean value. Infrared absorption bands at 7400 nm and 9900 nm were found in the reflectance spectra of the contaminated foils. While the absorption bands of the contaminant show some correlation to those of coolanol-15 (Skylab thermal control fluid), there is insufficient evidence to definitely point to contamination by this fluid. The thermal control coatings of D024 became progressively darker on later missions, again covered by a yellow-brown film. Absorption bands from 9000 nm to 11000 nm were seen in the reflectance spectra from a section of a D024 metal handle. The S020 spectrograph experienced a significant decrease in the transmission of their indium and beryllium thin film filters.

The reflectance spectra of these filters contained two main absorption bands at 9900 nm and 13500 nm. Once again there were too few bands to definitely determine the contaminant species.

Although the T027 sample array did not detect any contaminants, as the data analysis of other Skylab experiments progress more evidence of contamination may be found. Detailed analysis of the data from the three experiments S230, D024, and S020 along with data from other Skylab sensors, should yield the needed parameters for the deposition math model (ODRAP) developed for Skylab. It is strongly recommended that this model be modified and updated as more contamination evidence is collected, in order to predict the level of contaminants on future space flights.

APPENDIX A

ED-2002-1655 Preflight and Postflight T027 Sample Measurement Plan, March 23, 1973

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A	Drawing 89900000124, Sheets 1 thru 6, Sample Installation and Sample Details - Sample Array	A-1

1.1 Introduction - This appendix selects portions of ED-2002-1655 Preflight and Postflight T027 Sample Measurement Plan, March 23, 1973, to describe the sample array hardware, in orbit stowage, operations, recovery, and telemetry data, requirements. More details on the hardware can be found in MCR-70-140 (Rev 1) Operating, Maintenance and Handling Procedures for T027 Sample Array System Flight Hardware, September 10, 1971.

1.2 General Hardware Description - The system shown in Figure 1 contains 248 samples which were exposed for various durations to collect contaminants. Two quartz crystal microbalances (QCM) are being flown for Marshall Space Flight Center (MSFC) to measure the rate of contaminant deposition on a near real-time basis. Table 1 gives a general description of the hardware elements and their function. Figures 2-6 illustrate the flight hardware. Molded and "O" ring seals located on the array and stowage container will isolate the samples during, before, and after exposure to space.

The sample array as shown in Figure 6 consists of a lower carrousel, a top lower carrousel, a post, a box, two quartz crystal microbalances (QCM's), and an upper carrousel. There are 248 optical samples in addition to the two QCM's.

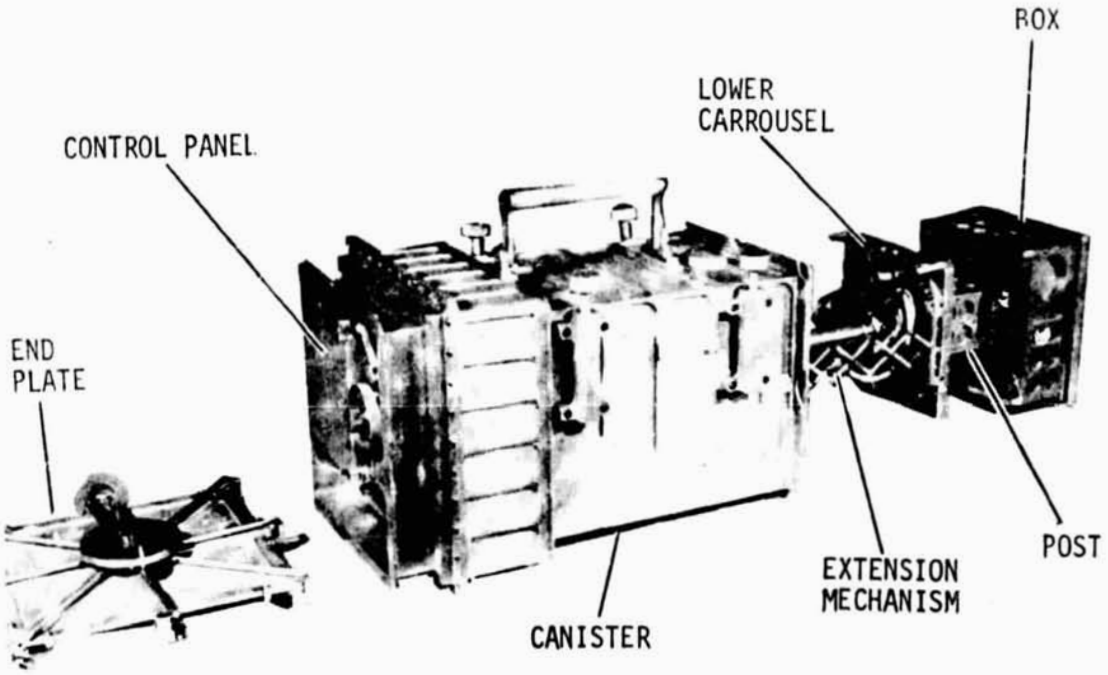

Figure 1. Sample Array System

TABLE 1 - GENERAL HARDWARE DESCRIPTION

Equipment	Function/Description
Sample Array System	
a. Canister	The canister houses the sample array, the control optical samples, the extension mechanism, and the control panel; and provides the interface flange and seal for mating with the +Z SAL. In addition, the canister has two end plates.
b. Sample Array	The array contains the optical samples and motor-driven carrousels for time exposures. In addition, the array contains two quartz crystal microbalances which provide near real-time measurements of rate of contaminant deposition.
c. Extension Mechanism	This mechanism allows the sample array to be extended out of the SAL into the space environment.
d. Control Panel	The panel, located on the rear of the canister, contains the power and program start switches, the ejection mechanism, the extension rod deployment latch mechanism, the array valve actuator, two covered pressurization valves, and the power and multiplexer connectors.
e. Extension Rod	The rod allows the array assembly to be extended out of the SAL so that the top of the lower carrousel will be even with or beyond the OWS meteoroid shield.
f. Ejection Rod	In case of malfunction or emergency which prevents further use of the SAL, this device is used to jettison the array assembly into space.

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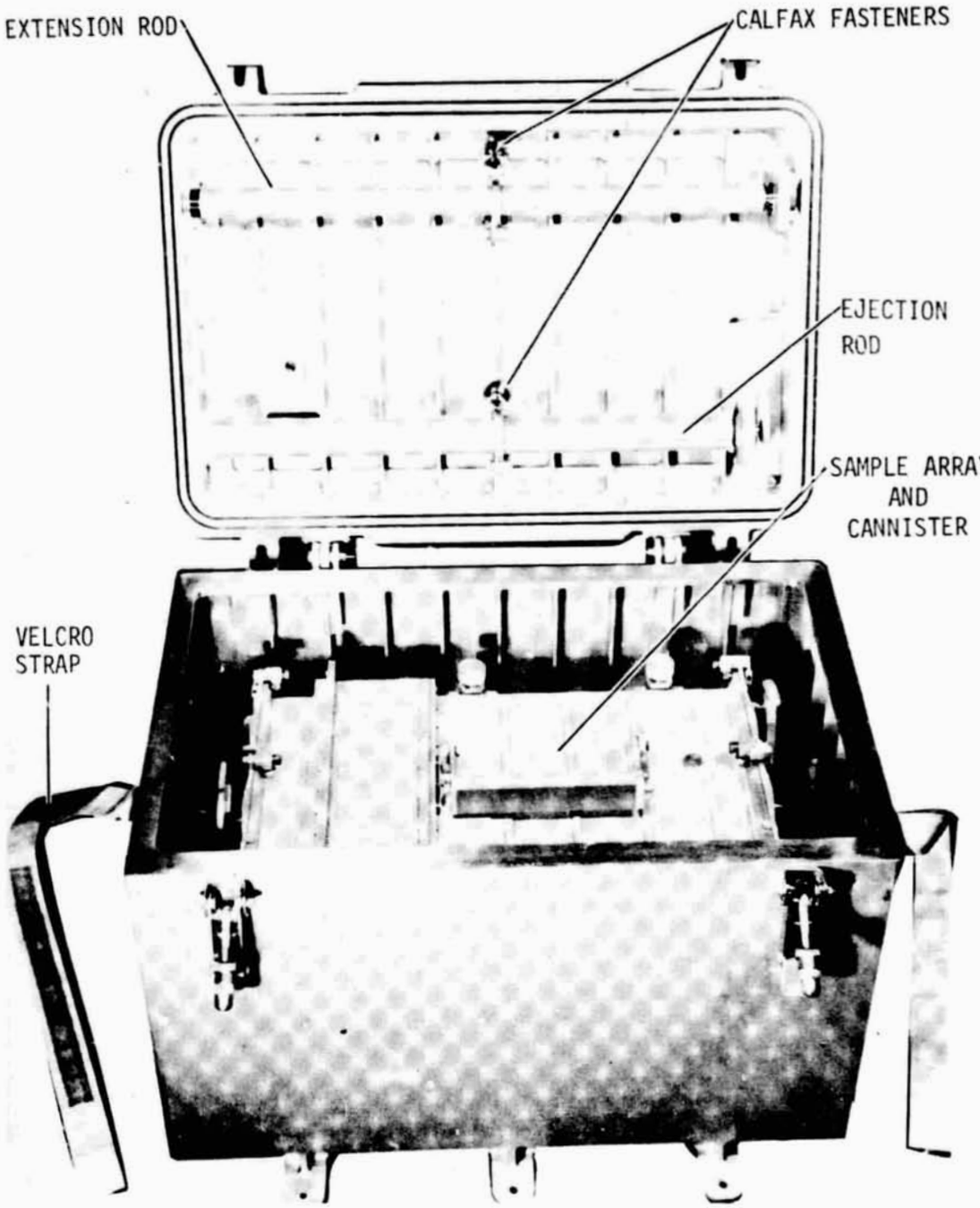

Figure 2. Sample Array System in Stowed Configuration

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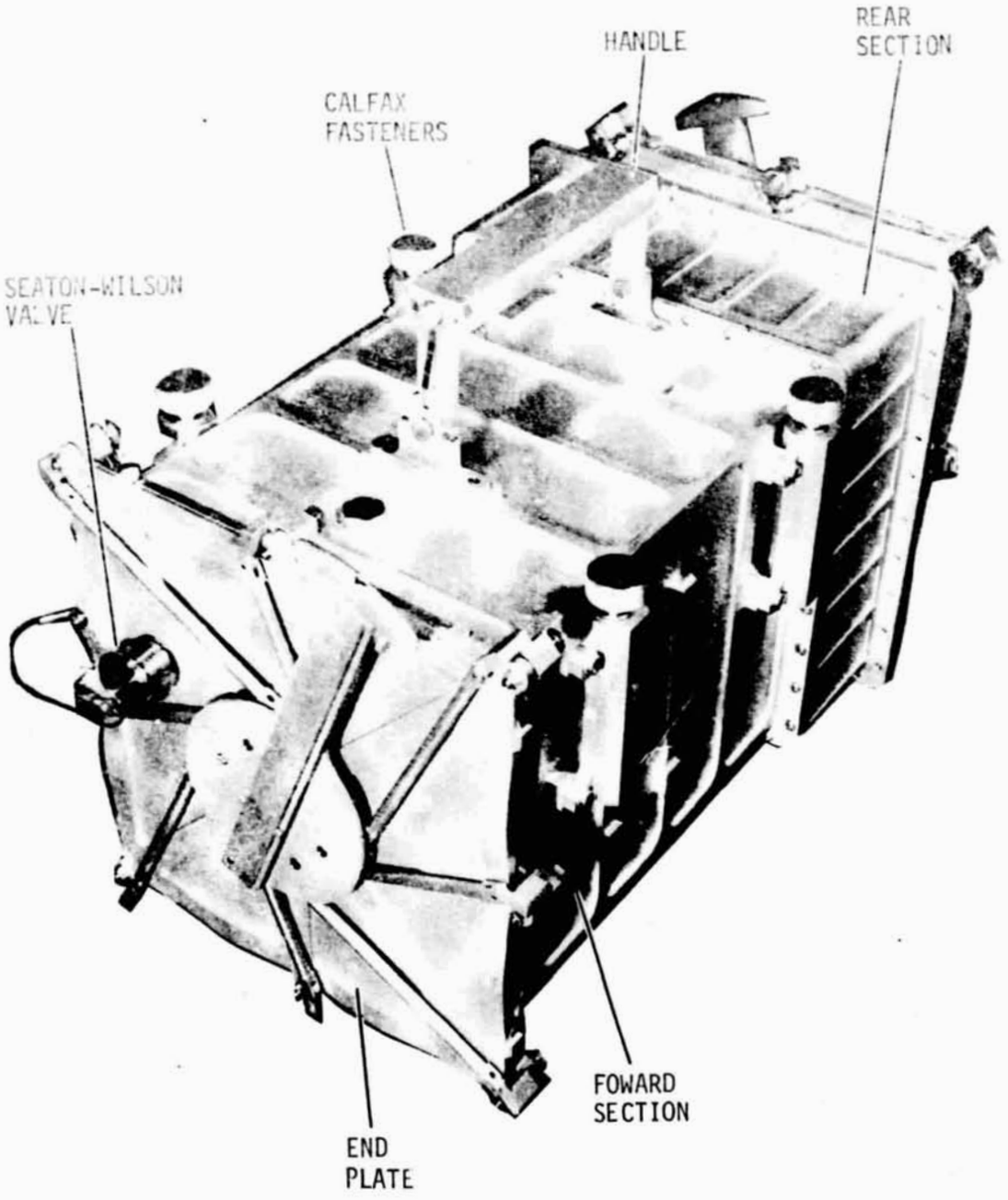

Figure 3. Sample Array and Canister

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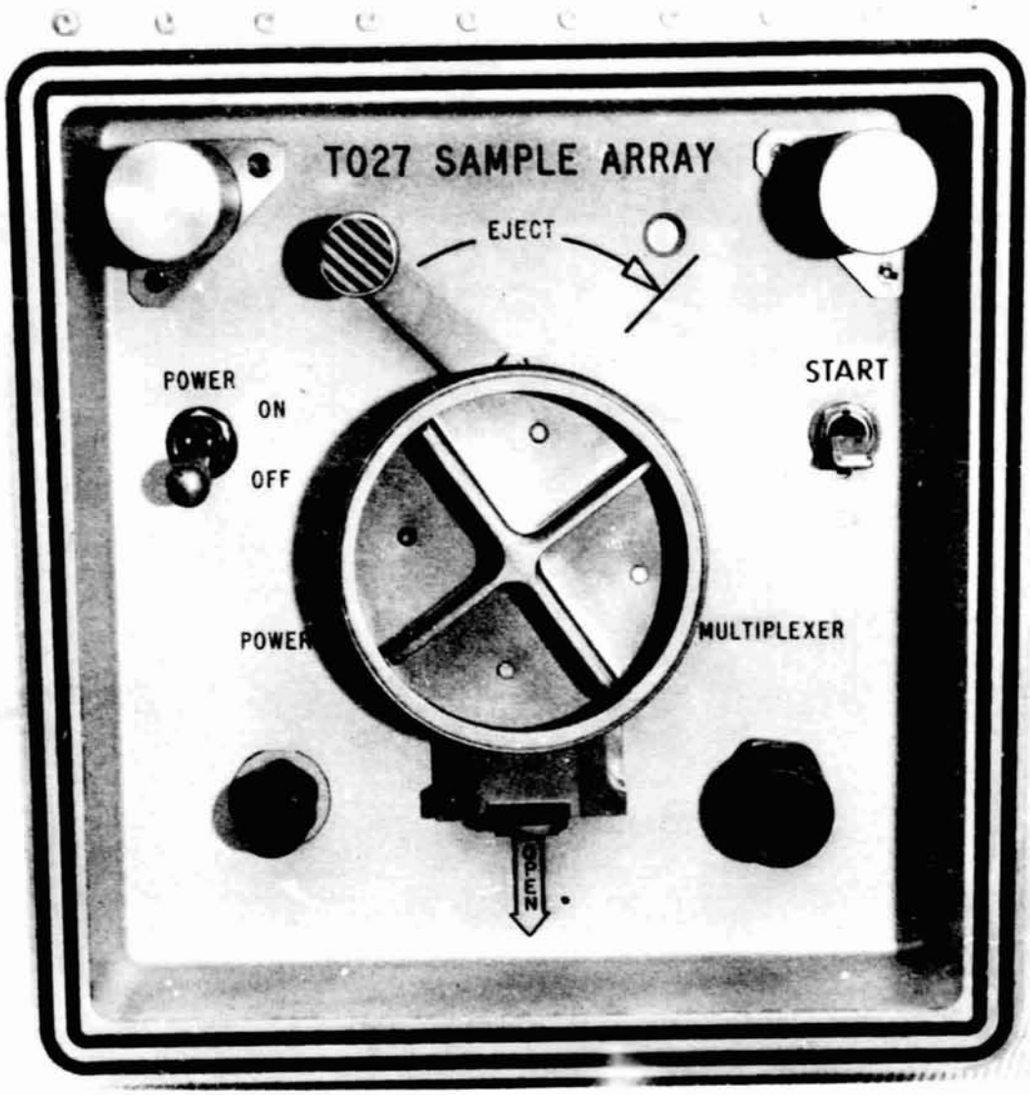

Figure 4. Sample Array Control Panel

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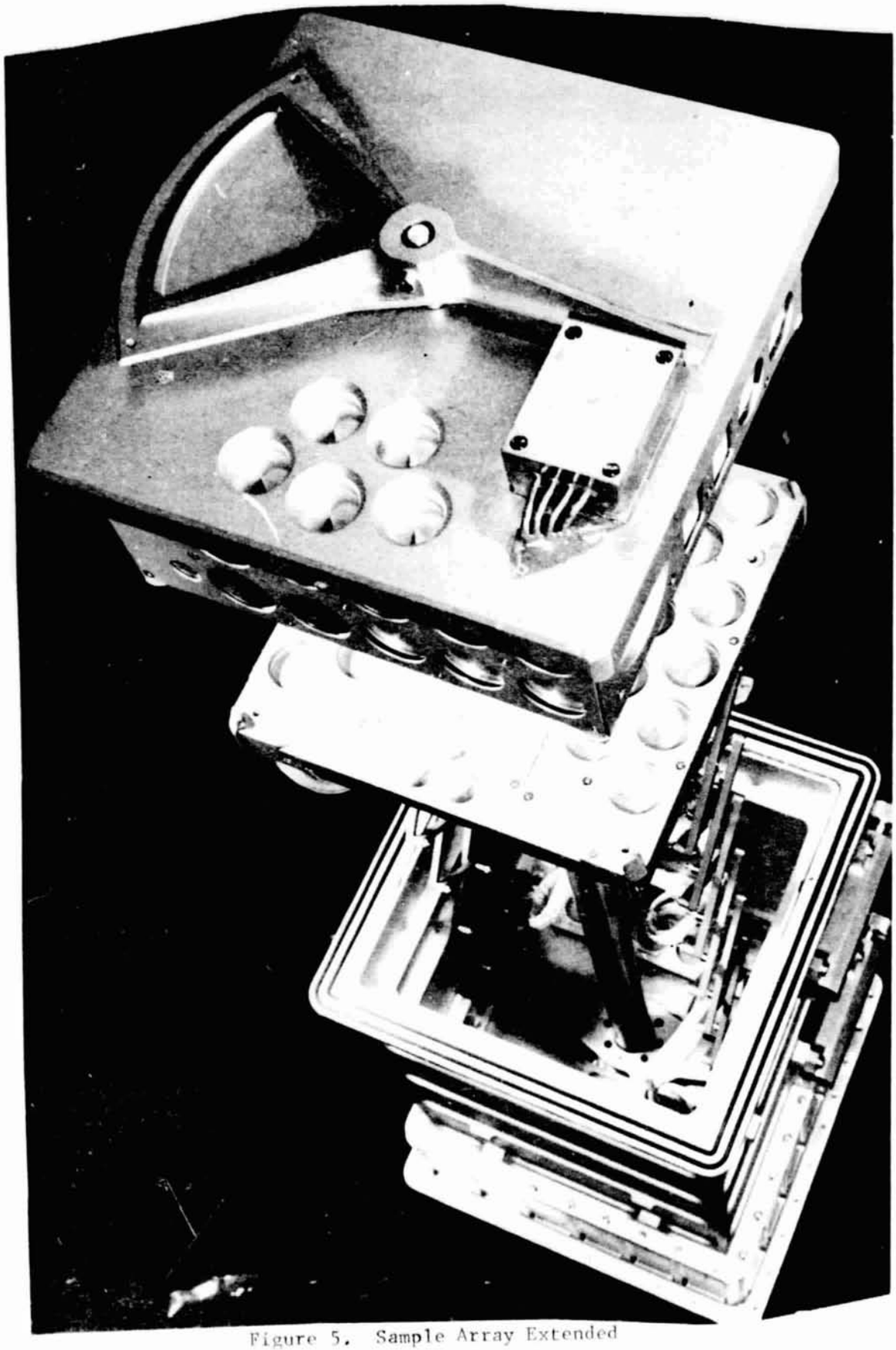

Figure 5. Sample Array Extended

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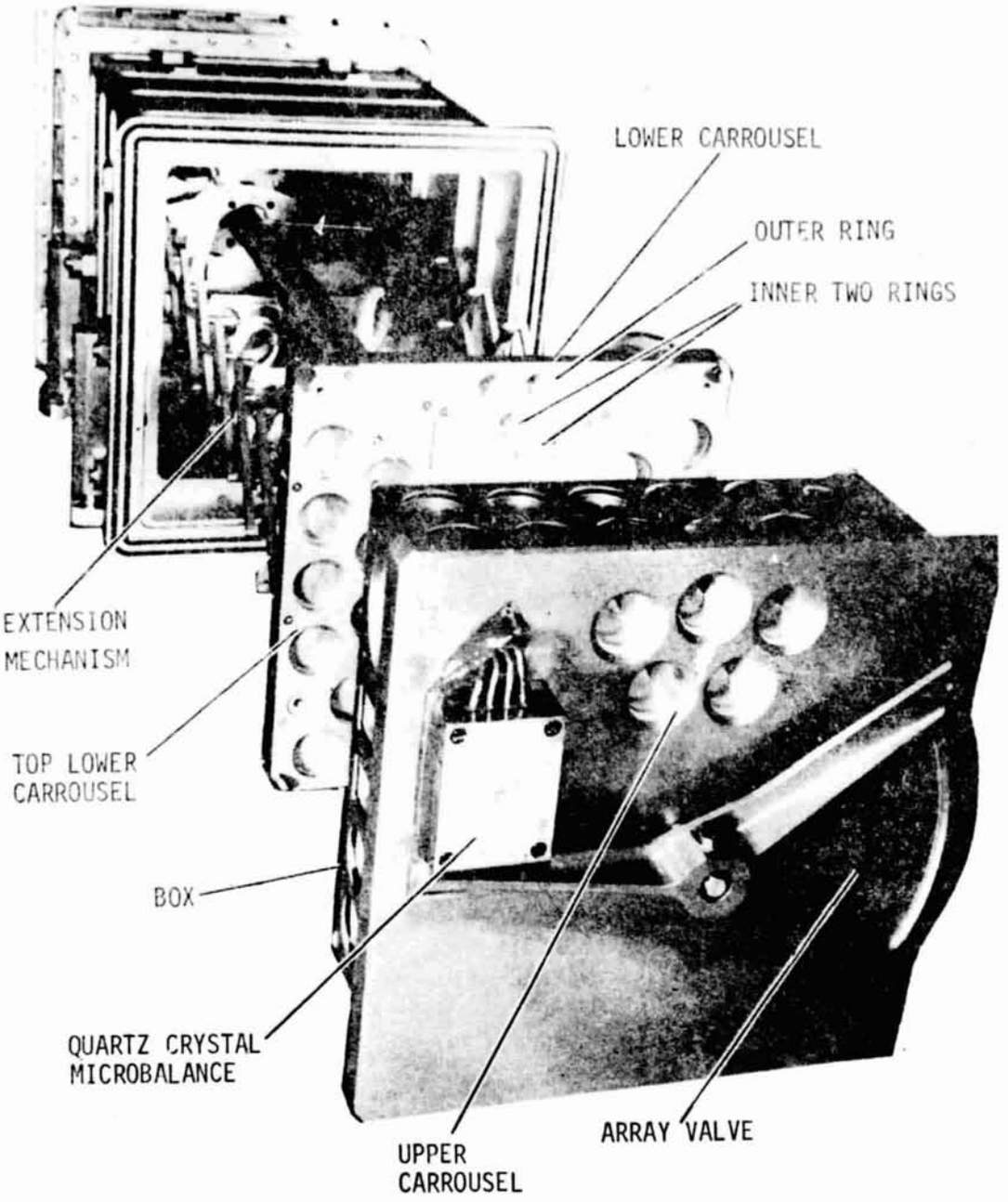

Figure 6. Sample Array Sample Locations

The lower carrousel has three rings which expose samples to space environment. The inner two rings simultaneously expose one sample each for one hour. The outer ring simultaneously exposes two samples for two hours. These ring samples are only exposed during the first 24 hours.

The top lower carrousel contains 29 samples, the post contains 30 samples, and the box contains one QCM and 36 samples. These samples are all exposed continuously during the five-day exposure period.

The upper carrousel contains 30 samples and one QCM. The carrousel exposes five samples for one day each for five consecutive days. The upper carrousel samples are protected by a valve on the front of the carrousel before and after experiment operation (see Figure 6). The valve covers and seals five openings on the front surface. The valve is opened and closed by the array valve actuator assembly located on the control panel. This assembly has a large outer knurled aluminum knob and an aluminum internal valve actuator knob (see Figure 4).

On the inside of the rear canister section there are 45 control samples. These samples are located on the four inner walls and on the back side of the control panel. Sliding plates automatically cover approximately half of these samples when the array is deployed. When the sample array is retracted, all of the control samples are exposed to the internal canister environment. The control sample locations are shown in Figure 7.

The sample array upper and lower carrousels are driven by electric motors. The motors receive 28 VDC pulses from the array electronic system. An oscillator provides a clock for the hourly pulses to the lower motor and pulses to the upper motor every 24 hours. The QCM's as mentioned previously are further defined in the following paragraph and shown in Figure 8.

Quartz crystal microbalances (QCM's) provide near real-time measurements of rate of contaminant deposition on the samples. The QCM located on top of the upper carrousel is visible when the front cover is removed. The other QCM is located in the array box. The electronics for both QCM's are contained in the cylindrical portion of the QCM. The QCM's operate as transducers by providing 0-5 volt analog signals proportional to the accumulated mass deposited upon the sensing surfaces. The basic

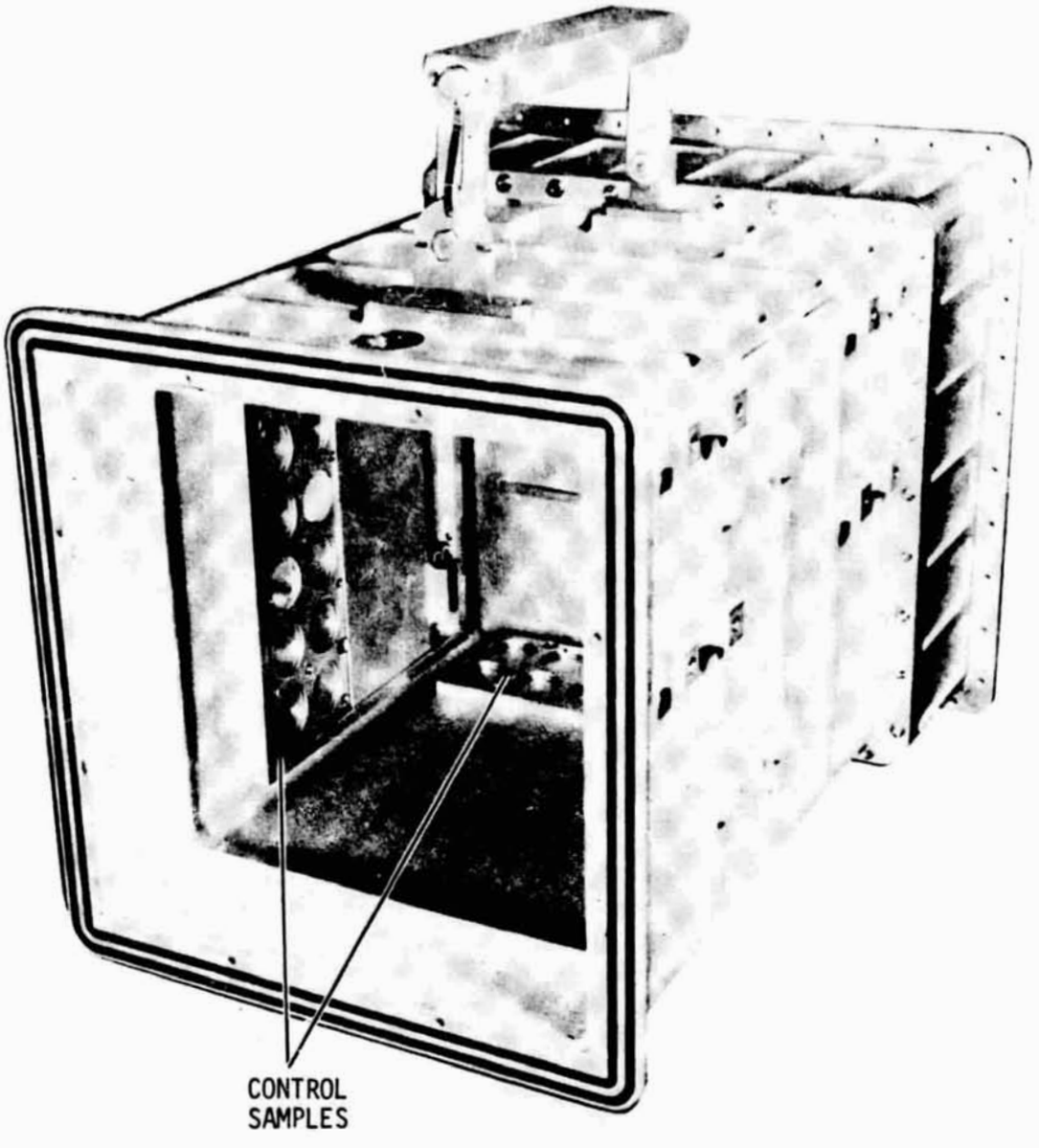

Figure 7. Sample Array Canister Control Samples

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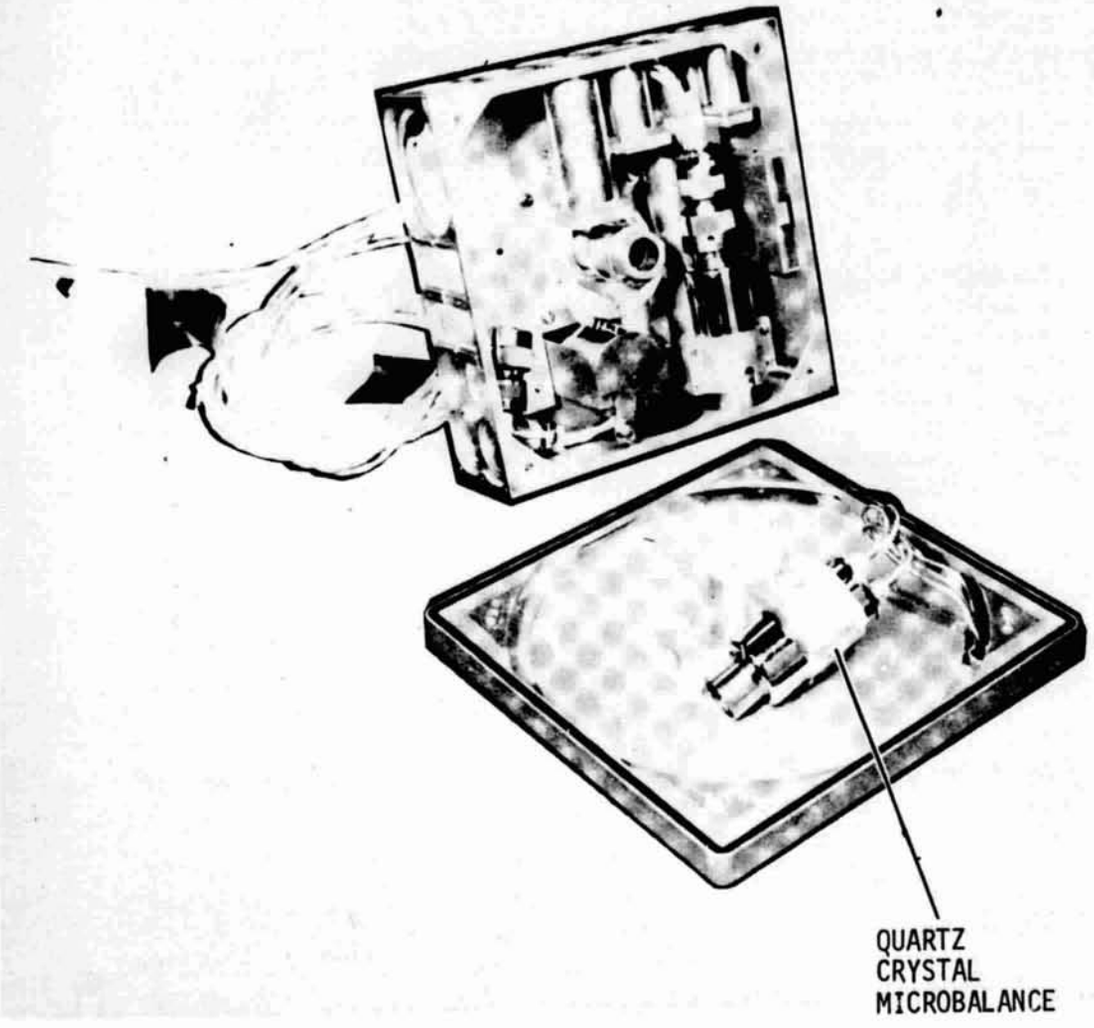

Figure 8. Quartz Crystal Microbalance in Array Box

principle involves measuring the difference between two crystal oscillators initially operating at near the same frequency (10 MHz). The two frequencies are subtracted yielding an audio signal that shifts upward in frequency as mass accumulates. This audio signal is then processed to provide a 0-5 volt output corresponding to 0-12 KHz frequency difference. Two 10 MHz crystal oscillators provide a 4 volt peak-to-peak output to a dual gate Metal Oxide Semiconductor Field Effect Transistor (MOSFET). The MOSFET non-linearly mixes the two frequencies producing a different frequency at the output after appropriate filtering. The unit is configured such that an increase in mass causes a decrease in the frequency, which produces a rise in difference frequency. The analog information provides a signal for input to a telemetry channel.

The extension mechanism consists of bearing and seal glands which are located in the canister, and an extendable link assembly shown in Figure 9. The bearing and seal glands allow the extension rod to deploy the sample array as well as maintain the OWS pressure integrity. The extendable link assembly provides support for and prevents extensive rotation of the sample array. The extension rod is approximately one inch in diameter by 20 inches long.

In the stowage configuration the sample array canister has two identical end plates, which maintain an air-tight enclosure during launch, in-orbit stowage, and recovery. On each end plate, there is a Seaton-Wilson valve with a lanyard connected protective cap. This valve provides pressurization and depressurization capabilities. The end plates are removed and stowed in the sample array stowage container during experiment operation. The end plates are reinstalled to the canister ends when the sample array is removed from the SAL. The areas under the end plates are evacuated to space vacuum.

1. Inorbit Stowage - The sample array system is stowed in a stowage container which is hard-mounted to the OWS floor in the location shown in Figure 10. At launch, the sample array canister and the sample array stowage container are pressurized with dry nitrogen to 5 psia. After the initial usage, the sample array canister and the container are stowed under a depressurized condition. The area under both end plates of the sample array canister and the container are depressurized to vacuum for 15 minutes each. The sample array canister interior is sealed under a space vacuum condition with the canister array valve prior to removal from the SAL.

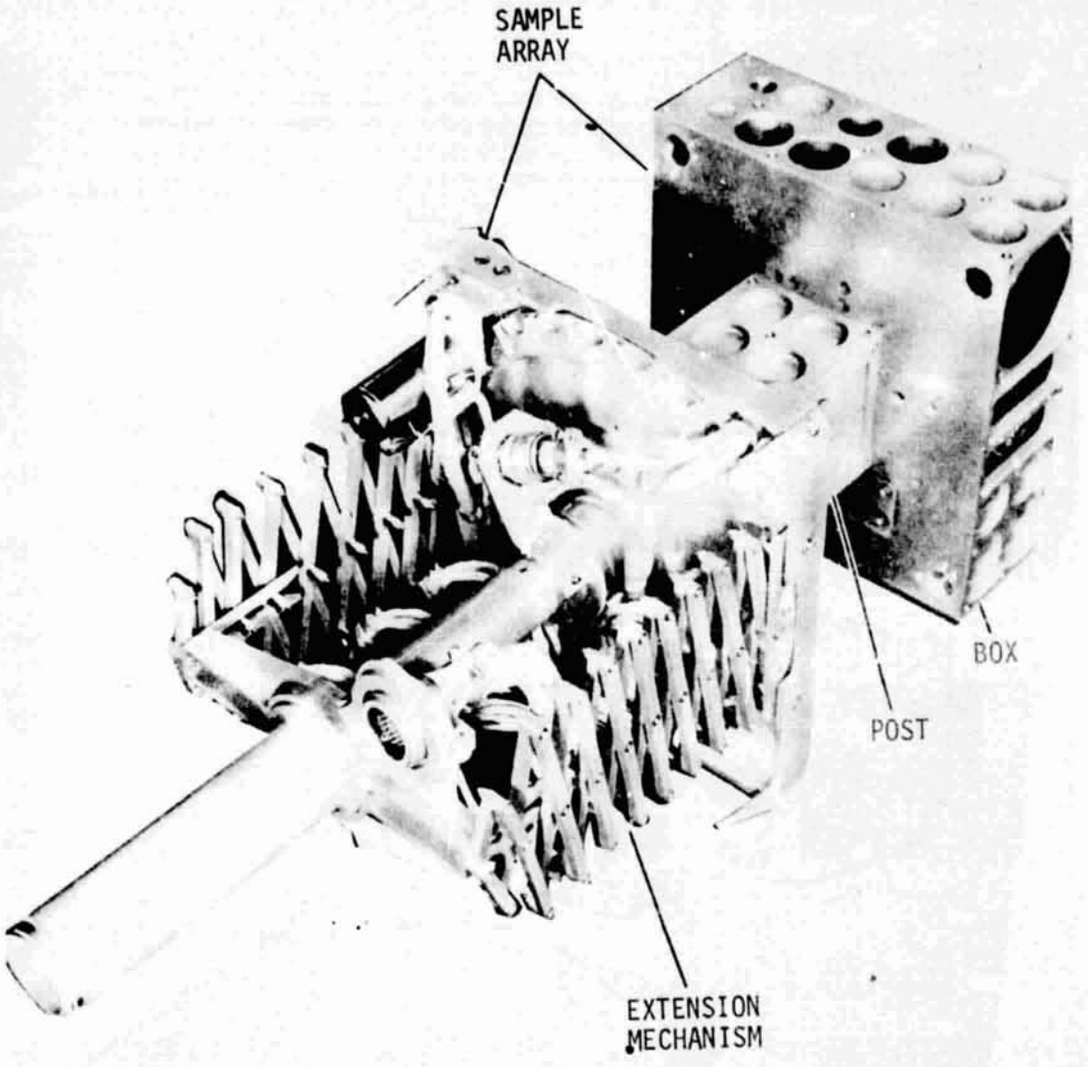

Figure 9. Sample Array Extension Mechanism

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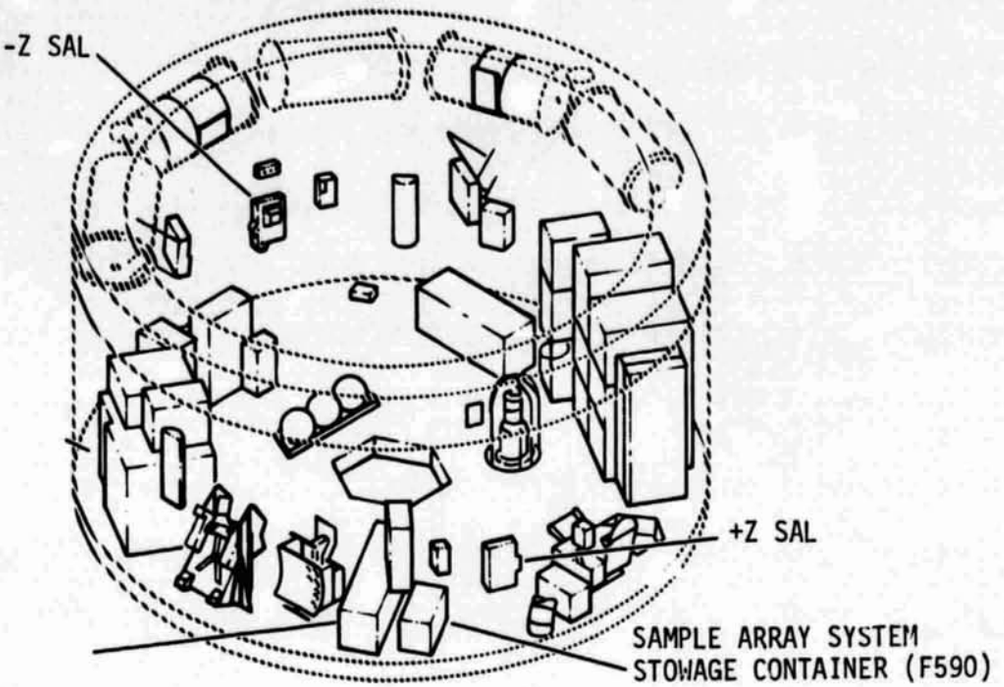

Figure 10. OWS Experiment Location

1.4 Operation - The astronaut will remove the sample array canister from the flight stowage container and restrain it. Then the end plates are removed from the canister and stowed. Next, the array canister is installed in the +Z SAL, power and data cables are connected, and the array is extended out into space. Once activated, the array will operate automatically for five consecutive days after which the system automatically shuts down. While extended through the solar SAL (+Z), the top surface of the lower carrousel will be flush with the OWS micrometeoroid shield. The performance of the sample array could be as short as three days because of priorities in scheduling, in either case at the completion of exposure the array canister is removed and stowed under vacuum.

1.5 Recovery - Near the end of the mission, the array canister with cover plates is stowed in the command module locker as shown in Figure 11. On the recovery ship the canister will be removed and stored in the ground storage container which is the same as the flight stowage container. The container is to be purged and sealed with gaseous dry nitrogen and returned to MSC within four days after splashdown. The array inside the container will then be flown to MMC-Denver for the postflight measurement program.

1.6 Data Requirements - The measurements listed in Table 2 are required for the T027 sample array experiment.

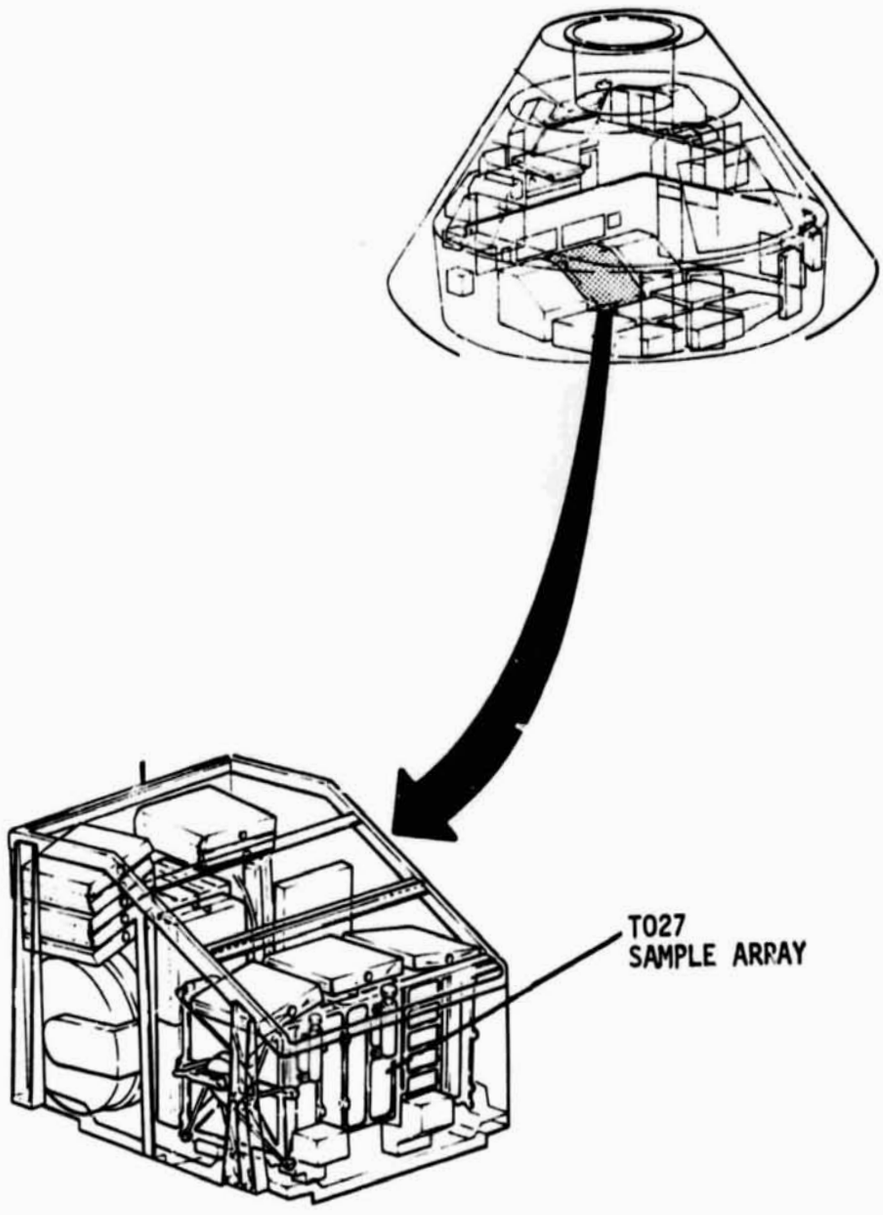

Figure 11. Command Module Stowage Location

TABLE 2 - T027 SAMPLE ARRAY SYSTEM T/M MEASUREMENT LIST

Measurement Name	Meas. No.	Meas. Range	Samples per Sec	Remarks
Day Driver CMD (Upper Platform Information)	K7315T027	Bilevel 0-5 VDC	1.25	Originates in the T027 Sample Array System - OWS
Hour Driver CMD (Lower Platform Information)	K7314T027	Bilevel 0-5 VDC	1.25	Originates in the T027 Sample Array System - OWS
Temperature, Quartz Crystal Microbalance No. 1	C7309T027	-6 to +248°F 0-5 VDC		Originates in the T027 Sample Array System
Temperature, Quartz Crystal Microbalance No. 2	C7310T027	-6 to + 248°F 0-5 VDC	1.25	Originates in the T027 Sample Array System
Frequency, Quartz Crystal Microbalance No. 1	M7016T027	0-12 KHz 0-5 VDC	1.25	Originates in the T027 Sample Array System
Frequency, Quartz Crystal Microbalance No. 2	M7017T027	0-12 KHz 0-5 VDC	1.25	Originates in the T027 Sample Array System

APPENDIX B

Selections From 85TR1-61M1001 Qualification Test Report
On Sample Array System, Optical Scattering and Contamination
Experiment (T027), November 29, 1971 and Pertinent Letters.

1.1 Introduction - This appendix selects important selections from 85TR1-61M1001 Qualification Test Report On Sample Array System, Optical Scattering and Contamination Experiment (T027), November 29, 1971 and Pertinent Letters.

1.2 Table of Contents

85TR1-61M1001

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1.3 Abstract - A Sample Array System, manufactured by Martin Marietta Corporation, Denver Division, MMC part number 89900000100-09, was subjected to qualification testing in accordance with Qualification Test Procedure 85TP1-61M10001 which is included in this report.

The Sample Array System was subjected to the following inspections and tests:

- o Pretest inspection
- o General performance test
- o Thermal vacuum test, with and without solar simulation
- o Vibration test
- o Electromagnetic interference test
- o Humidity test
- o Temperature and altitude tests (storage and transportation)
- o Oxygen test
- o Final general performance tests
- o Post-test inspection

The qualification test results and conclusions indicate that the Sample Array System, Optical Scattering and Contamination Experiment (T027), will be acceptable for its intended mission in the Skylab Program. The qualification test revealed some operational difficulties that were identified in letter, S&E-QUAL-ATE-414-70, dated December 15, 1970, (Appendix B). A reply to each of the operational difficulties was made in letter, S&E-SSL-SE-70-313, dated December 21, 1970, (Appendix B).

Table I presents the discrepancies that were identified during qualification testing, along with the recommended corrective action where appropriate.

1.4 Introduction - This report presents the procedures, requirements, and results of the qualification testing of one Sample Array System, Optical Scattering and Contamination Experiment (T027). The Sample Array System was manufactured by the Martin Marietta Corporation, Denver Division, and was designed to operate in the internal atmosphere of a spacecraft with provisions to collect contaminants found external to the

Table 1 Problems/Discrepancies and Recommended Action

Problems/Discrepancies Noted By S&E-QUAL-ATE	Recommended Action/Comments By S&E-SSL-SE-70-313
1. The Sample Array will not continue to operate when subjected to a 30 millisecond power interruption. This also knocks out the power supply that supplies power to the QCM's.	There is no requirement for a power interrupt time in the CRS. It is our intention to complete the qualification tests and then perform an extended series of performance tests to determine whether the event reoccurs or whether it can be dismissed as being due to parameter(s) which cannot be controlled/monitored in a test environment.
2. Some mechanical interference exists when extending the Sample Array due to sagging of the carrousels. This problem may or may not exist in zero gravity.	This is not believed to be a problem, since the tests are conducted under one "g". However, it will be re-examined by the design engineers to verify this position.
3. Gross leakage was found through the Sample Array when the pressure is pumped from the atmosphere surrounding the S.A. No leakage occurred around the mating surface with the Airlock Simulator however.	There is reason to believe that this test was not conducted properly. However, it will be reconsidered.
4. The single set screws attaching the two drive motors to their drive gears loosened and did not drive either carrousel until tightened. There should be a key or pin of some type to transmit this torque.	This is a Class II, no-cost change, which is being implemented into the flight unit.
5. Sixty pounds of force was required to retract the carrousels against a vacuum during the cold cycle of the Thermal Vacuum Test. The temperature of the chamber shroud was -230°F and the outer carrousel temperature was -43°F. During the high temperature cycle of the same test, the retraction force was only 45 pounds (temperature of shroud +210°F).	This may require a waiver from the human factors people; however, it requires further consideration.

Table 1 (Cont'd)

6. Both of the stowage containers that were used during the Qualification Test (Qual Unit and Development Unit) caused binding and would not release the Sample Array without a special technique of hitting the retainer screws while someone lifted the S.A. out (two man operation).	This is apparently because the qualification unit could not be "fitted" into its storage container, due to schedule problems. It is believed to be an alignment problem that can be easily corrected.
7. High torque forces were required to unscrew the valve actuator thumb screw and the knurled nut on the Sample Array. These forces were not measured but could cause the astronauts difficulty in zero gravity.	The specific torques must be measured to determine whether this is a discrepancy or opinion.
8. There is no method of ascertaining that the Sample Array is operating without looking at the carrousels when they are operating (once every hour/day for eleven seconds). This will not be visible to the astronauts. An indicator on the control panel could save the experiment.	Since it now appears likely that CQM readout will be made in near real-time, it is suggested that the carrousel data channels be monitored to determine if the carrousels operate properly. This obviates the need for crew monitoring, which otherwise would be required.
9. During vibration tests, two of the glass samples chipped. Their rigid type of mount is conducive to this type of failure. Also, the vent valve cover on the stowage container vibrated loose. Its locking mechanism did not operate.	This was not experienced during development tests. The problem will be examined by the design engineers.
10. Numerous out of specification conditions were found during EMI testing. These occurred during RF Radiated Interference, and Broadband and Narrowband Conducted Interference Tests.	These are attributed to the QCM's and probably are waiverable. The formal EMI report is not available, but informal discussion between -SE and Astrionics personnel indicate this is not a serious problem.

Table 1 (Concluded)

11. The contamination samples in the carrousels are not mechanically clocked properly with the exposure openings provided for them. This could give erroneous indications when post flight evaluation of samples occur.	This refers to item 4 above, and is believed to be corrected when that discrepancy is fixed.

spacecraft on exposed optical surfaces. The Sample Array (MMC Part No. 89900000100-09) configuration was in accordance with published drawing list revision No. 1, dated January 4, 1971. Any deviations were covered by Material Review Board action. Information from Martin Marietta Corporation is that fabrication of the qualification unit was covered by quality control inspection, and that the records of such inspection are retained at their Denver facility. All qualification testing was performed at MSFC except the thermal vacuum solar simulation test which was performed at MSC.

1.5 Thermocouple Location - Table 2 lists the location of the 35 thermocouples which were used to monitor the temperatures of the sample array and test chamber during the qualification testing. Figure 1 shows the position of the numbered thermocouples on the sample array.

1.6 Problems and Discrepancies - Table 1 lists the problems/discrepancies and recommended actions for the sample array flight qualification test.

1.7 Letters - The following four retyped copies of letters illustrate some of the response to the problems that occurred during the sample array flight qualification test.

Table 2 Thermocouple Location

Thermocouple No.	Location
1	Top upper carrousel sample plate
2	Bottom front plate
3	Top front plate
4	Front of forward QCM
5	Bottom right side upper carrousel
6	Top lower carrousel
7	Top connecting post
8	Back top of upper carrousel by motor
9	Back bottom of upper carrousel
10	Lower carrousel motor
11	Top left side lower carrousel front
12	Left side upper carrousel
13	Left side lower carrousel
14	Exterior right side antirotation boom
15	Exterior left side antirotation boom
16	Extension rod top
17	Interior canister floor
18	Lower right of lower carrousel front
19	Right side canister
20	Lifting handle
21	Top control box
22	Right side lower part of control box
23	Left side forward of canister
24	Next to power connector
25	Next to latch
26	Left side control box
27	Next to start switch
28	Forward carrousel bottom of front plate
29	Bottom forward flange of canister
30	Bottom control box
Not Shown on Figure 1	
31	Inside top of test fixture
32	Inside bottom of test fixture
33	Spacecraft wall simulator
34	Spacecraft wall simulator
35	Spacecraft wall simulator

S&E-QUAL-ATE-414.70 December 15, 1970

TO: Mr. Leonard S. Yarbrough,
S&E-SSL-SE

FROM: Chief, Environmental Test Section,
S&E-QUAL-ATE

SUBJECT: Preliminary Report of Qualification Testing on the Sample Array, Optical Scattering and Contamination Experiment (T027)

The Qualification Test on the Sample Array is now 80% complete. The only environments remaining to be put on the test specimen are: (1) Altitude, Temperature, and Stowage; (2) Humidity; (3) Oxygen, and (4) two remaining axis of vibration. By working the two remaining weekends (Saturday and Sunday) prior to Christmas, all environmental testing will be complete leaving only the general performance test to be run after the holiday season (January 4, 1971).

Some operational difficulties have been encountered during this test program which are worthy of note. For the most part, they are human factors problems that may work a hardship on the astronauts performing the experiment. Below are these problems/discrepancies:

a. The Sample Array will not continue to operate when subjected to a 30 millisecond power interruption. This also knocks out the power supply that supplies power to the QCM's.

b. Some mechanical interference exists when extending the Sample Array due to sagging of the carrousels. This problem may or may not exist in zero gravity.

c. Gross leakage was found through the Sample Array when the pressure is pumped from the atmosphere surrounding the S.A. No leakage occurred around the mating surface with the Airlock simulator however.

d. The single set screws attaching the two drive motors to their drive gears loosened and did not drive either carrousel until tightened. There should be a key or pin of some type to transmit this torque.

e. Sixty pounds of force was required to retract the carrousels against a vacuum during the cold cycle of the Thermal Vacuum Test. The temperature of the chamber shroud was -230°F and the outer carrousel temperature was -43°F. During the high temperature cycle of the same test, the retraction force was only 45 pounds (temperature of shroud +210°F).

f. Both of the stowage containers that were used during the Qualification Test (Qual Unit and Development Unit) caused binding and would not release the Sample Array without a special technique of hitting the retainer screws while someone lifted the S.A. out (two man operation).

g. High torque forces were required to unscrew the valve actuator thumb screw and the knurled nut on the Sample Array. These forces were not measured but could cause the astronauts difficulty in zero gravity.

h. There is no method of ascertaining that the Sample Array is operating without looking at the carrousels when they are operating (once every hour/day for eleven seconds). This will not be visible to the astronauts. An indicator on the control panel could save the experiment.

i. During vibration tests, two of the glass samples chipped. Their rigid type of mount is conducive to this type of failure. Also, the vent valve cover on the stowage container vibrated loose. Its locking mechanism did not operate.

j. Numerous out of specification conditions were found during EMI testing. These occurred during RF Radiated Interference, and Broadband and Narrowband Conducted Interference Tests.

k. The contamination samples in the carrousels are not mechanically clocked properly with the exposure openings provided for them. This could give erroneous indications when post flight evaluation of samples occur.

It is recommended that these discrepancies be reviewed and appraised for the overall effect on intended missions. The experience gained by this Section during this test program shows the necessity for an indication (light or carrousel position indicator) that the experiment is operating. On two occasions it was thought that the equipment was operational only to find out a day later that facility power interruption had occurred and reset was required.

James G. Reavis

S&E-SSL-SE-70-313 December 21, 1970

THRU Mr. R. Lake, S&E-R-F

TO Mr. J. Waite, PM-SL-DP

FROM Chief, Flight Experiments Branch, S&E-SSL-SE

SUBJECT Status Report of Sample Array Qualification Testing

Attached for your information is a report from S&E-QUAL-ATE on the Sample Array Qualification Tests. The following comments apply to the corresponding problems/discrepancies in the attachment:

a. At hour 22 of the performance test following vibration, the hourly carousel motor did not shut off. The test was repeated and the event did not reoccur. This may or may not be related to the problem reported in the attached report. An interruption of power requires recycling of the Sample Array control logic; low and bus voltage can also interfere with the control logic. The CRS limits of 28 v.d.c. $\pm$ 4 v.d.c. do not affect the Sample Array's performance, but a lower voltage than 24 v.d.c. could very well degrade its performance. There is no stated requirement for a power interrupt time stated in the CRS. It is our intention to complete the qualification tests and then perform an extended series of performance tests to determine whether the event described above reoccurs or whether it can be dismissed as being due to parameter(s) which cannot be controlled/monitored in a test environment.

b. This is not believed to be a problem, since the tests are conducted under one "g". However, it will be re-examined by the design engineers to verify this position.

c. There is reason to believe that this test was not conducted properly. However, it will be reconsidered.

d. This is a Class II, no-cost change, which is being implemented into the flight unit.

e. This may require a waiver from the human factors people; however, it requires further consideration.

f. This is apparently because the qualification unit could not be "fitted" into its storage container, due to schedule problems. It is believed to be an alignment problem that can be easil

corrected.

g. The specific torques must be measured to determine whether this is a discrepancy or opinion.

h. Since it now appears likely that QCM readout will be made in near real-time, it is suggested that the carrousel data channels be monitored to determine if the carrousels operate properly. This obviates the need for crew monitoring, which otherwise would be required.

i. This was not experienced during development tests. The problem will be examined by the design engineers.

j. These are attributed to the QCM's, and probably are waiverable The formal EMI report is not available, but informal discussion between -SE and Astrionics personnel indicate this is not a serious problem.

k. This refers to item d. above, and is believed to be corrected when that discrepancy is fixed.

The interruption of facility power mentioned in the final paragraph of the report was corrected to the extent that auxiliary batteries were used during later tests to avoid this problem. It is regrettable that a running time meter was not used to monitor facility power from the beginning of the tests, but that's another matter.

If there are any questions, please advise.

Leonard S. Yarbrough

Enc:
As stated

14 December 1971

Refer to: 71-Y-14267

To: National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attn: Mr. Arthur T. Ousley/S&E-R-F

Subj: Contract NAS8-21495, Qualification Test Report on Sample Array System, Optical Scattering and Contamination Experiment (T027), 85TR1-61M10001, November 29, 1971

After reviewing the xerox copy of the qualification test report on the sample array system, I have the following questions and comments concerning this report and the array system.

1. The report doesn't contain the reduced data from all of analog telemetry channels and all of the 35 thermocouples. The information obtained during the qualification test is important to me in developing the overall calibration of the samples and the array system and any data obtained during the test is needed.

2. An out of specification leakage rate about the QCMB seal is shown on page 2. The rework recommended in the report appears to work, since the acceptance test of the flight sample array did not show any leakage. Unfortunately, since the unit leaked before the thermal/vacuum test, any additional leakage resulting from the environment would be difficult to determine. Are your material research people confident that if the seal is tight during acceptance tests it will remain so in the space environment? It is very important that the upper carrousel head seal the samples from any non-space environment and I am concerned about the epoxy sealing properties after exposure to solar radiation and vacuum.

3. The report does not contain any results from the two QCMB's which operated during the test. Did the thermal/vacuum tests have any effect on the balances? In particular, when the chamber self-contaminated what was the response of the crystals?

4. Page 4 describes the chamber losing vacuum and being contaminated with diffusion pump oil. How did the array system respond during this period? Did the lower carrousel operate during this time? Reduced data from all of data channels will help me evaluate the performance of the system. Even though the data printer failed, the first 24 hours of data should allow a comparison between the predicted thermal calculations and the measured values. Has there been any analysis of the thermal profile of the system in this test?

5. On page 5 the erratic behavior of the lower carrousel rotating every 6 seconds in the 22nd hour must be explained. A power interruption could recycle the counting logic but it should then still rotate once every hour. Did the carrousel rotate about 150 positions during this 15 minute period?

6. The storage/humidity tests described on page 6 showed no anomalies. The preliminary salt/fog tests performed here at Denver on the photometer storage container showed corrosion of the metal. Have comparisons been made to determine why the results disagree?

7. The final performance test again showed the excessive leakage rate about the upper QCMB as shown on page 6. As the entire sample array system was designed to minimize any non-metallic materials, the use of Epon 934 to seal the cable of the QCMB was a compromise in order to timely accommodate the MSFC/SSL QCMB guest sample. Although this epoxy is on the Skylab approved materials list, its location close to the upper carrousel samples dictates deligent control of the amount of adhesive used and in addition a vacuum degassing operation should be performed after the material hardens. During the vacuum degassing, the temperature of the area should be raised to at least 10% higher than the highest predicted temperature the material will experience. This vacuum bakeout is not currently in the process procedures, it could be done on the flight and backup units during the recleaning period after the MDAC-WD integration tests.

Sincerely,
MARTIN MARIETTA CORPORATION

J. A. Muscari
Principal Investigator, T027

cc: Messrs. R. Naumann,
S&E-SSL-P
T. R. Heaton
J. Kierein

/plc

S&E-R-F (3-72) January 5, 1972

TO: Martin Marietta Corporation
Attn: Dr. J. A. Muscari

FROM: S&E-R-F/Arthur T. Ousley

SUBJECT: Qualification Test Report on Sample Array System, Optical Scattering and Contamination Experiment (T027), 85 TRI-61M10001, November 29, 1971

In answer to your memorandum 71-Y-14267 (attached), dated December 14, 1971, the following comments are presented:

1. Reference comment (1) of your memo. The data is available and will be reduced and sent to you under separate cover.

2. Reference comment (2) of your memo. The leakage about the QCMB seal was measured before the start of qualification testing and again in the final performance test after all environmental testing. Both measurements were 7.6 cc/min. (3cc/min. allowable). It was concluded from this that the environmental exposures had no adverse effect on the sealing material. As you state, the flight unit had no leakage during acceptance test which indicates the present sealing method is satisfactory.

The materials research people at MSFC have stated that the Epon 934 is a 100% reactive material which will not outgas any until the decomposition temperature is exceeded. This temperature is in excess of 350°F. They further state that a vacuum bakeout would be unnecessary.

3. Reference comment (3) of your memo. The QCMB's attached to the SA Qual article were treated as separate entities during the qualification testing even to the point of data being collected by two different MSFC organizations. The data on the QCMB's was organized in a separate report. The data will be sent to you under separate cover and the report will be forwarded when completed.

4. Reference comment (4) of your memo. The Sample Array System performed normally through all phases of this test. The data will be made available to you for your analysis.

5. Reference comment (5) of your memo. During the 22nd hour, the carrousel drive motor rotated continuously. The gear drive mechanism under these conditions causes the carrousel to change positions every 6 seconds with approximately 5 seconds dwe'l at each position. The carrousel rotated about 82 positions during the 15 minute period. According to the MMC electronics people, a power interruption can distract the counting logic in such a fashion as to result in the condition described in the report. We could not duplicate this anomaly, nor did it recur during the remainder of the testing.

6. Reference comment (6) of your memo. We were unaware of the corrosion detected during salt fog testing at MMC. It is not unusual to obtain different results from salt spray and humidity tests since they are entirely different tests. The salt fog test was not included in qualification testing because the device will not see this environment in use.

7. Reference comment (7) of your memo. See paragraph 2, this memo.

Arthur T. Ousley
Project Manager, T027

cc:
MMC/Mr. Heaton
MMC/Mr. Kierein
S&E-SSL-P/Mr. Naumann
A&TS-PR-MBA/Mr. Smith
S&E-QUAL-ES/Mr. Fowler

APPENDIX C

MCR 72-135 T027 Cleaning And Handling Procedures For Optical Samples

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APPENDIX E

T027-SA-1-74 Sample Array Carrousel Operation During Low Temperature And Vacuum Post Flight Test Report

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A Sample Array - Carrousel Operation During Low Temperature And Vacuum - Test Procedure, T027-SA-12-73 Rev 1

APPENDIX F

Sections From Analysis of Possible Organic Contamination On Sample Holding Plates and Mass Spectrometer Probes Returned From Skylab By Denver Research Institute.

Solvent Preparation and Sample Plate Washing Procedure

We anticipated that any organic contamination present on the sample holding plates would be there in trace quantities so we therefore checked out solvents to be sure they were free of contamination. Although we started with the reagent grade solvents benzene, hexane, methylethylketone and ethanol there was enough contamination present that it was necessary for us to redistill the solvents. This contamination was observed by taking a 100 ml. aliquot of the solvent to near dryness then placing a portion of this concentrate on the mass spectrometer probe for analysis. After distilling the solvents we were satisfied that thesolvents were free of contamination. Although the mass spectra of the solvents are not included in the report they are available.

The hexane was used to wash the stainless steel surgical trays in which the sample plates were transported to DRI and in which they were subsequently washed with the four solvents.

Upon receipt ofthe sample plates three of them were selected for analysis by Dr. Westcott. They are plates (99/77-84) and (104/53-61) and (207/206-217). The wash procedure as outlined in the Statement of Work was followed.

Gas Chromatographic Analysis of Sample Plate Solvent Washes

Prior to analysis we washed four stainless steel surgical trays, with tops, to remove all hexane soluble organics which might be present. A hexane wash of these trays was analyzed by mass spectrometry to be sure that the trays were clean and then the trays were given to Dr. Westcott. The trays were returned to DRI each containing a sample plate and in addition a fifth tray containing the fifth sample plate given to us. This fifth tray was cleaned at the Martin Co. Although the chromatograms are labeled according to the sample plate number any contamination present could come from the tray in which the sample plate was transported and washed according to the Statement of Work.

Chromatographic conditions for each run were the same and are indicated on the individual chromatograms as well as on the form below. Dr. Westcott selected plates (99/77-84), (104/53-61) and (207/206-217) for analysis.

The chromatograms are presented with all four washes of each plate analyzed arranged in order of the washing namely hexane, benzene, methylethylketone and methanol. Actually the order of analysis followed was to do the hexane wash of all three plates then the benzene wash of all three plates, the methylethylketone wash and finally the methanol was done. This means that the peaks which are present at twelve and thirteen minutes after injection when analyzing the washes from plate and/or tray number 207/206-217 are unique to the sample and not a possible chromatographic contamination. In general, the chromatograph temperature was held at 100°C. for two minutes until the solvent peak emerged then the temperature was increased from 100°C. to 300°C. in twelve minutes. The chart speed is one-half inch per minute. The small peaks which came out between 10 and 14 minutes after sample injection are due to silicone bleed from the septum through which the sample is injected onto the chromatographic column. When the methanol washes were analyzed the methanol tailed badly because of its polarity and thus masked any possible contamination present. Our analysis procedure was oriented towards the relatively non-volatile organics because it is assumed that volatiles would readily escape under the vacuum conditions exterior to the Skylab.

The chromatograms show only one significant peak and one lesser peak in each wash of plate (207/206-217) except in the methanol wash where they are probably masked by the methanol.

Coincidently this plate arrived in the tray cleaned at the Martin Company so possibly the peaks are from the tray rather than the plate. We have no knowledge of the respective plate locations or handling so we are not able to determine if this plate is more likely to be contaminated. Under these chromatographic conditions a peak one inch high corresponds to approximately (6×10^{-9}gm). Therefore, a rough quantitative calculation of the hexane soluble peak is:

$$\frac{6 \times 10^{-9}\text{ gm}}{1\text{ inch}} \times \frac{7.5\text{ inch}}{.2\ \mu\text{l}} \times \frac{1000\ \mu\text{l}}{1\text{ ml solution}} = 225000\ \frac{\text{n gm}}{\text{ml}} = 225\ \frac{\mu\text{gm}}{\text{ml}}$$

Since at .2 μl quantity of the final 1 ml of hexane used to wash the plate was injected then the 225 μgm came from the plate and/or the tray and likewise an equal contribution from the sum of the contaminants in the benzene and methylethylketone washes, based upon peak heights. The sum of these fractions is roughly $(225\ \mu\text{gm})_{\text{hexane}}$ + $(112\ \mu\text{gm})_{\text{benzene}}$ + $(112\ \mu\text{gm})_{\text{methylethylketone}}$ for a total of 450 μgm, or almost hals a milligram. Because the chromatogram is composed of predominantly one peak, the mass spectrum of the solvent containing the contaminant should yield essentially the spectrum of this one component with a trace of the second component.

Mass Spectrometric Analysis of Sample Plate Solvent Washes

At the time we were doing this mass spectrometry we were installing our mass spectrometer data system and lacked the knowledge of its proper and efficient operation. Consequently, although we have some of the mass spectra on computer tape with the option of plotting them on the digital plotter, most of them are on visicorder paper which is difficult to reproduce in the report. Since most of the mass spectra were negative in that the plates and probes were clean, and therefore the spectra show only instrument background, there is no need to include the spectra. The one spectrum of real interest, the hexane wash of plate and/or tray (207/206-217), is on tape though and has been plotted and included in the report. All the visicorder spectra are available upon request.

We are not familiar with this mass spectrum and have searched the NIH - Aldermaston Mass Spectra File and the Compilation of Mass Spectra Data by Cornu and Massot with no positive identification. The spectrum presented is normalized in that the most intense peak (m/e 149) is set to 100% and the rest of the peaks are presented as a percentage of this base peak.

Esters of phthalic acid typically have a base peak at m/e 149 but this is not the more common dioctylphthalate with molecular weight 390. Possibly the molecular ion of this component is the small peak at m/e 312. The ratio of the m/e 149 to m/e 91 is similar to the spectrum of isophthalic acid with molecular weight 166. At this point, lacking the specifics of the tray washing procedure, we cannot make a definite structural assignment to this component.

Mass Spectrometer Probes

After analyzing the solvent washes of three plates we selected the two probes (207/206-217) and 104/53-61) for analysis. Considering that there was about half a milligram of contaminant in the solvent washes of plate and/or tray (207/206-217) we looked to find the same contaminant on the probe, however, the results were negative; this probe was clean as was probe (104/53-61).

The probe analysis procedure was to attach the probe to the end of our mass spectrometer direct introduction probe and insert it into the mass spectrometer direct introduction probe and insert it into the mass spectrometer via the vacuum lock. This placed the probe adjacent to the ion block which was maintained at a temperature of 250°C.

We had considered that the contaminant present on plate and/or tray (207/206-217) actually came from the tray rather than the plate and the lack of this contaminant on the probe confirms this. The probe (207/206-217) was exposed to the same Skylab environment as the plate but did not contact the tray in which the plate was transported and washed. Even though the probe has maybe one-hundredth the surface area as the plate, there would still be about one hundredth of the contamination of 5 micrograms, a quantity very easy to observe, since the direct probe introduction is the most sensitive mass spectrometric method.

Mass Spectra Log

Log Number	Sample
7811	Hexane
	Benzene
	Methanol
7825	Methylethylketone
7901	Hexane
7902	Hexane
7903	Hexane
7905	Hexane
7906	Methanol
[illegible]	Methanol
[illegible]	Methanol
[illegible]	Methylethylketone
7917	Benzene
7918	Hexane
7919	Methanol
7920	Benzene
8002	Benzene wash of all four trays
8003	Dibutylphthalate (suspect contaminant)
8004	Hexane
8005	Methylethylketone
8006	Methanol
8010	Methanol (contains dioctylphthalate)
8104	Redistilled methanol
8205	Plate 104/53-61 Hexane wash
8206	Plate 104/53-61 Hexane wash
8207	Plate 104/53-61 Benzene wash
8208	Plate 104/53-61 Methylethylketone
8303	Plate 99/77-84 Hexane wash
8304	Plate 99/77-84 Hexane wash
8503	Plate 207/206-217 Hexane wash
8504	Plate 207/206-217 Hexane wash

Mass Spectra Log

Log Number	Sample
8505	Plate 207/206-217 benzene wash
8506	Plate 207/206-217 methanol wash
8507	Plate 207/206-217 methylethylketone
8601	Plate 207/206-217 hexane
8703	Probe 207/206-217
8704	Probe 104/53-61
8705	Probe 104/53-61

Conclusion

Both gas chromatographic and mass spectrometric analysis of the solvent washes of plates (99/77-84), (104/53-61) and (207/206-217) confirm that contamination of perhaps an ester of phthalic acid is present in the amount of 500 micrograms in the wash of plate (207/206-217). Actually, the wash of this plate may contain contamination from the stainless steel surgical tray in which the tray was transported to DRI and subsequently the solvent wash was performed. This tray was washed at the Martin Co. instead of DRI as the other four trays were, so we do not have an analysis of the final wash of this tray during its cleaning. The corresponding mass spectrometer probe (207/206-217) which was exposed to the same Skylab environment as the plate (207/206-217) did not have this contaminant, however it was not placed in the tray for washing. Even though the surface area of the probe could be one hundredth that of the plate that would still leave about 5 micrograms on the probe and that is quite sufficient sample size for mass spectrum analysis especially via the direct probe system which is the most sensitive sample introduction method. If the contaminant did indeed come from the tray rather than the sample plate then we can state that there was no significant contaminant on the three plates and two probes selected for analysis.

APPENDIX G

Experiment Proposal For Manned Space Flight, ATM Contamination Measurement, Experiment Number T027, August, 1967.

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APPENDIX H

MCR-68-78 Potential AAP Cluster Or Apollo Contamination Monitor In Support Of ATM, March, 1968

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APPENDIX R

T027-SA-1-74 Sample Array Carrousel Operation During Low Temperature And Vacuum Post Flight Test Report, January 9, 1974

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A	Sample Array - Carrousel Operation During Low Temperature And Vacuum - Test Procedure T027-SA-12-73, Rev 1.	1

3. SUMMARY

3.1 Carrousel Operation at Ambient Conditions - This test performed two back-to-back functional checks of the carrousel operation at ambient temperature and pressure. The first part of the test was a 48-hour functional with the telemetry cable attached. The second part was a 24-hour test without the telemetry cable attached. The S.A. functioned normally throughout the entire test; no anomalies were detected.

3.2 Carrousel Operation at Low Temperature and Vacuum - This test was intended to check out carrousel operations at mission simulated conditions. A steady state operating temperature of $-80^{\circ}F$ was imposed on the upper carrousel motor after a simulated mission cooling rate. Pressure was maintained at less than 10^{-5} torr. The upper carrousel failed to completely index on the 24th hour and the test was terminated at the 26th hour. Proper operation of the lower carrousel was observed throughout the test.

3.3 Mechanical Inspection - Following the later test an inspection of the upper carrousel drive mechanism was made. There was no indication of mechanical jamming at room temperature. A burr was observed on the sample array face plate that may have put a drag on the upper stepper driver motor, but it is not believed that its presence alone could stop the motor. It was noted also at this time that the upper carrousel Geneva drive mechanism has a 1/3 smaller mechanical advantage than the lower carrousel drive mechanism and was therefore more likely to stall under equal loading conditions.