21600-FR

15 June 1971

FINAL REPORT

DESIGN, FABRICATE, PERFORM TESTS, AND DELIVER CERAMIC ENVELOPES IN SUPPORT OF ELECTROSTATIC GYRO DEVELOPMENT

L. C. Mellum

Contract No. NAS8-26312

Prepared for:

George C. Marshall Space Flight Center
Huntsville, Alabama 35812

Honeywell Inc.
Government and Aeronautical Products Division
2600 Ridgway Parkway N.E.
Minneapolis, Minnesota 55413

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FOREWORD

This report was prepared for George C. Marshall Space Flight Center in fulfillment of Task IIIB of Exhibit "A" - Scope of Work for Contract NAS8-26312.

The report covers all work performed under this contract from inception on 24 June 1970 through completion on 15 June 1971.

CONTENTS

ILLUSTRATIONS

SECTION I
OBJECTIVE AND SCOPE

The purpose of this program was the design, development, and fabrication of an alumina ceramic envelope assembly for the cryogenic electrically-suspended gyroscope (CESG), which is under development for use in the Stanford University relativity experiment. The CESG design presently envisioned for the actual satellite experiment to test general relativity will utilize quartz as the rotor and envelope materials because of the requirement for density homogeneity. However, for the development and evaluation phases of the CESG rotor suspension circuitry and rotor spinup designs, fabrication of a "tooling" envelope of the more durable alumina ceramic material was considered cost effective.

Alumina ceramic is the standard material for electrically suspended gyroscope (ESG) envelopes, as manufactured by Honeywell; therefore, the required process techniques for this material are well defined. However, because the CESG must operate at cryogenic temperatures and also has a requirement for gas spinup channels surrounded by raised restriction lands, a limited amount of development work was required to evaluate adherence of the land material when exposed to liquid nitrogen temperatures. Also, the requirement for small clearance ($\approx 2 \times 10^{-4}$ inch) between the rotor and the gas restriction lands necessitated very close tolerances on the size and concentricity of the spherical gas restriction land surfaces with respect to the rotor and the support electrodes.

In addition to the ceramic envelope assembly, one set of thin-walled copper tubes was designed and fabricated for use as rotor spinup gas inlet, exhaust, and pressure sensing tabulation. These tubes were cemented into simulated envelope ports, cycled five times to liquid nitrogen temperature, and leak checked in order to verify the integrity of the cemented joint design.

An experimental effort of limited scope was also conducted to evaluate sputtered quartz as land material for the "flyable" CESG envelope which is to be fabricated of quartz.

The results achieved for the aforementioned tasks of this contract are summarized in the following sections.

SECTION II

AS-FIRED CERAMIC ENVELOPES AND COPPER PLATING TESTS

AS-FIRED CERAMIC ENVELOPES

A drawing was prepared for as-fired ceramic envelope halves and three sets of parts were purchased from Western Gold and Platinum Company, Belmont, California. The order was placed on 3 June 1970 and the parts were received at Honeywell during the first week of August 1970.

The ceramic envelope drawing is shown as Figure 1. The design of the ceramic envelope halves is similar to the quartz configurations (F970835 and 836) being fabricated by Honeywell under Stanford University Contract PRO347, except that ceramic parts have a 3.52-inch diameter flange at the equator. This flange provides a means of holding the parts during machining operations and also enables the two halves to be sealed using a gold wire O-ring as is done with other ESG envelopes. The flange was removed from the envelope assembly supplied under this contract in order to be compatible with the CESG gyro shield.

One set of envelope halves was used as material for the envelope assembly which was completed under this contract. The remaining two sets were shipped to George C. Marshall Space Flight Center in the unfinished condition, as specified by the contract.

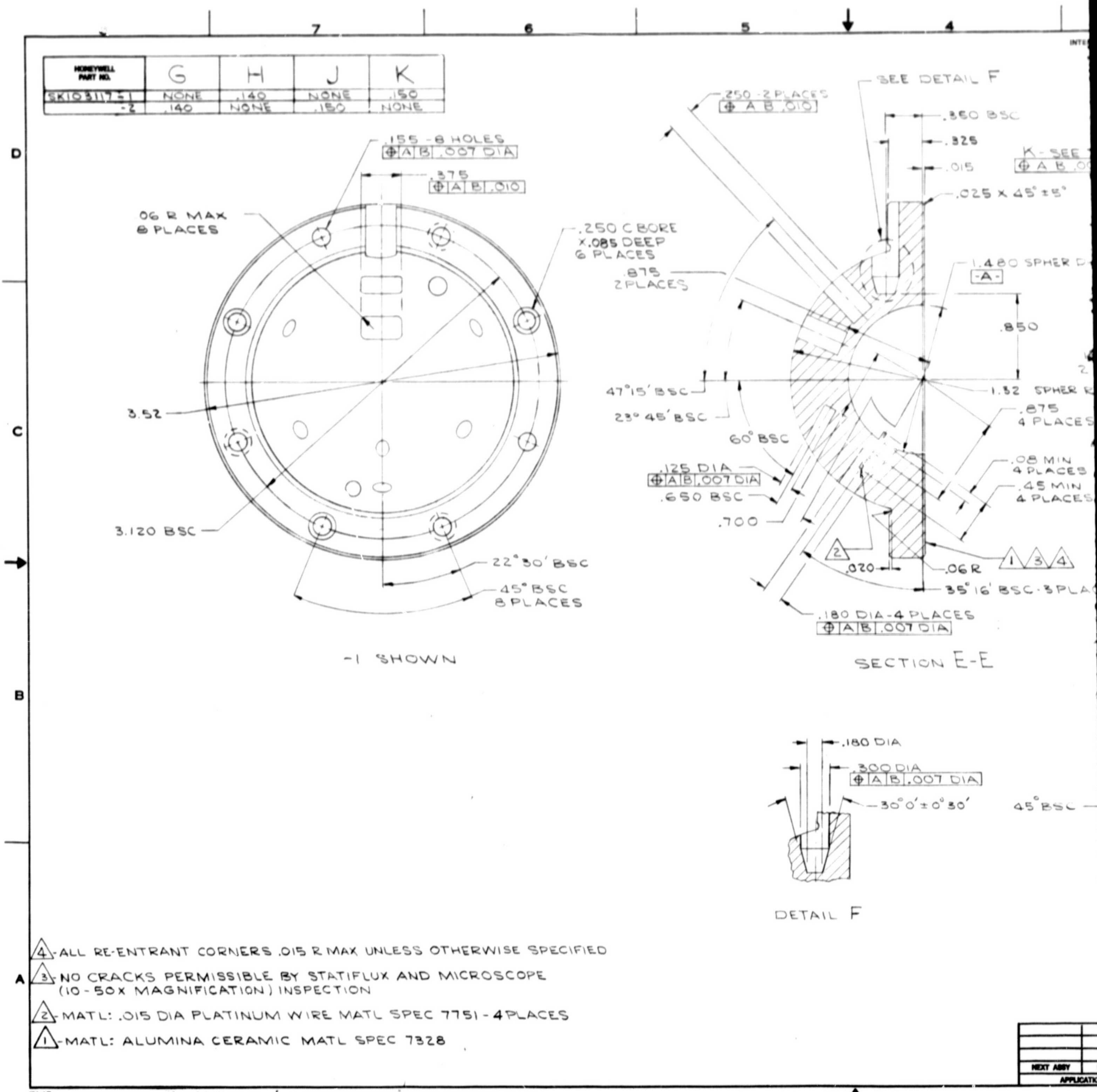


Figure 1. As-Fired Envelope Drawing

FOLDOUT FRAME 1

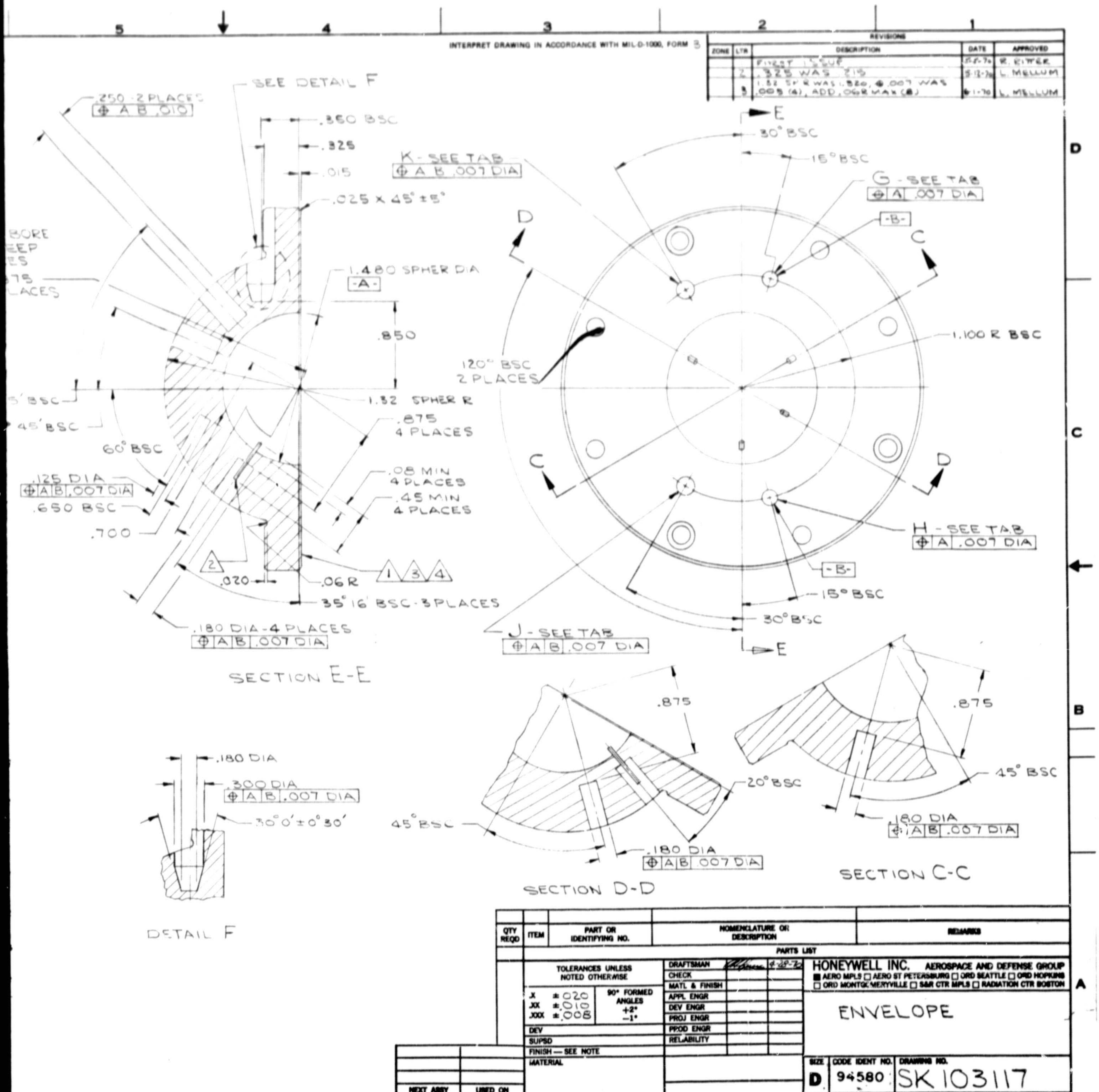


Figure 1. As-Fired Envelope Drawing

FOLDOUT FRAME 2

COPPER PLATING TESTS

Tests were conducted on two tooling ceramic envelope halves to evaluate the adherence of copper plating. Sputtered chrome-copper was used as the metallized film for one sample, and sputtered titanium-copper was used on the second. Both parts were exposed to liquid nitrogen temperature after machining the copper plating to thicknesses of 0.0012 to 0.0015 inch. Dimensional integrity of the plated surfaces was unchanged by the low temperature exposure as evidenced by visual examination and cavity roundness measurements (see Figures 2 and 3).

The titanium-copper metallized part was shipped to Dr. Francis Everitt at Stanford for further testing. The chrome-copper part was replated with additional copper and was utilized for machining experiments to improve concentricity of the gas restriction and support electrode surfaces.

The requirement to generate size and sphericity of the gas restriction surfaces to close tolerances and also "on location" with respect to the electrode surfaces is recognized to be an extremely difficult task.

Results of initial tests showed excessive eccentricity of the gas restriction and electrode surfaces. However, results of subsequent development showed that adequate concentricity of these surfaces could be generated by use of a more accurate grinding setup followed by a limited amount of lapping.

Figure 4 is a recording of a test part showing concentricity of the copper-plated gas restriction and electrode surfaces at three latitudes. As can be seen from the recording, concentricity of the two surfaces was within 50 microinches TIR.

Figure 5 is a recording of the roundness of this same test part at approximately the same latitudes after exposure to two cycles of liquid nitrogen temperature. The size and roundness of the copper plated surfaces were

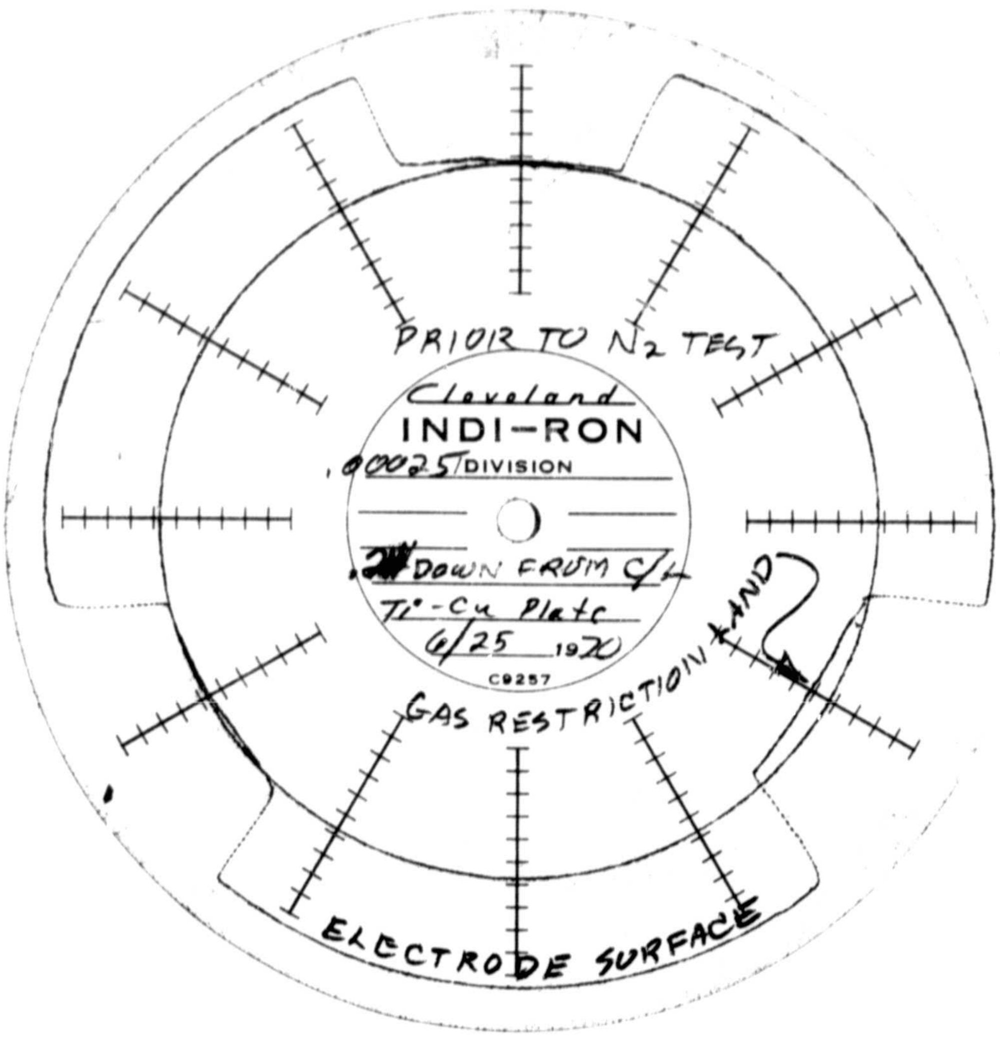


Figure 2. Roundness Chart of Titanium-Copper Plated Test Envelope Prior to Liquid Nitrogen Exposure (One Division Equals 0.00025 inch)

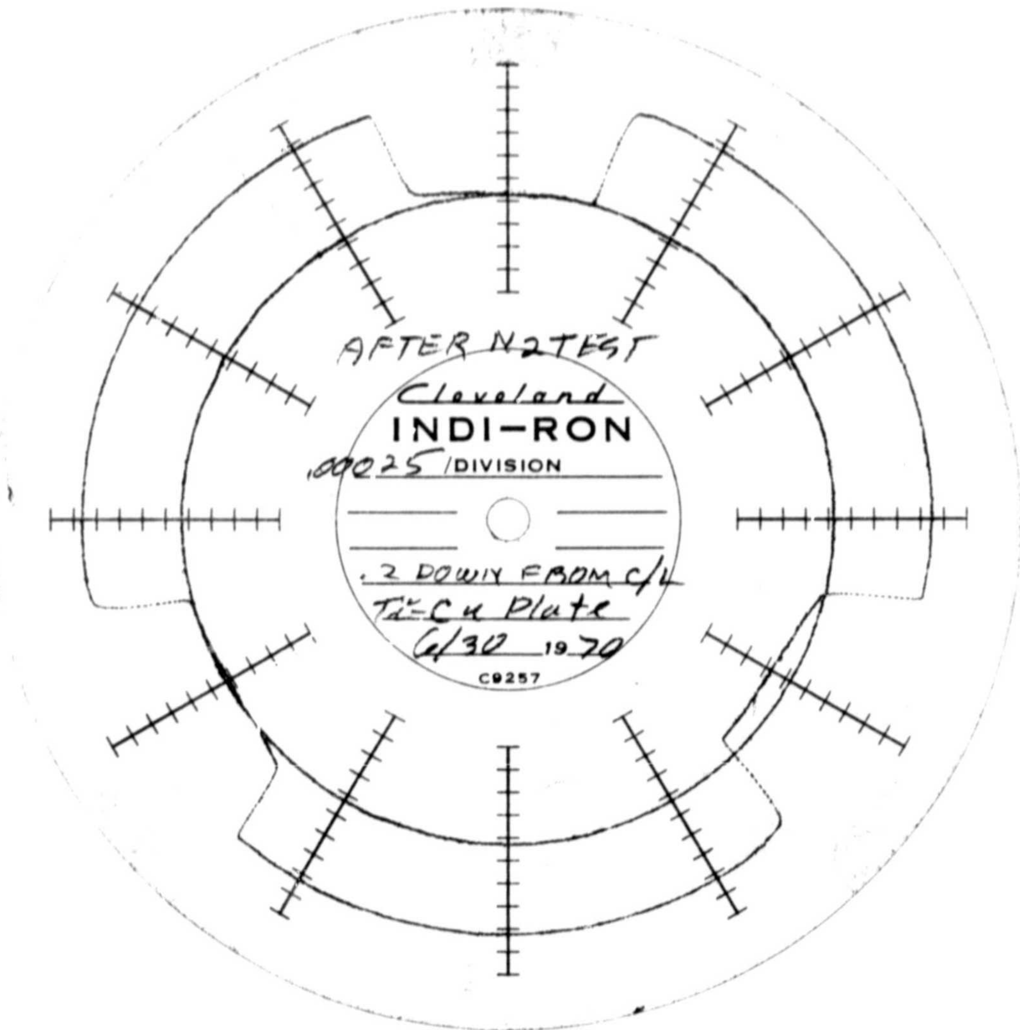


Figure 3. Roundness Chart of Titanium-Copper Plated Test Envelope After Liquid Nitrogen Exposure (One Division Equals 0.00025 inch)

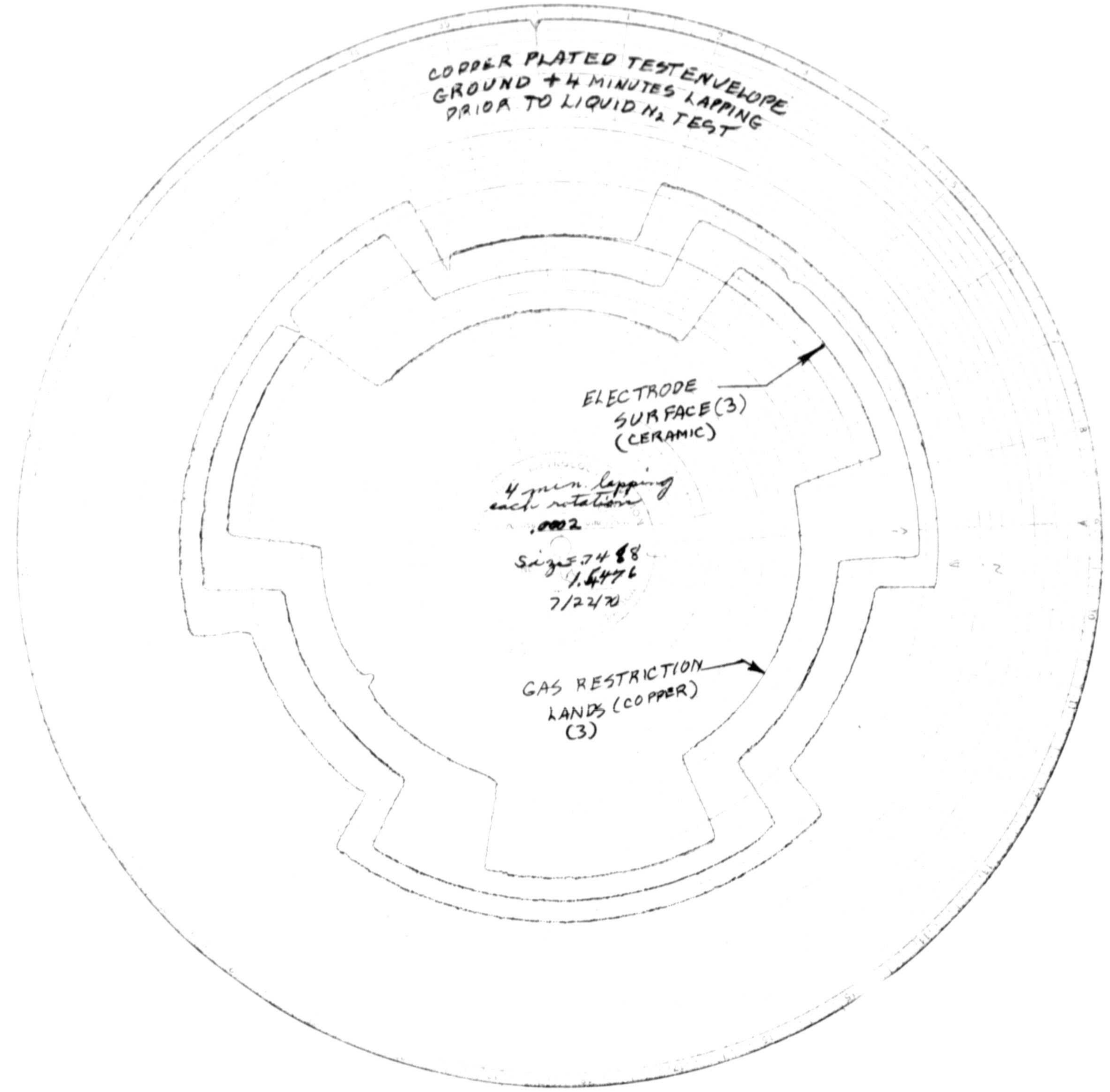


Figure 4. Concentricity of Copper Plated Gas Restriction Lands and Cavity Surfaces of Sample Envelope Half Prior to Liquid Nitrogen Exposure (One Division Equals 0.0002 inch)

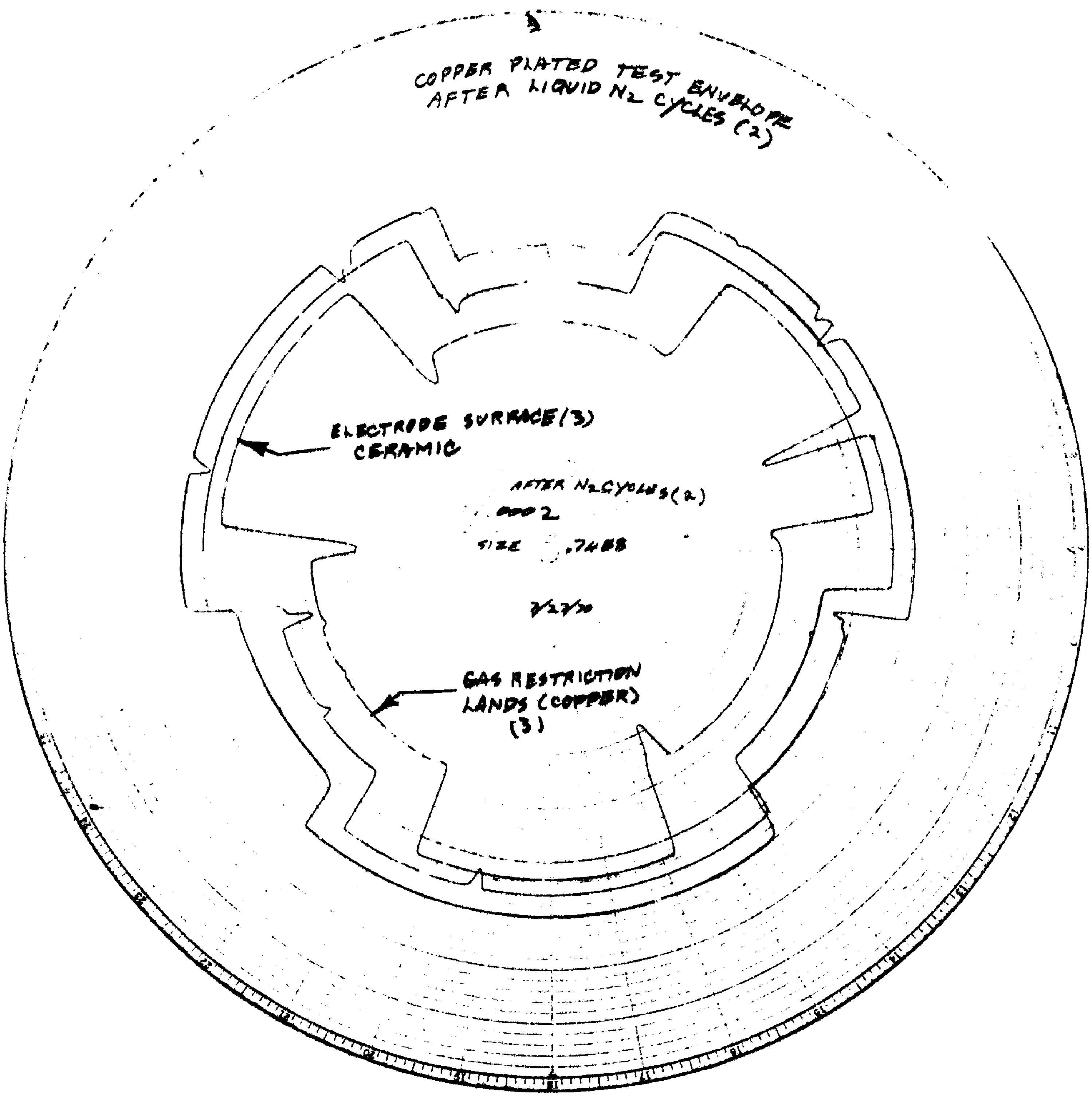


Figure 5. Concentricity of Copper Plated Gas Restriction Lands and Cavity Surfaces of Sample Envelope After Two Cycles to Liquid Nitrogen Temperature (Each Division Equals 0.0002 inch)

unchanged by this test. The chart does show lifting of the copper plating at some edges but this proved not to be a serious problem as the plating of this sample part extended beyond the metallized areas. Therefore, the edges of the plating were not adequately bonded to the ceramic.

Further work involved removal of the excess copper plating of the test sample by photoetching after which the sample was recycled to liquid nitrogen temperature (two cycles). There were no detectable dimensional changes as a result of this test. These results served to verify the suscipicion that lifting of the edges of the plating duringthe initial temperature cycling was due to the fact that the plating extended beyond the metallized areas and therefore the edges were not adequately bonded to the ceramic. This will not be a problem on the deliverable hardware, as all functional areas were metallized and photoetching was used to remove all excess plating.

Figures 6 and 7 are recordings of the test envelope which were taken after photoetching and temperature cycling, respectively.

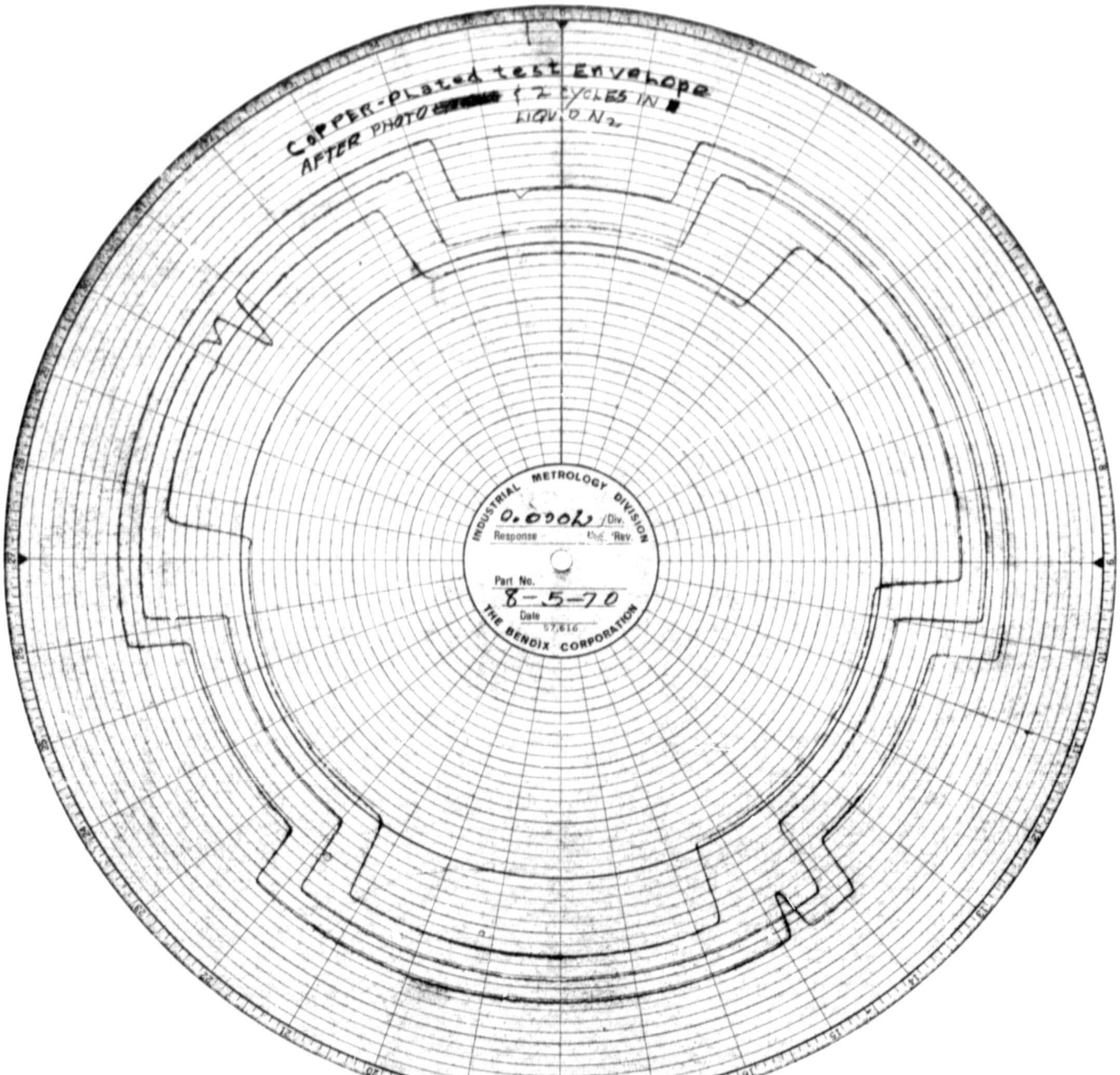


Figure 6. Roundness Chart of Copper-Plated Test Envelope After Photoetch to Remove Excess Plating at Edges of Gas Restriction Lands (One Division Equals 0.0002 Inch)

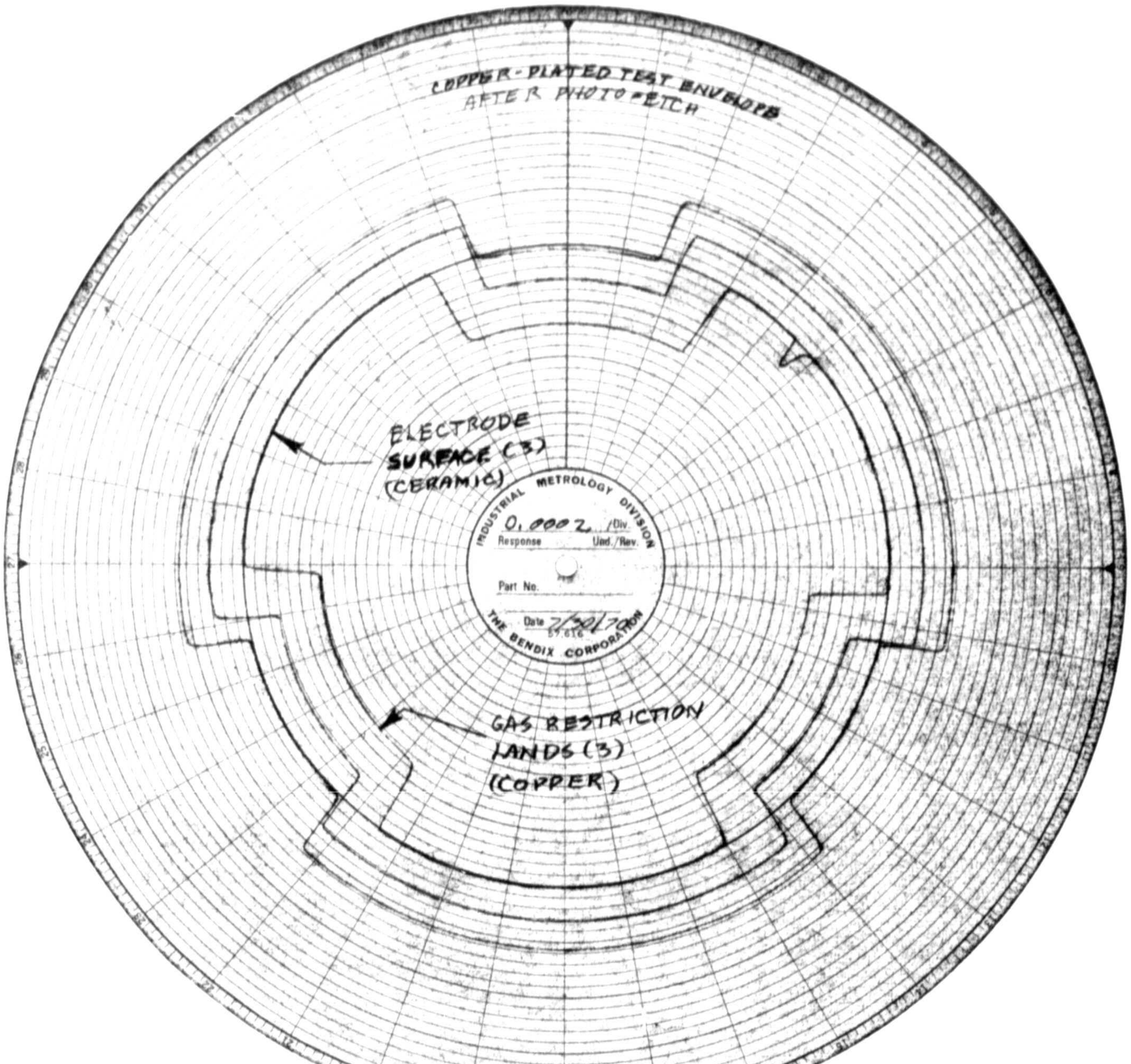


Figure 7. Roundness Chart of Copper-Plated Test Envelope After Photoetch and Two Cycles to Liquid Nitrogen Temperature (One Division Equals 0.0002 Inch)

SECTION III
CERAMIC ENVELOPE AND COPPER TUBULATION FABRICATION

CERAMIC ENVELOPE

The completed ceramic CESG envelope is shown in Figures 8 and 9 which are assembled and disassembled views, respectively. The envelope was fabricated in accordance with the machining and assembly drawings which are contained in the appendix.

The envelope is a three-piece alumina ceramic structure consisting of two hemispheres and one readout ring.

Each hemisphere contains three rotor support electrodes as well as a rotor spinup gas channel surrounded by raised "gas restriction" lands which are in turn surrounded by auxiliary pumping channels. The electrodes are positioned in each hemisphere such that when the two envelope halves are assembled, an orthogonal triad of three mutually perpendicular electrode pairs is formed. The electrodes are of sputtered titanium-gold, approximately 5000 angstroms thick, and the gas restriction lands are 0.0015-inch-thick electrodeposited copper over sputtered titanium-copper metallized film. The electrode cavity and gas restriction radii are the same as the quartz envelope (Part No. F970835 and F970836) being manufactured by Honeywell for Stanford University, under Stanford Contract PRO347 when the two designs are at room temperature (≈ 72°F). At other temperatures, the relative sizes of the ceramic and quartz envelopes will differ according to the differences in thermal expansion coefficients of the two materials.

The ring-shaped member shown in Figure 9 fits onto a ground diameter of the assembled hemispheres.

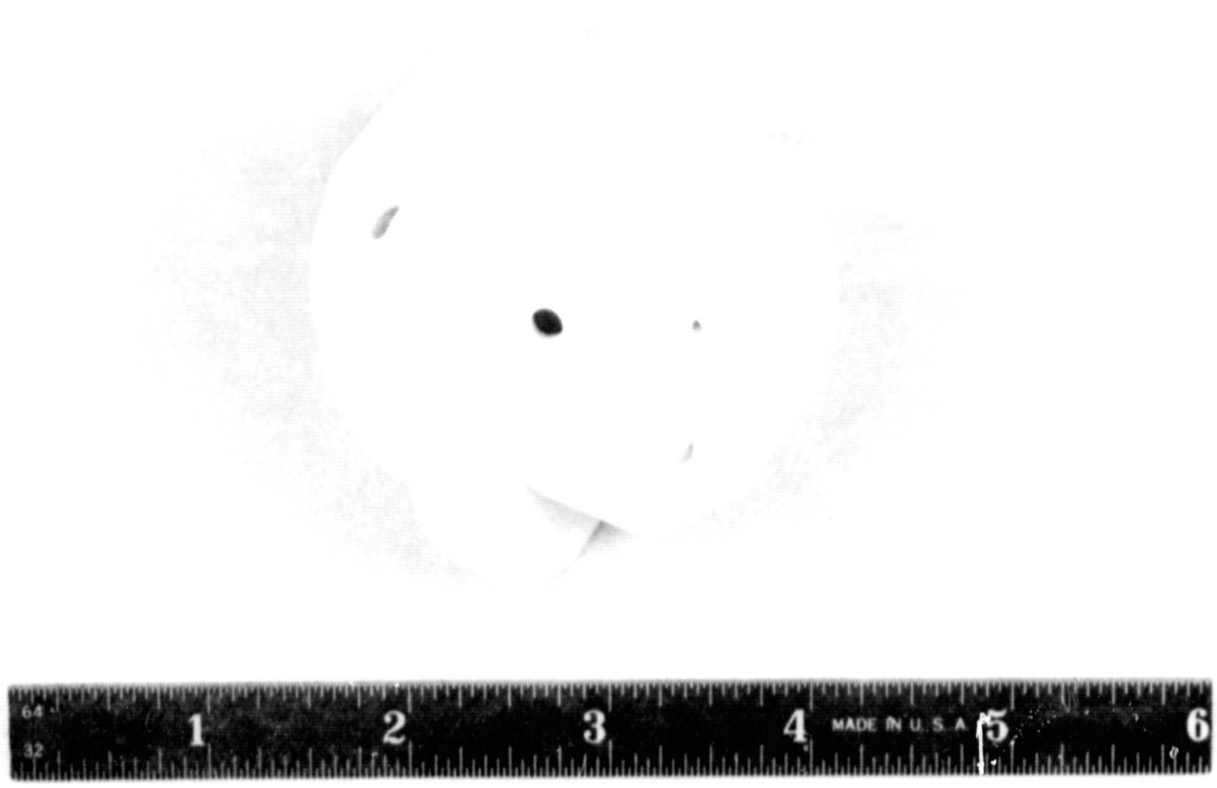


Figure 8. Envelope, Assembled

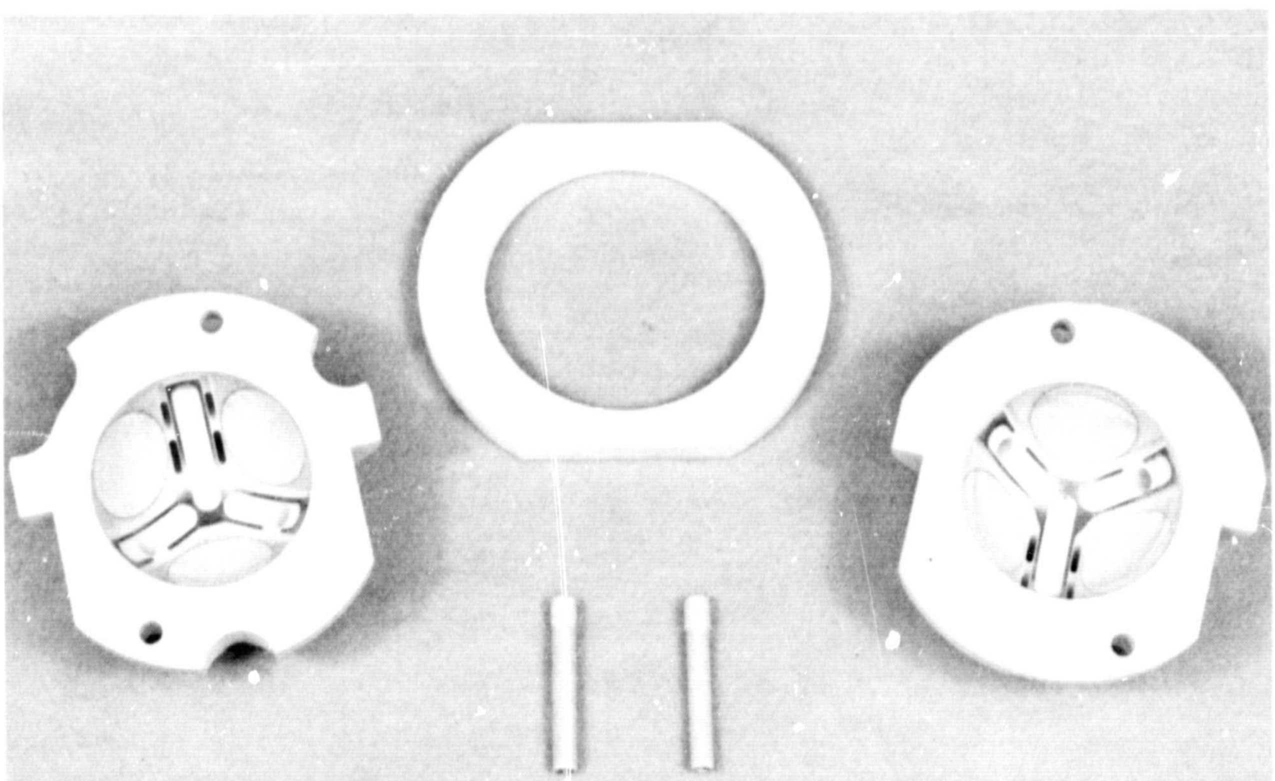


Figure 9. Envelope, Disassembled

This diameter is ground such that when the ring is installed, one surface is in the equatorial plane of the assembled hemisphere and the plane of the ring perpendicular to the mating surfaces of the hemispheres as well as the plane of the rotor spinup channels. The intended use of this ceramic ring is to provide a surface for deposition of a superconducting metal ring which will be a part of the gyroscope readout system.

Only one problem was encountered during fabrication of the envelope assembly, and that was concerned with adhesion of the copper plating for the gas restriction lands. During spherical machining of the parts as initially metallized and plated, it was noted that the adhesion of the plated deposit and/or metallized film was inadequate, thus necessitating rework of the parts. The rework involved complete removal of the plating and metallized film, after which the parts were again cleaned, metallized, and plated. No adhesion problems were encountered in machining the second deposit.

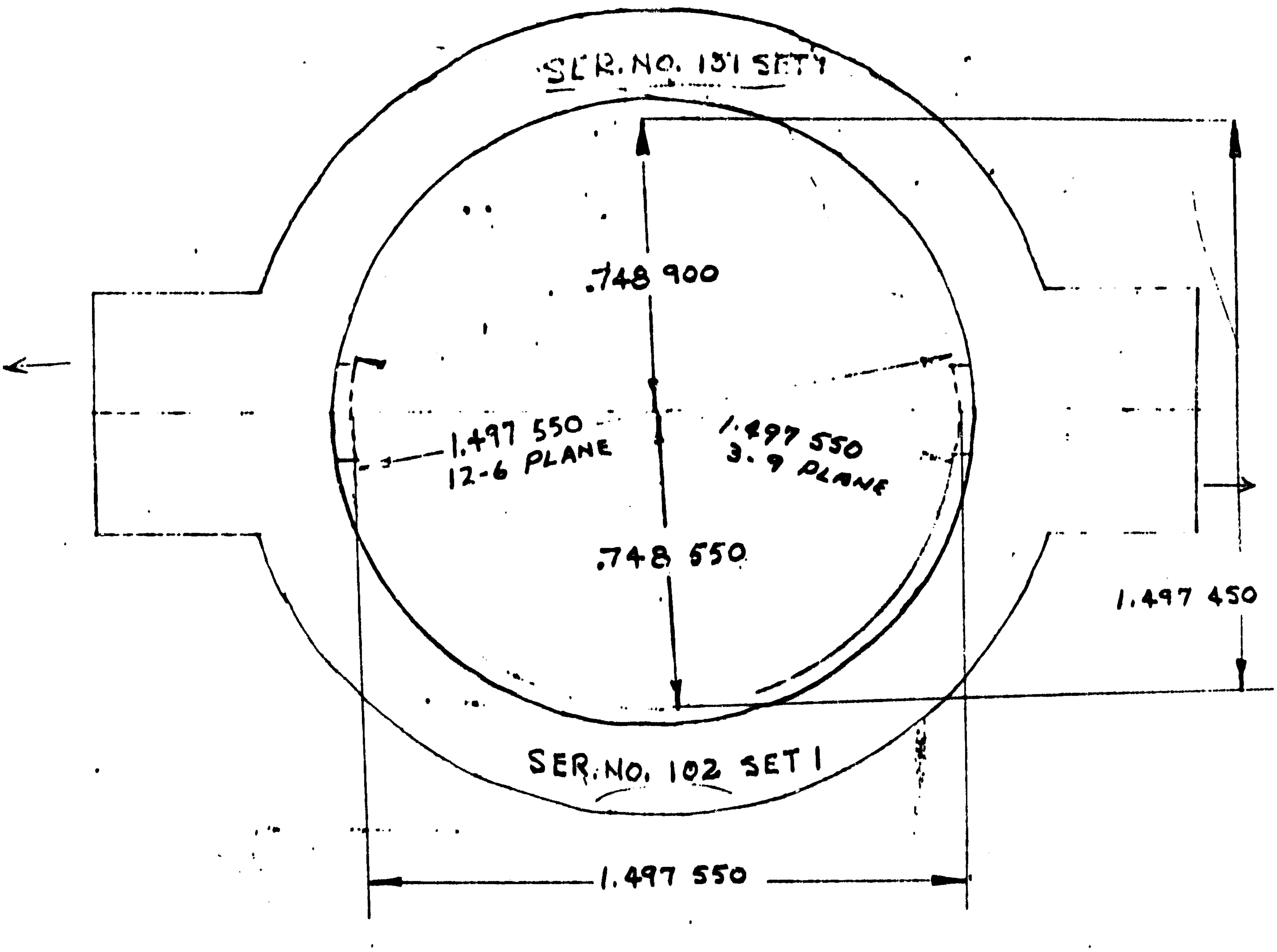
It is suspected that the poor adhesion of the initial copper plating was due to a related problem which was encountered during the metallizing-plating process used for these parts. The normal process involves d-c sputtering of a titanium film onto the ceramic, with a phased-in copper overcoating to enhance adhesion of the relatively thick electrodeposited copper plating. However, during plating of these particular parts, the sputtered copper film was inadvertently removed prior to electroplating and rework had consisted of adding a second titanium-copper film by sputtering over the previous titanium deposit.

Examination of the failed deposits showed evidence of titanium on both the copper and ceramic surfaces, indicating that the bond failure was most probably at the sputtered titanium-to-titanium interface. It is suspected that the bond of the second sputtered titanium film may have been less than adequate because of the formation of an oxide coating on the previous deposit when the copper overcoating was removed. This problem was not repeated in the second rework process, as the previously deposited titanium was completely removed from the ceramic prior to resputtering.

Fabrication of the envelope was completed and the parts were shipped to George C. Marshall Space Flight Center during January 1971. Dimensional checks were made of the gas restriction lands, with results which agreed closely with similar measurements made at Honeywell. Measurements made at Honeywell of the gas restriction land spherical diameter showed the dimension to be 1.4972 ± 0.0001 inch. Measurements made at Marshall Space Flight Center indicated this feature to be 1.49745 ± 0.00010-inch. Figure 10 is a copy of the measurements made at Marshall Space Flight Center.

These results compared quite well, and both showed that clearance should be available when the envelope was assembled with the hollow, nickel-plated, aluminum rotor which had previously been designed and fabricated by Honeywell for Stanford University under Stanford Contract PRO927. The aluminum rotor was designed as a more durable tooling unit to approximate the size and weight of the quartz rotor which is planned for the "final design" CESG. The aluminum rotor size was measured to be 1.496945 ± 0.000005-inch at Honeywell, and 1.497000-inch at Marshall Space Flight Center. These measurements also compared quite well, and both sets of data would indicate that adequate clearance should result when the rotor was installed in the envelope.

A problem of "no clearance" resulted, however, when the envelope and rotor were subsequently assembled and tested at Stanford University. The envelope and rotor were then returned to Honeywell and reworked to give measurable clearance. Also, it was necessary to repolish the nickel-plated rotor to remove deposits of gold which had been arced off from the electrodes during testing at Stanford University.



1.496 600 Ball, 00095 TIR - 1.497 [illegible] 2 [illegible] 5W

Figure 10. Gas Restriction Land Dimensions (Measurements by Mr. W. Angele, Marshall Space Flight Center)

Under provisions of Stanford Contract PRO347, the fixture shown in Figure 11 was designed and built to accurately measure the rotor-to-land clearance. With this fixture, the contact point of the indicator operates through one of the 0.180-inch diameter vent holes of the envelope, while the rotor is moved from "bottom to top" by use of a teflon probe. Measurements made after rework with the assembly stabilized at 69.2°F showed the diametral clearance to be 0.00033-inch when measured through one set of vent holes and 0.00035-inch when measured through the second set of vent holes. The design goal for the radial, rotor-to-land clearance was $0.0003\,^{+0.0003}_{-0.0001}$ -inch.

The previously encountered problem of "no clearance" was the result of mismatch of the origin of radii of the two hemispheres in the directions parallel with and perpendicular to the split plane. The problem was corrected by fabricating a solid-steel sphere of the dimension required for the gas restriction lands. The lands were lapped until, with the sphere resting in each hemisphere, the proper dimensions were achieved from the top of the sphere to the equators of the two hemispheres. Checks were also made to verify that roundness and concentricity of the gas restriction lands were not degraded by the rework. Figures 12 through 17 are roundness charts made after the rework with an Indi-Ron roundness measuring instrument. For these checks, the probe and gaging head were positioned approximately as shown in Figure 18.

After lapping to establish the proper depth of each hemisphere, the "translational" mismatch of the envelope was corrected. The two hemispheres were clamped together with the steel sphere inside, and the alignment pin holes were ground oversize, after which larger alignment pins were fitted by lapping.

To complete the envelope rework, an additional gold coating was sputtered onto the electrodes of one hemisphere which had exhibited marginal adhesion during previous cleaning.

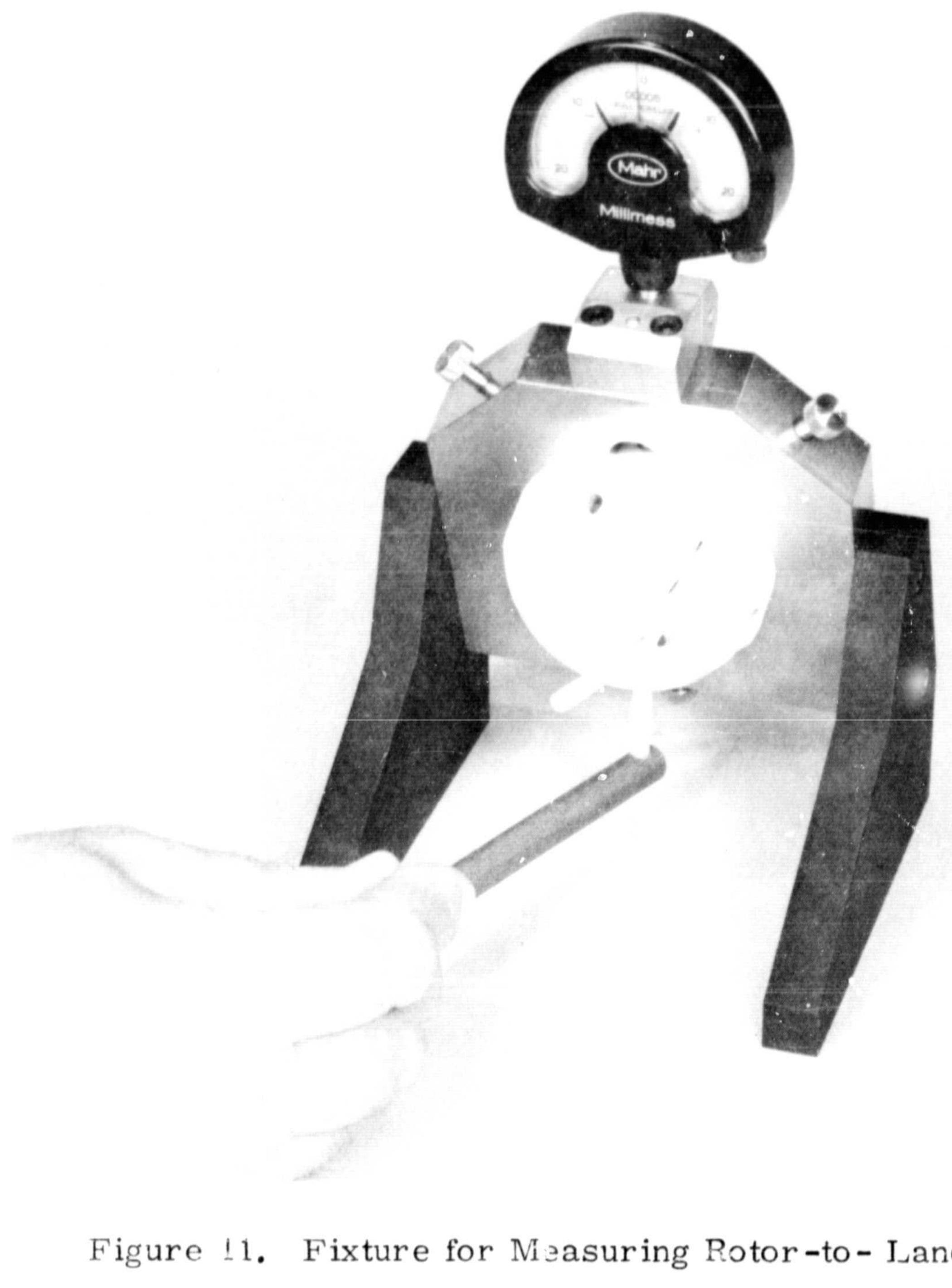


Figure 11. Fixture for Measuring Rotor-to-Land Clearance

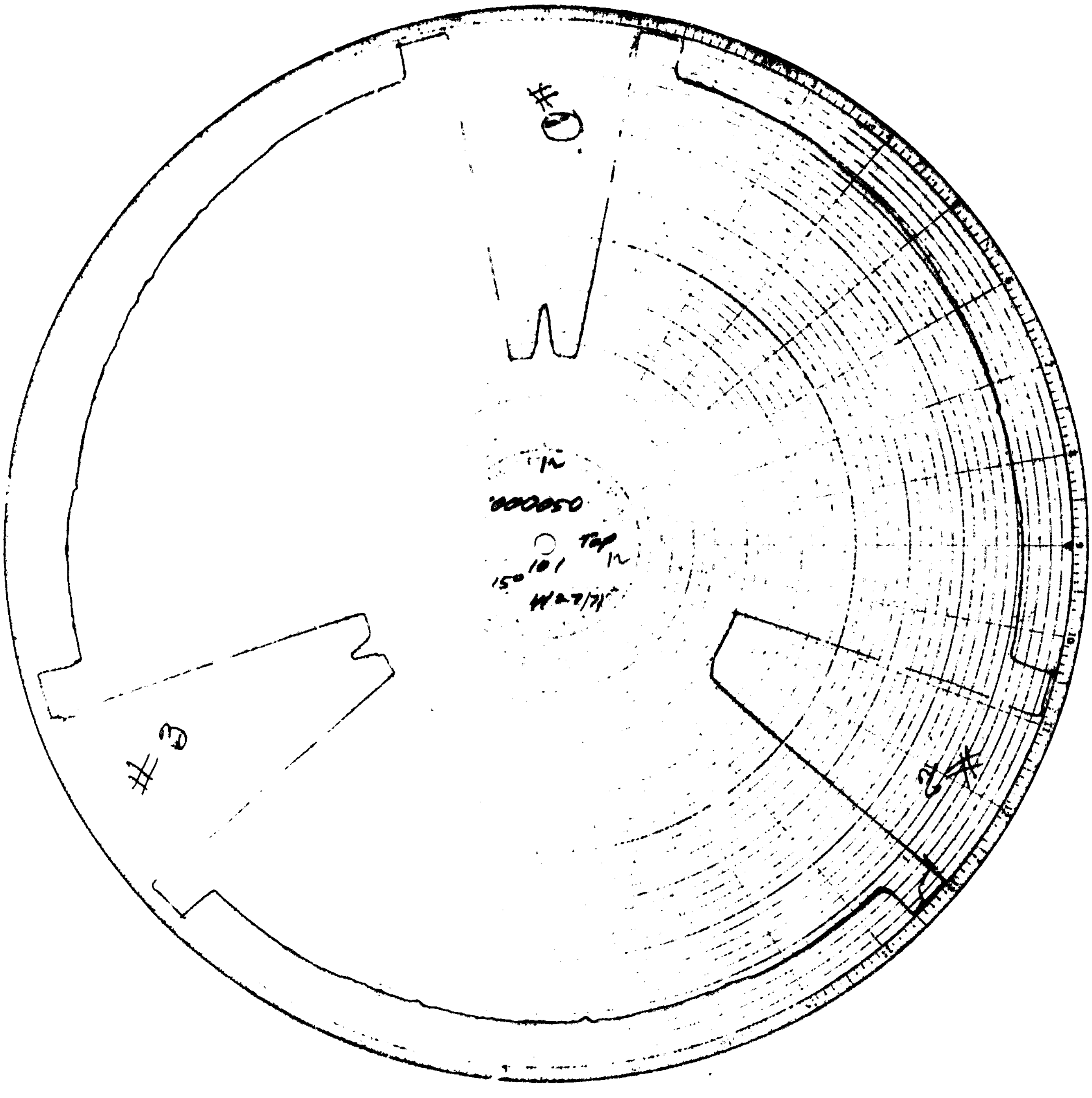


Figure 12. Land-to-Electrode Concentricity, Top Half After Rework (15° latitude)

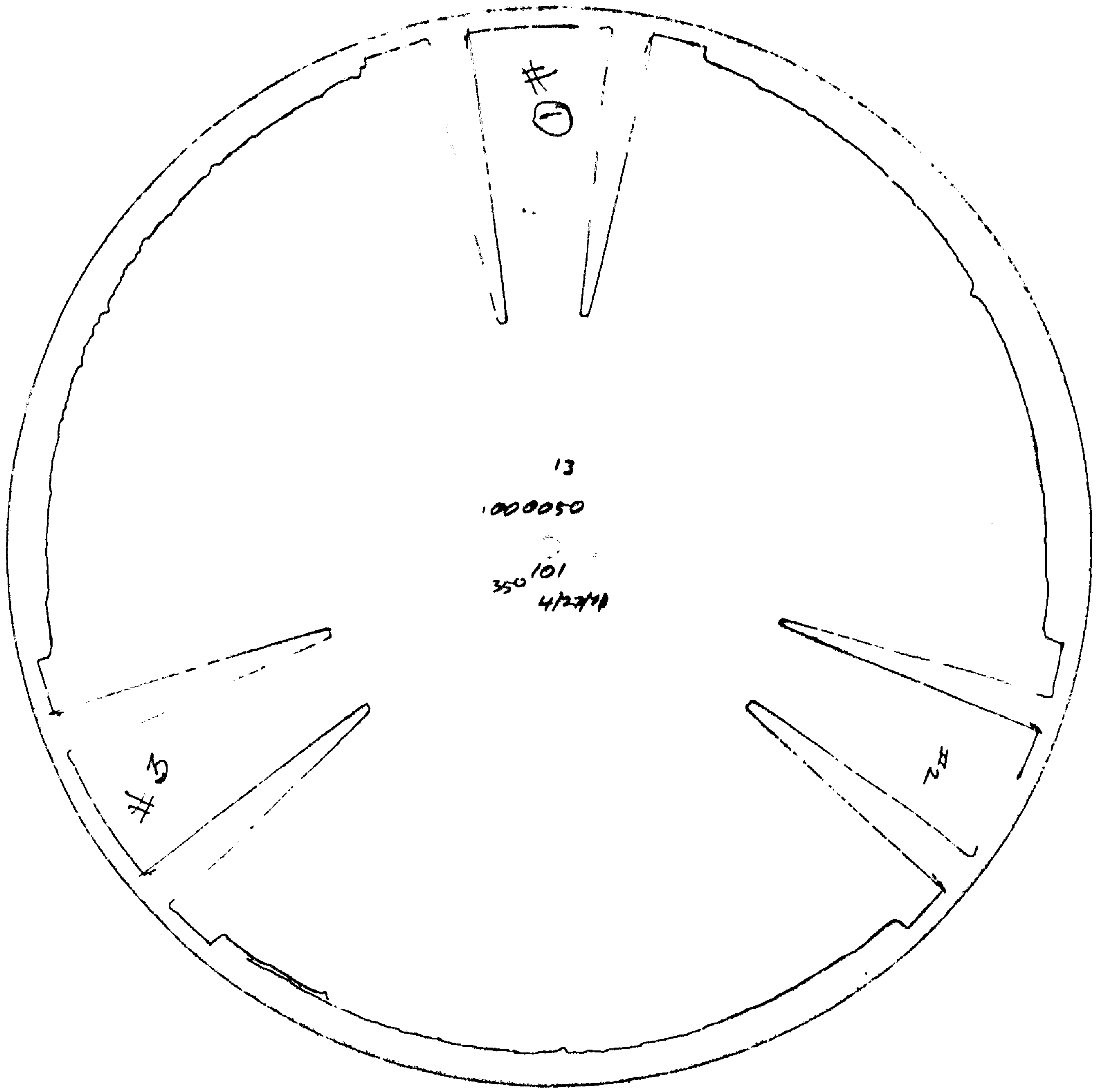


Figure 13. Land-to-Electrode Concentricity, Top Half, After Rework (35° latitude)

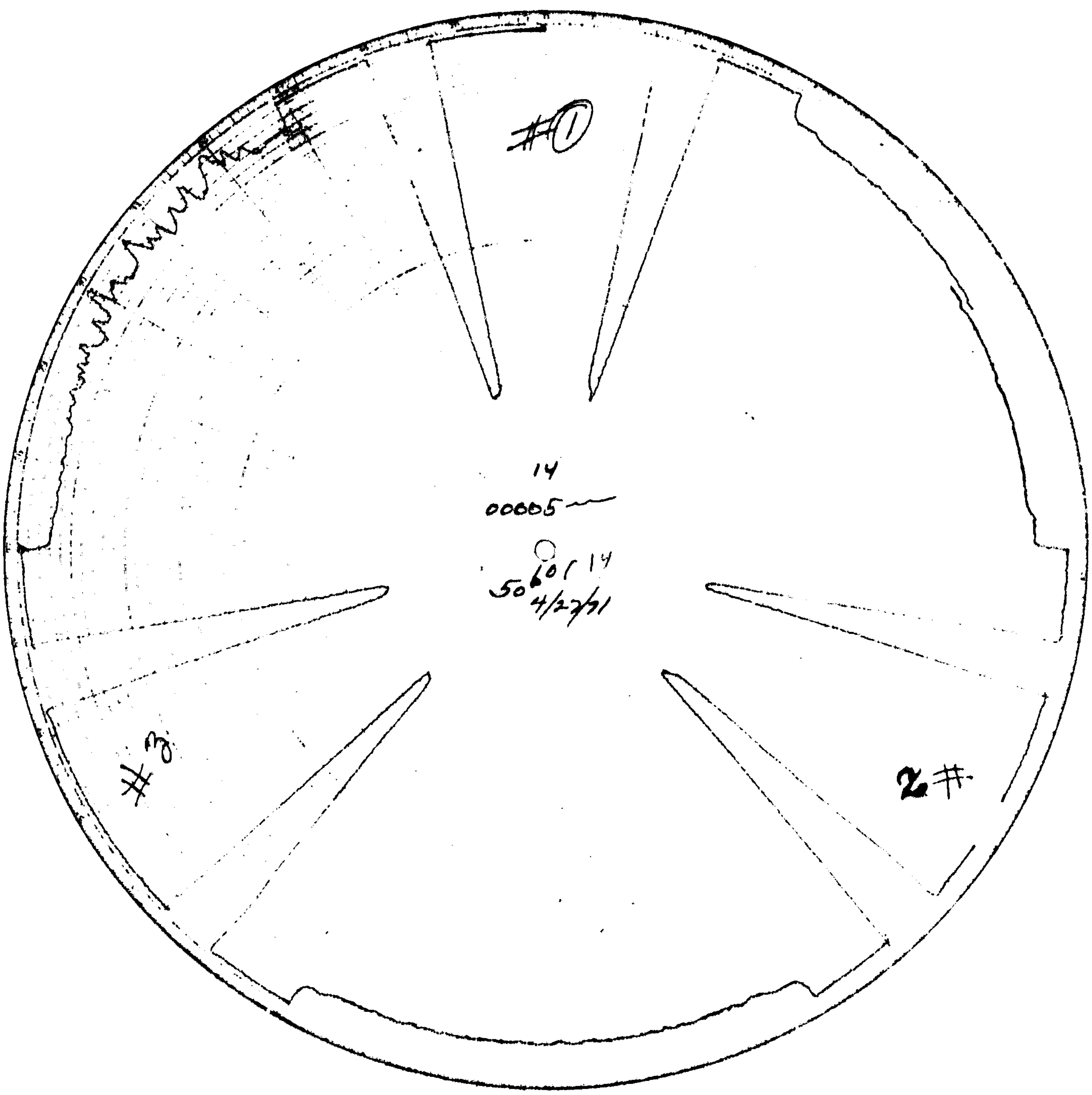


Figure 14. Land-to-Electrode Concentricity, Top Half, After Rework (50° latitude)

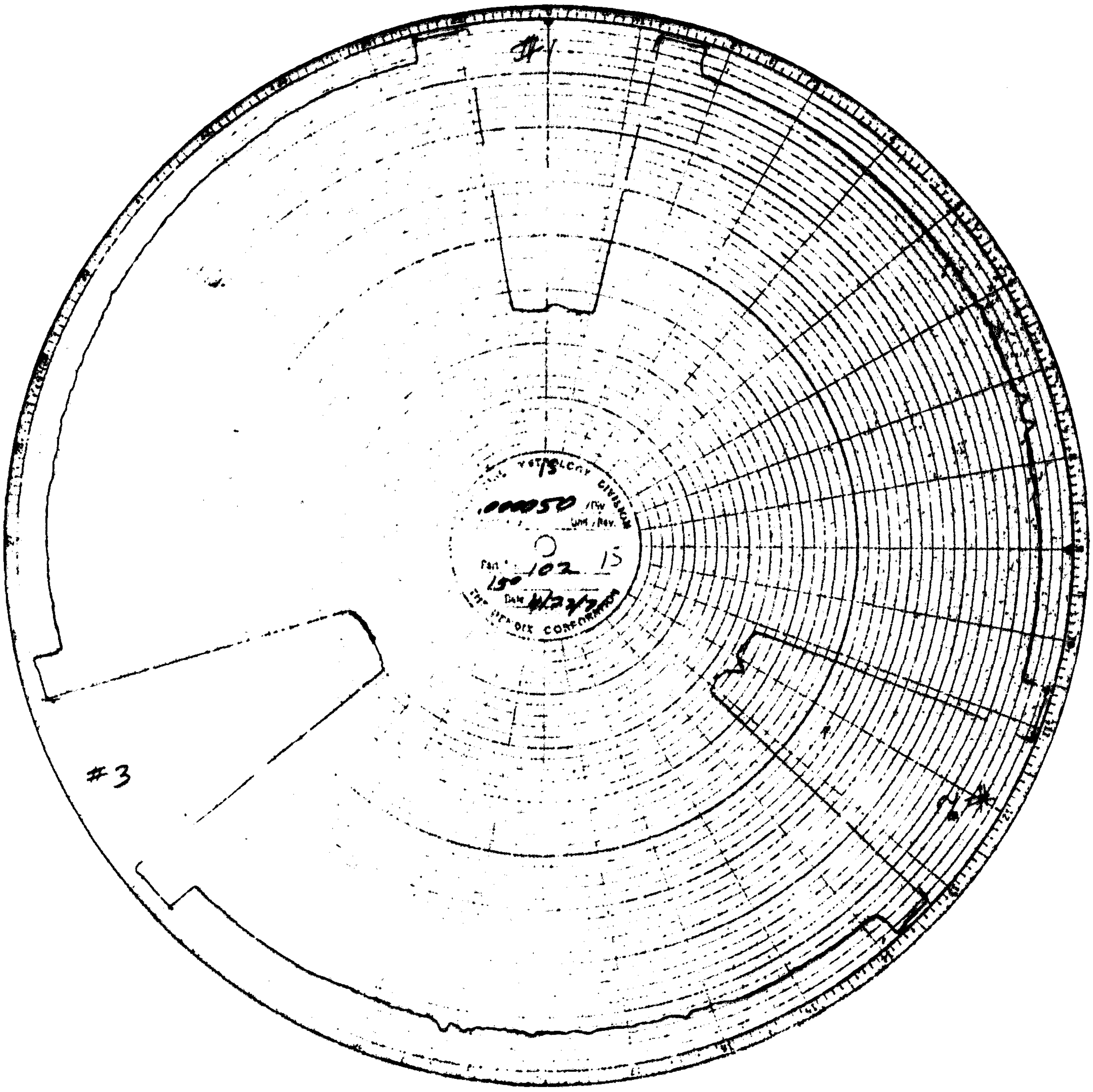


Figure 15. Land-to-Electrode Concentricity, Bottom Half After Rework (15° latitude)

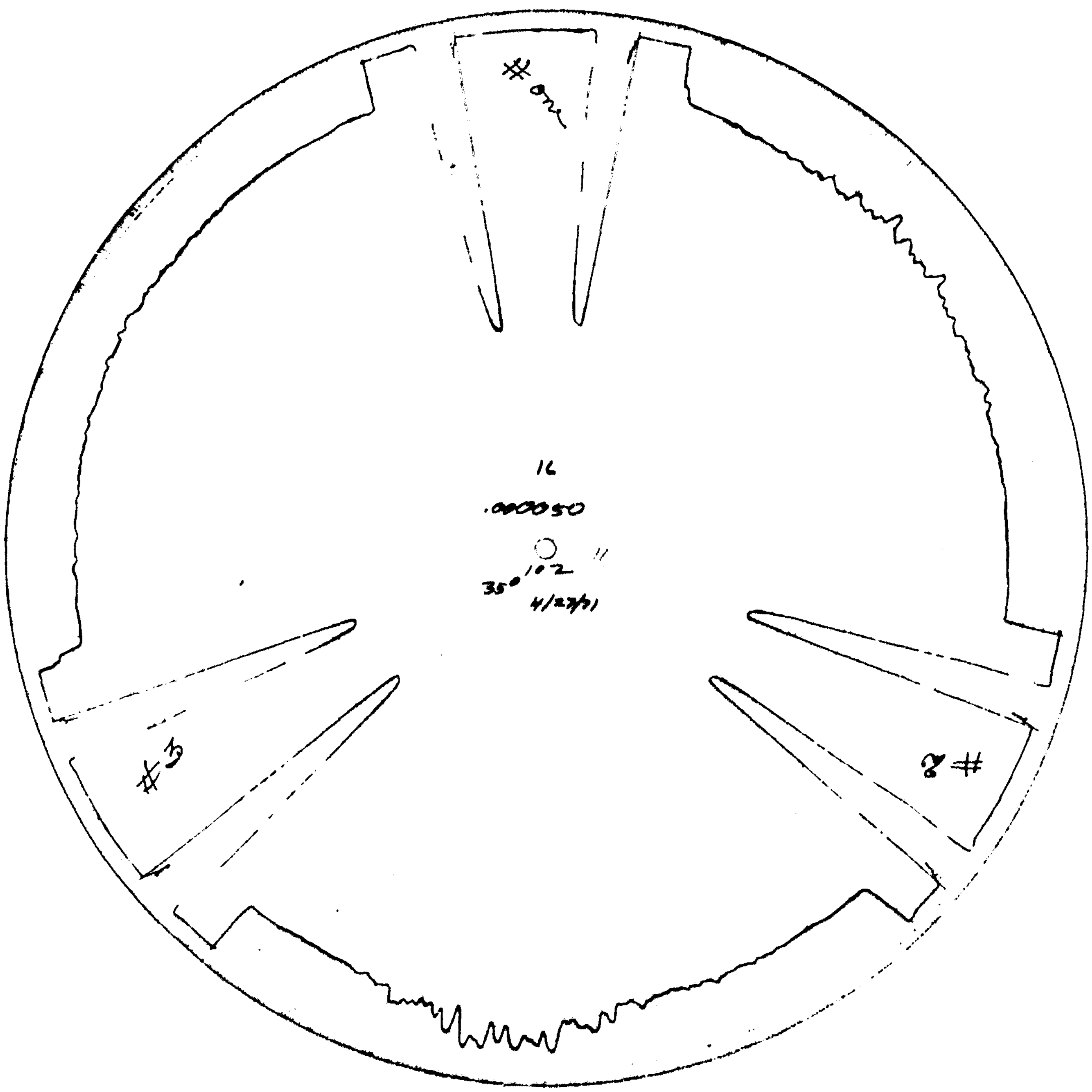


Figure 16. Land-to-Electrode Concentricity, Bottom Half After Rework (35° latitude)

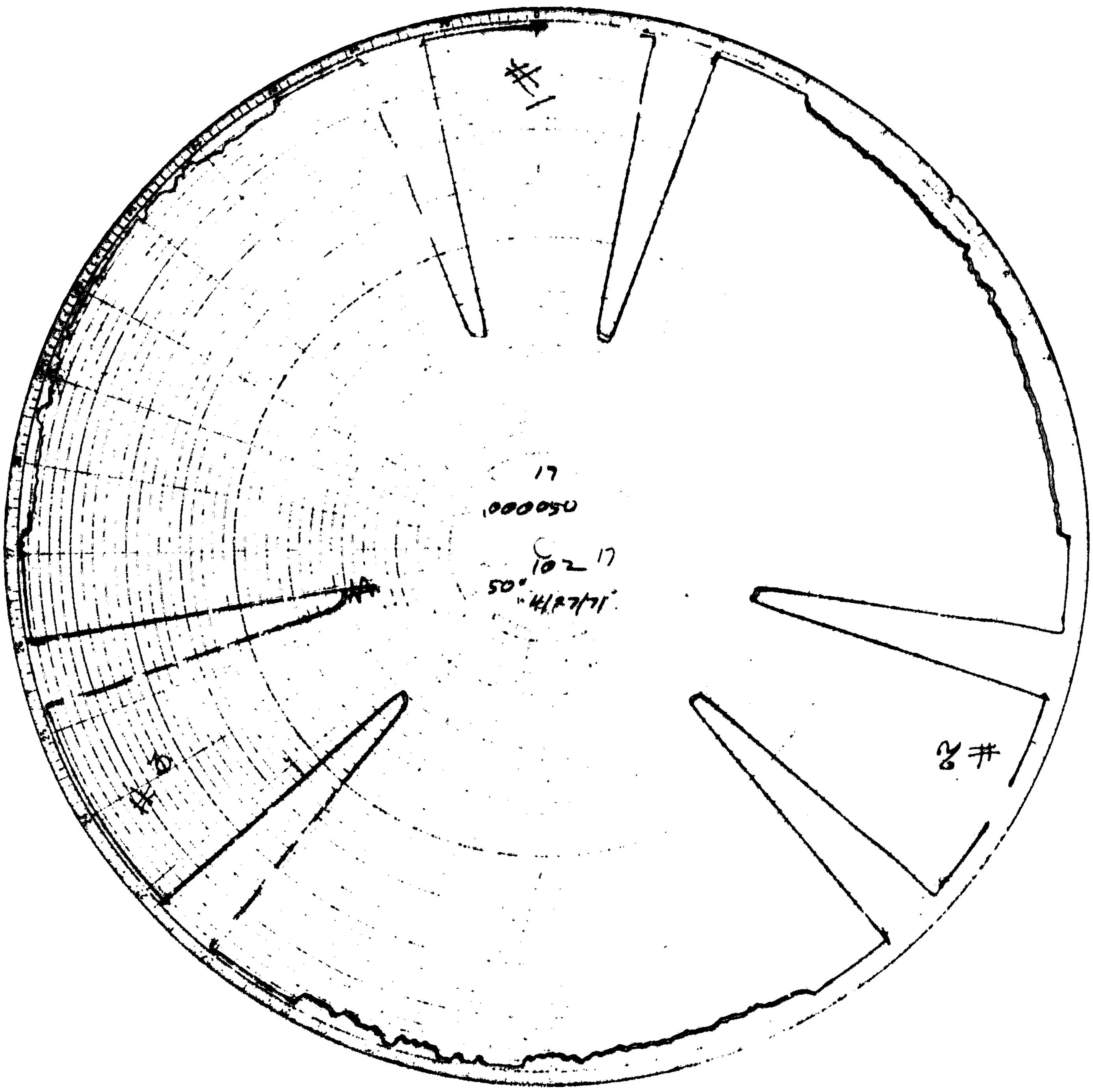


Figure 17. Land-to-Electrode Concentricity, Bottom Half After Rework (50° latitude)

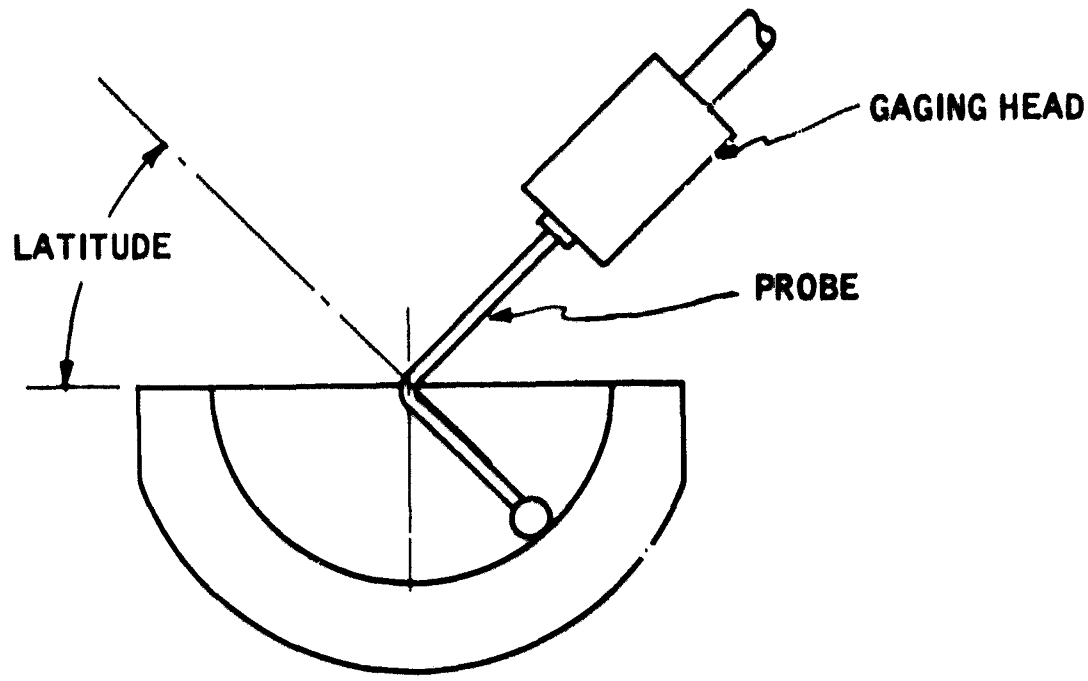


Figure 18. Indi-Ron Gaging Head Setup for Roundness and Concentric Measurements

The reworked envelope was then assembled with the nickel-plated aluminum rotor and the assembly was returned to Stanford University on or about 19 May 1971 for further testing. Initial capacitance measurements at Stanford verified that the rotor was "free" in the cavity, indicating that the rework had been successful.

COPPER TUBULATION DEVELOPMENT

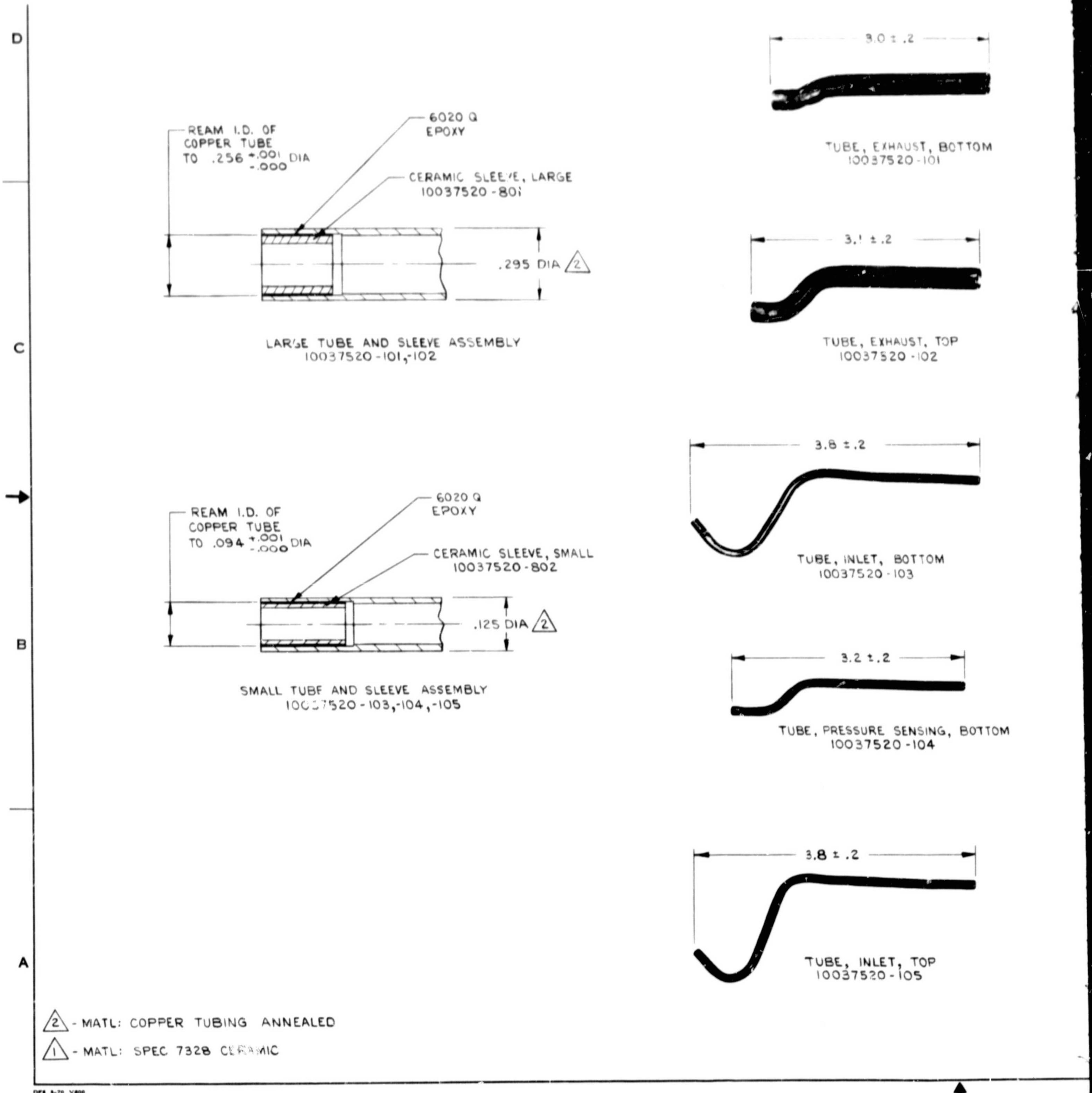
The object of this task was to design, fabricate, and test one set of pressure sensing, rotor spinup, and exhaust gas pipes for the ceramic CESG envelope assembly described earlier in this section.

The pipes were designed to fit into the parts of the envelope mounted in the gyro shields that were manufactured by the Davidson Optronics Company (Davidson drawings 638000 and 638001) for Stanford University. It was also a requirement that the pipe-to-envelope joints remain leak tight when exposed to cryogenic temperatures.

In order to minimize the effects of the thermal expansion difference between the copper pipes and the ceramic envelope, ceramic sleeves were cemented into the "joint ends" of the pipes. These sleeves are of sufficient strength to withstand the compressive loads introduced by shrinkage of the copper pipes, thus resulting in low tensile stresses in the pipe-to-envelope joints.

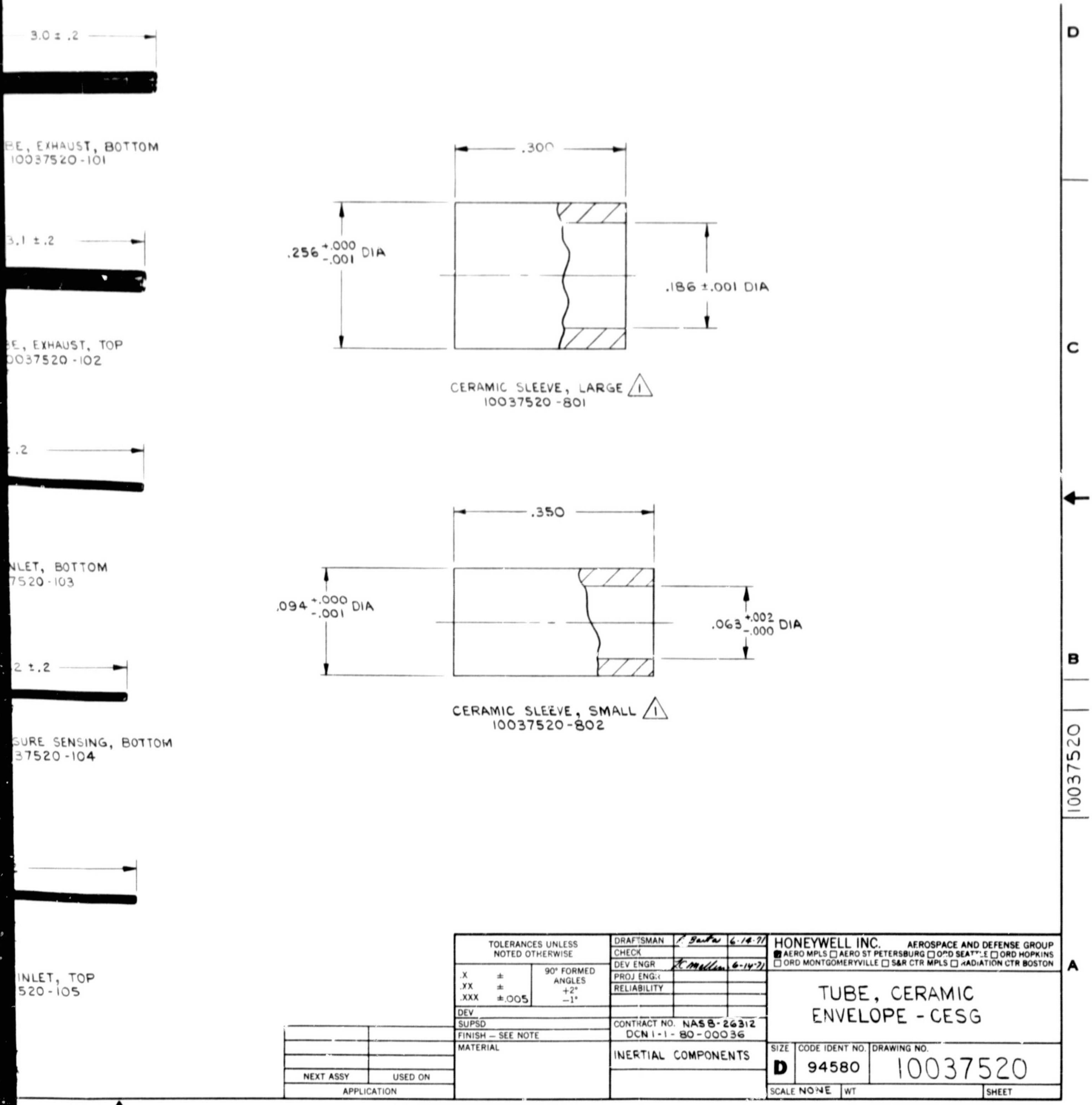
The dimensions and materials of the pipes and joints are shown by the drawing of Figure 19, and the positions of each pipe in the envelope-shield assembly are shown by the drawing of Figure 20, together with the envelope-to-pipe joint configuration. Prior to shipment, all pipes were assembled to sample "ports" of the same inside dimensions as those of the actual envelope. Dow Corning 30-079 rubber sealant was used as shown in Figure 21. The pipes appeared as shown in Figures 22 and 23 with the sample parts attached and removed, respectively.

All pipes were helium leak checked and then were cycled five times to liquid nitrogen temperature with intermediate leak checks. All joints remained leak tight to the detection limit of the CEC Model 24-120A leak detector ($\approx 2 \times 10^{-10}$ std. cc/sec of He) used. The leak check setup is shown in Figure 24.



FOLDOUT FRAME 1

Figure 19. Tube Assembly D



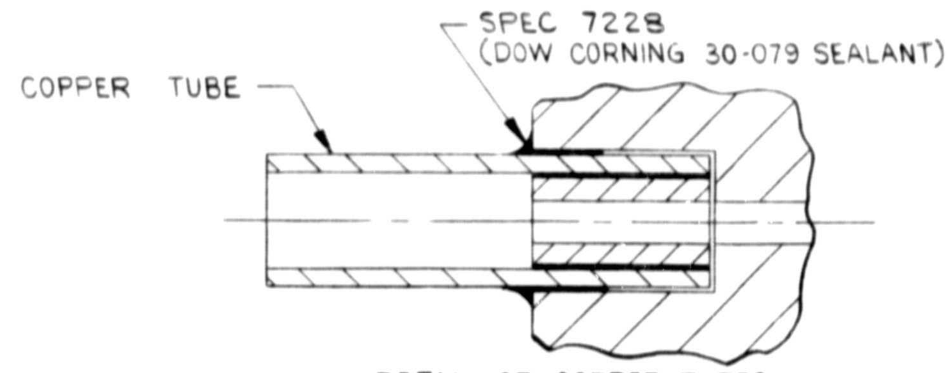
19. Tube Assembly Drawing

FOLDOUT FRAME 2

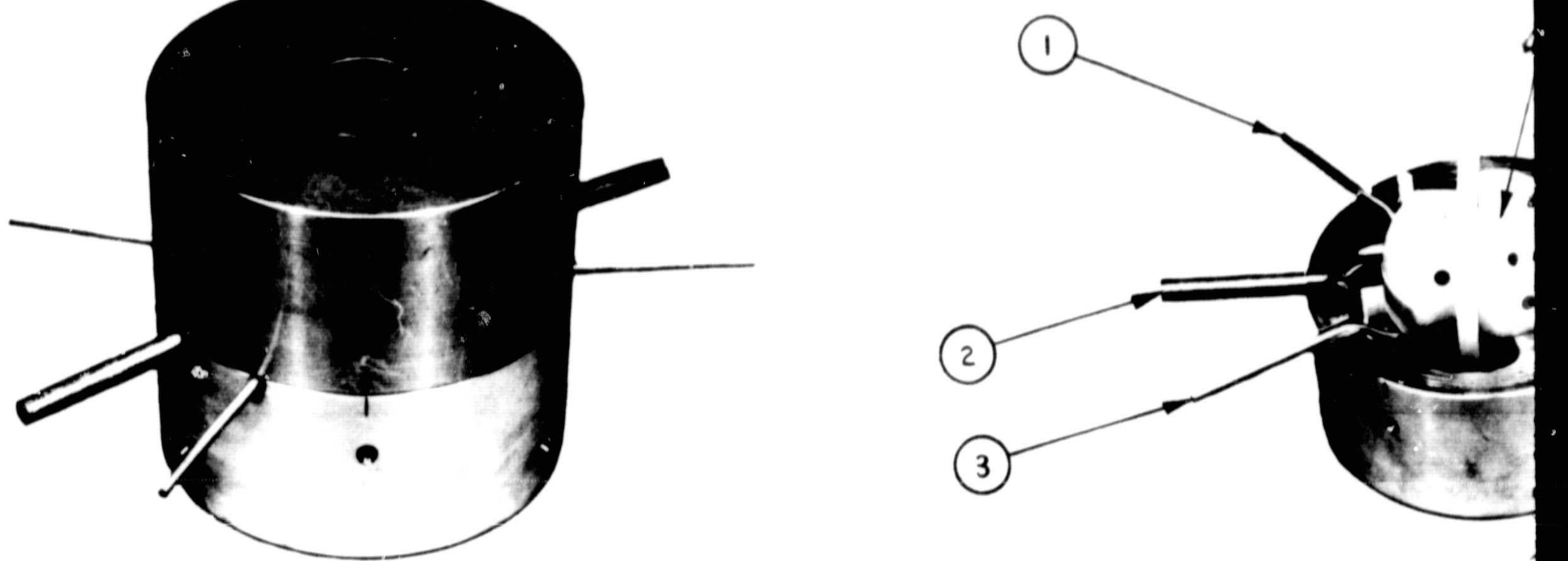
5 4 3 2

INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000, FORM 3

HONEYWELL PART NO.



DETAIL OF COPPER TUBES
TO CERAMIC ENVELOPE JOINTS



C

B

A

QTY	ITEM	PART NO.	DESC
1	8	638-0000 REF	MOCKUP, UP
1	7	10037520-105	TUBE, INLE
1	6	10037520-101	TUBE, EXHA
1	5	638-0001 REF	MOCKUP, LO
1	4	10034704-101	ENVELOPE A
1	3	10037520-104	TUBE, PRESS
1	2	10037520-102	TUBE, EXHA
1	1	10037520-103	TUBE, INLE

10037521-101

TOLERANCES UNLESS NOTED OTHERWISE

.X ±
.XX ±
.XXX ±

90° FORMED ANGLES +2° −1°

DRAFTSMAN
CHECK
DEV ENGR
PROJ ENGR
RELIABILITY

SUPSD
FINISH – SEE NOTE
MATERIAL

CONTRACT NO.
DCN1-1-8

INERTIAL

NEXT ASSY	USED ON
APPLICATION	

OF-5 7-73 V600

Figure 20. Tube Installation Drawing

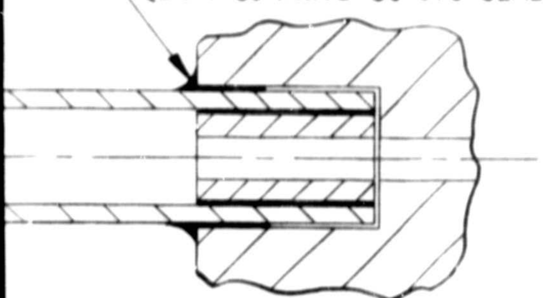
3 2 1

INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000, FORM 3

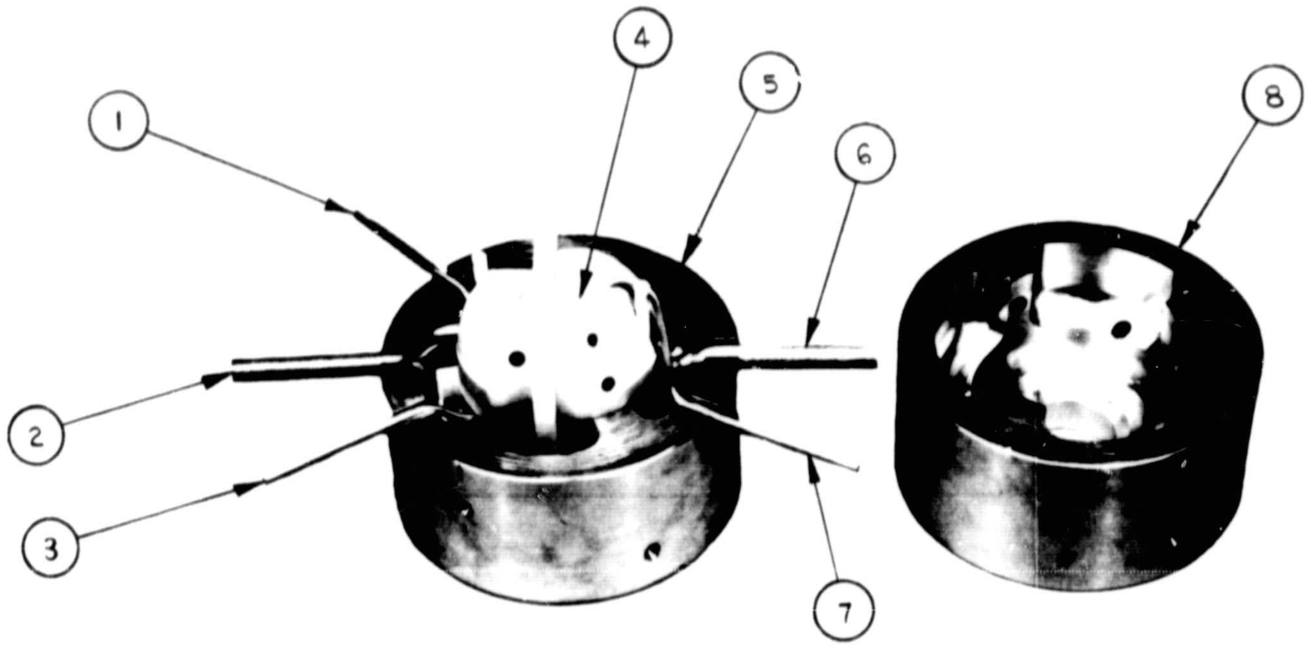
REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	1ST ISSUE	6-15-71	*RCM*

SPEC 7228
(DOW CORNING 30-079 SEALANT)



DETAIL OF COPPER TUBES
TO CERAMIC ENVELOPE JOINTS



C

B

A

10037521

QTY	ITEM	PART NO.	DESCRIPTION	REMARKS
1	8	638-0000 REF	MOCKUP, UPPER GYRO SHIELD	DAVIDSON OPTRONICS INC., CALIF
1	7	10037520-105	TUBE, INLET, TOP	
1	6	10037520-101	TUBE, EXHAUST, BOTTOM	
1	5	638-0001 REF	MOCKUP, LOWER GYRO SHIELD	DAVIDSON OPTRONICS INC., CALIF
1	4	10034704-101	ENVELOPE ASSY, CRYOGENIC ESG	
1	3	10037520-104	TUBE, PRESSURE SENSING, BOTTOM	
1	2	10037520-102	TUBE, EXHAUST, TOP	
1	1	10037520-103	TUBE, INLET, BOTTOM	

PARTS LIST

10037521-101

TOLERANCES UNLESS NOTED OTHERWISE
.X ±
.XX ±
.XXX ±
90° FORMED ANGLES +2° −1°

DRAFTSMAN	*R. Bata*	6-15-71
CHECK		
DEV ENGR	*R. Mellen*	6-14-71
PROJ ENGR		
RELIABILITY		

SUPSD
FINISH — SEE NOTE
MATERIAL

CONTRACT NO. NAS8-26312
DCN1-1-80-00036

INERTIAL COMPONENTS

HONEYWELL INC. AEROSPACE AND DEFENSE GROUP
■ AERO MPLS □ AERO ST PETERSBURG □ ORD SEATTLE □ ORD HOPKINS □ ORD MONTGOMERYVILLE □ S&R CTR MPLS □ RADIATION CTR BOSTON

CERAMIC ENVELOPE AND GYRO SHIELD ASSY - CESG

SIZE	CODE IDENT NO.	DRAWING NO.
C	94580	10037521

SCALE NONE | WT | SHEET

NEXT ASSY	USED ON
APPLICATION	

Figure 20. Tube Installation Drawing

FOLDOUT FRAME

FOLDOUT FRAME

FOLDOUT FRAME 2

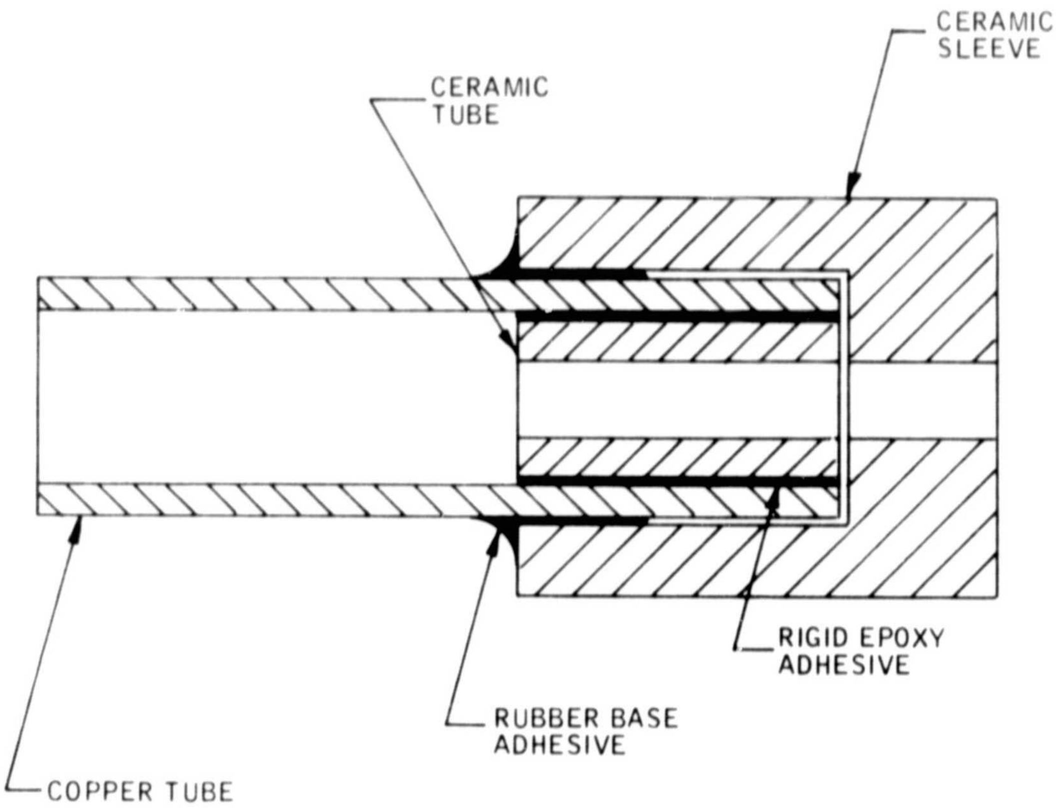


Figure 21. Copper Pipe-to-Sample Port Joint Design

The copper pipes were also tested for compatibility with the Davidson gyro shield by assembling the envelope and pipes into a mockup of the Davidson shield as shown in Figures 25 and 26. All clearances were adjudged to be adequate.

The completed copper pipes were shipped to Marshall Space Flight Center on 15 June 1971.

Figure 22. Copper Pipes with Sample "Ports" for Joint Integrity Testing

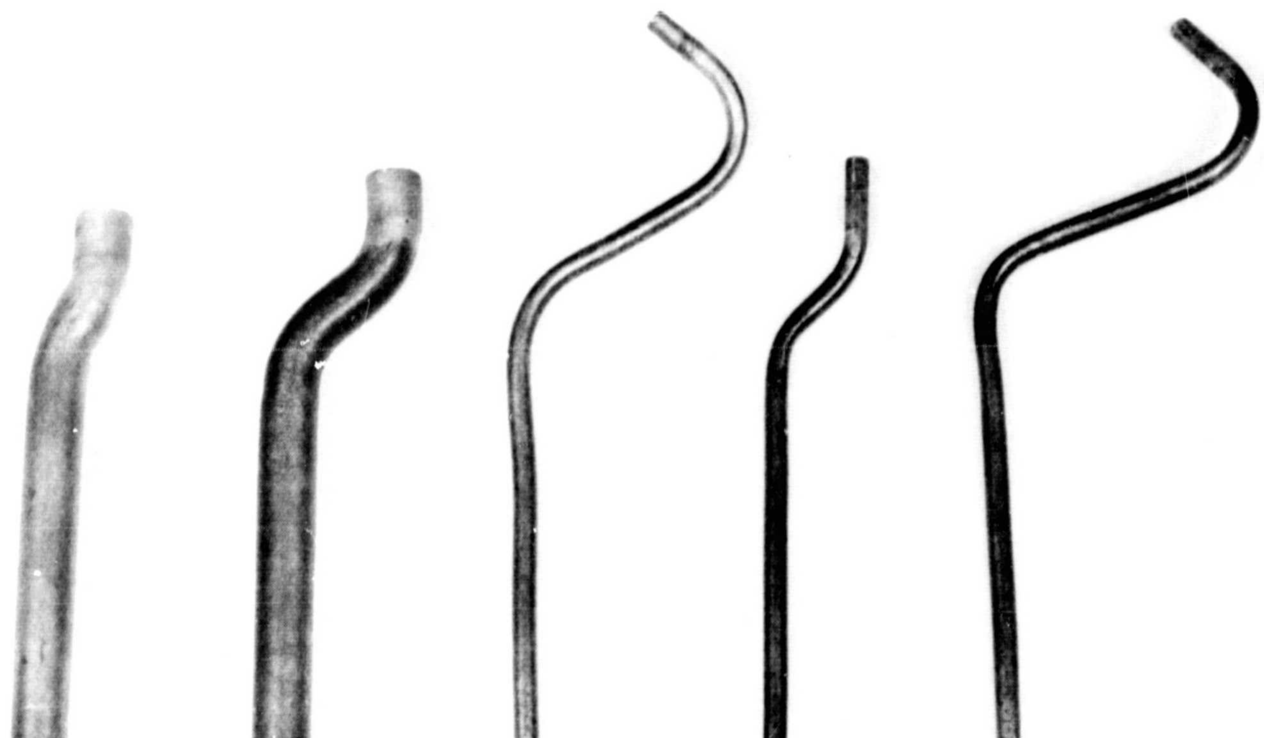


Figure 23. Copper Pipes After Removal of the Test Ports

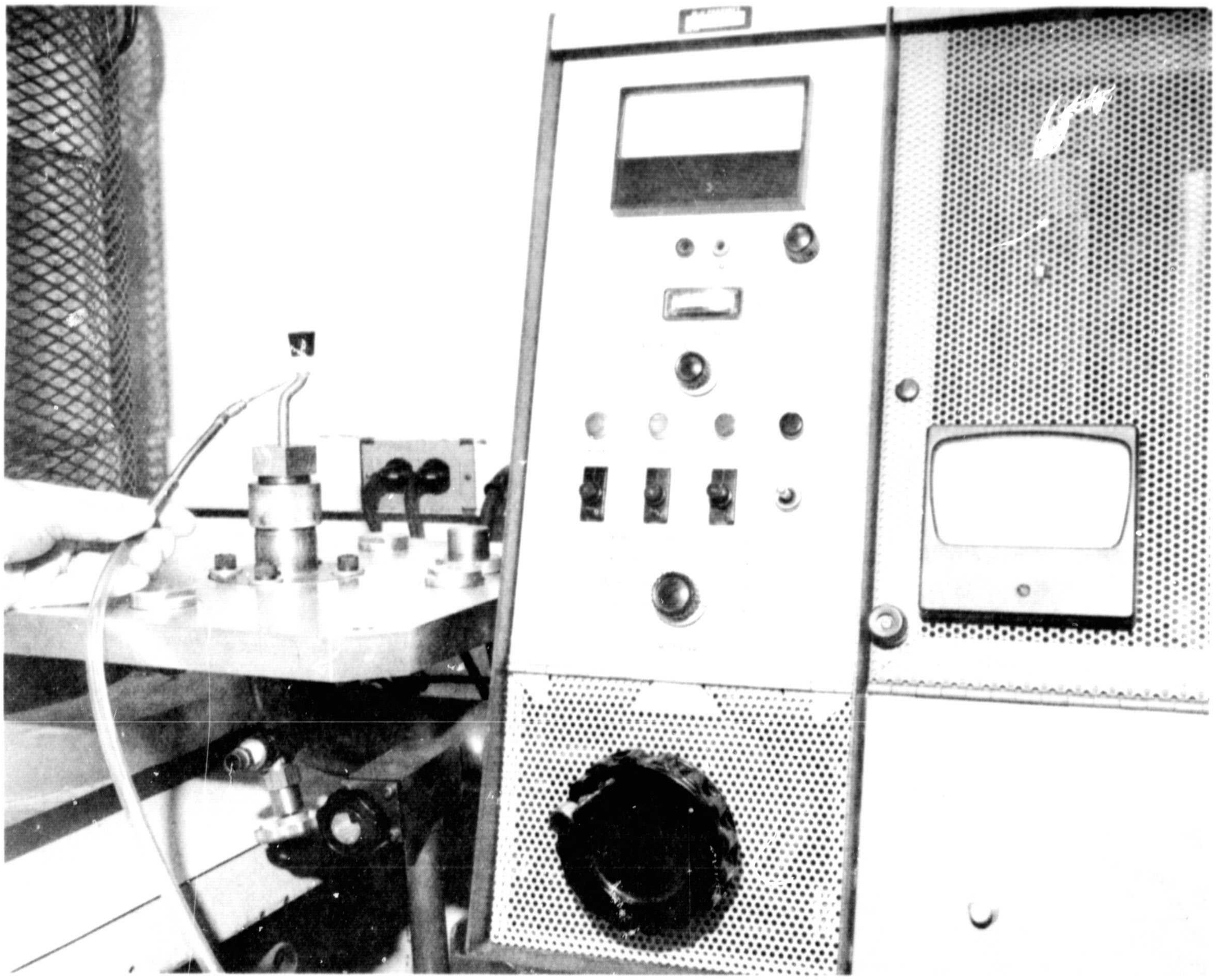


Figure 24. Leak Checking of a Copper Pipe-to-Sample "Port" Joint

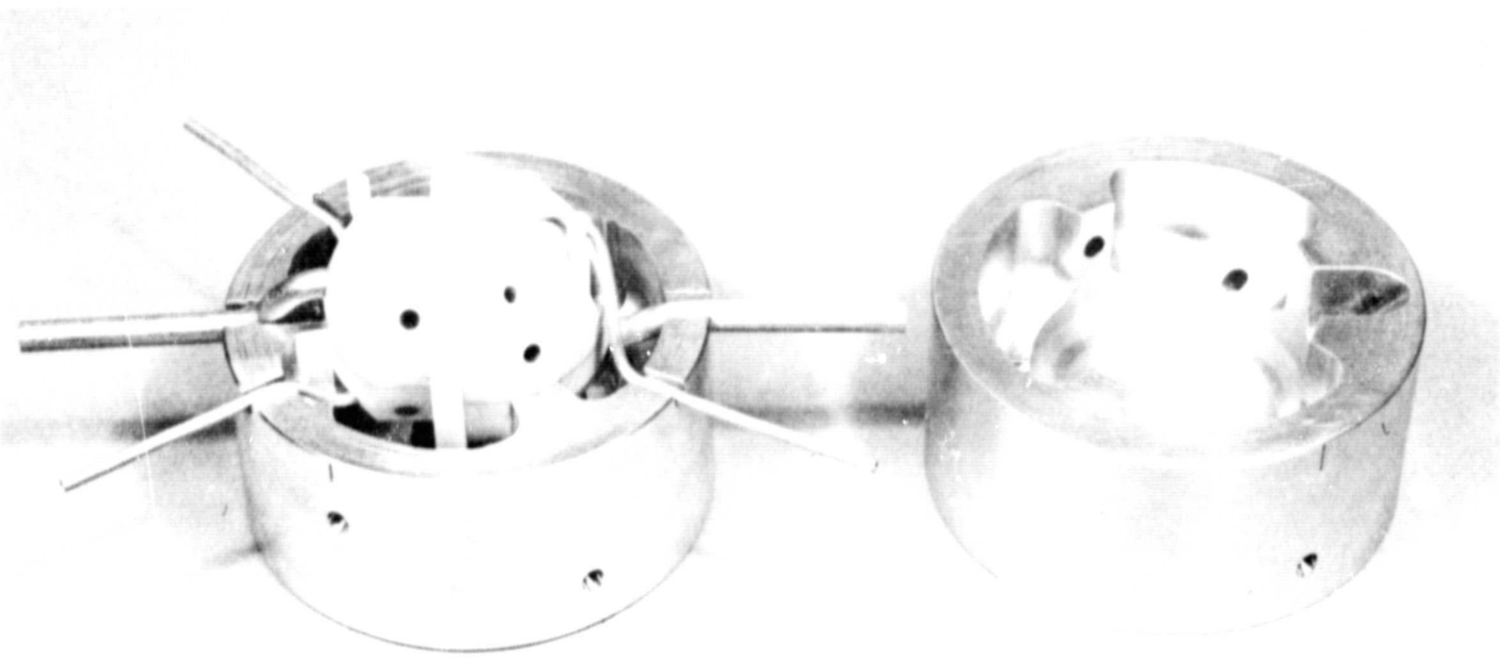


Figure 25. Ceramic Envelope in Gyro Shield Mockup with Copper Pipes Installed

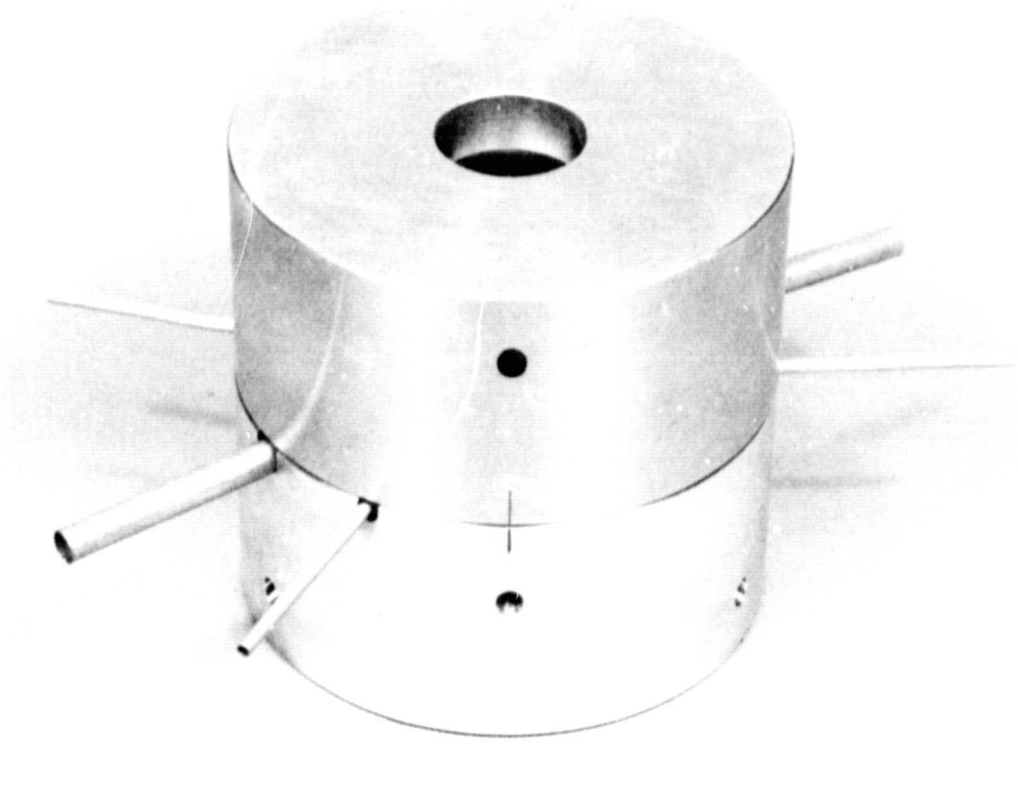


Figure 26. Mockup of Davidson Gyro Shield with Ceramic Envelope and Copper Pipes Installed

SECTION IV
EXPERIMENTAL QUARTZ SPUTTERING

The objective of this effort was to investigate the feasibility of sputtering quartz onto the interior surfaces of the quartz CESG envelope in sufficient thickness and of suitable quality for use as material for the gas restriction lands of the "final design" quartz CESG envelopes. The goal for this program was a homogeneous deposit, approximately 0.003-inch thick, with adequate adhesion to withstand stresses resulting from machining and exposure to cryogenic temperatures without measurable dimensional changes.

For this experimental task, a sample envelope half was fabricated by Honeywell and a subcontract order was placed with Modern Controls Inc., Minneapolis, Minnesota, for RF sputtering services.

A test envelope half and several flat disks were coated with quartz by RF sputtering. After 115 hours of sputtering, the coating thickness in the test envelope cavity measured 0.0004 to 0.0006 inch thickness, as compared with the previously established goal of 0.003 inch. The deposit on the flat disks was of nonuniform thickness, varying from 0.0005 inch to 0.0021 inch, and was quite porous. Figures 27 and 28 are photographs showing the general quality of the sputtered surfaces. Figure 27 is representative of the most porous areas, while Figure 28 is typical of the least porous areas.

The machinability of the sputtered deposit on one flat disk was evaluated by grinding a simulated rotor spinup gas restriction land and grooves. As can be seen in Figure 29, the sputtered coating appeared to be extremely fragile and prone to chipping.

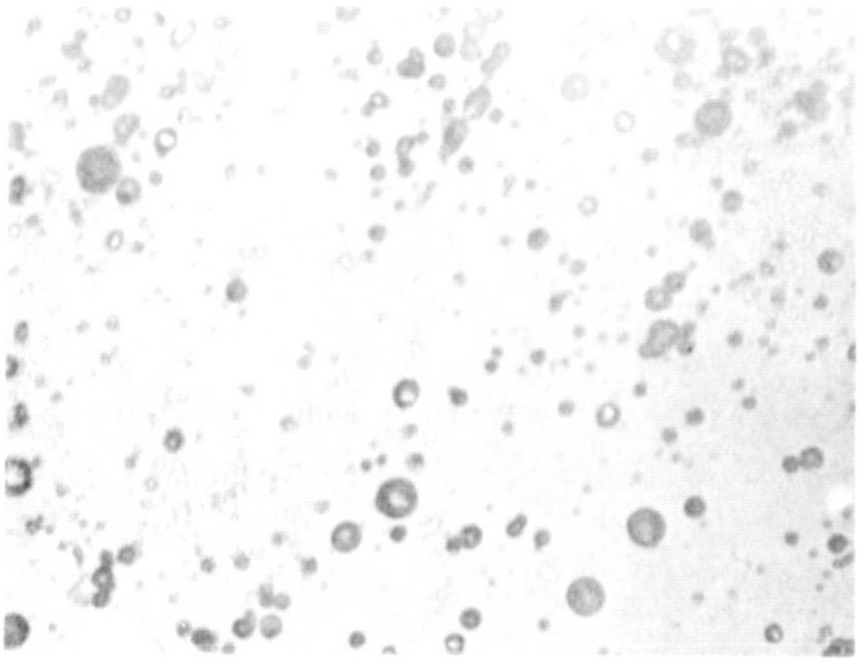


Figure 27 Photograph (80X) Showing Sputtered Quartz Film Typical of Areas of Greatest Porosity

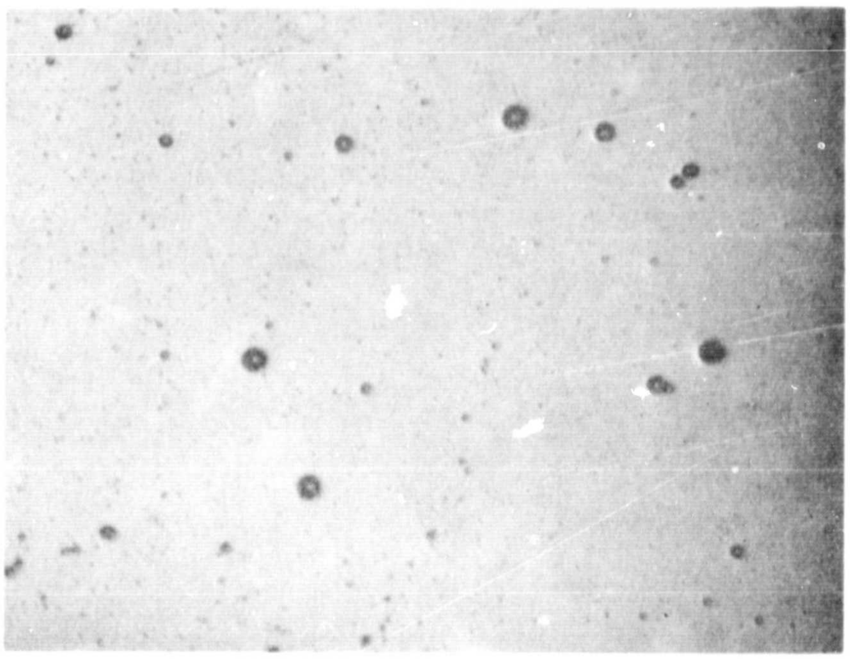


Figure 28 Photograph (80X) Showing Sputtered Quartz Film Typical of Areas of Minimum Porosity

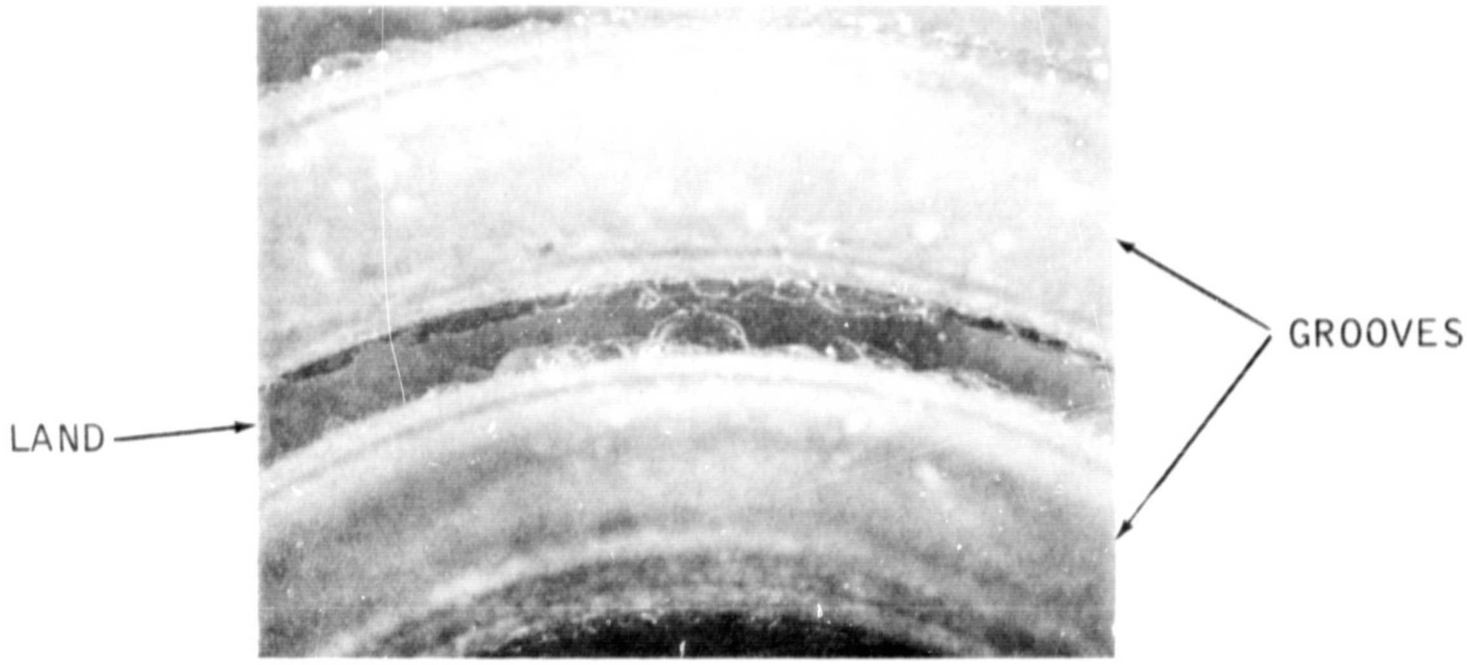


Figure 29. Photograph (10X) Showing Sputtered Quartz Test Sample With Simulated Rotor Spinup Gas Restriction Land and Grooves

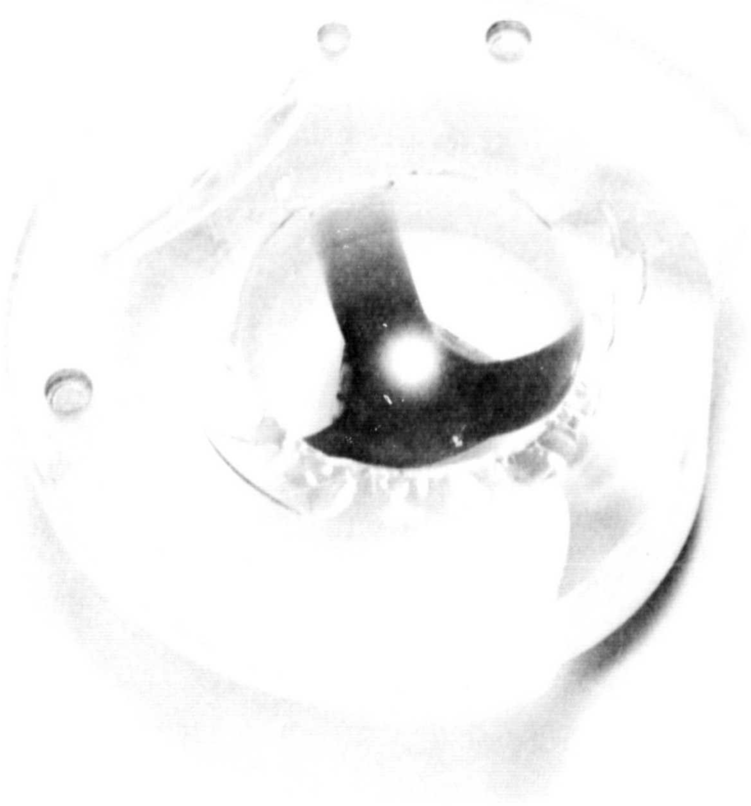


Figure 30. Quartz Test Envelope After Sputtering Test

Figure 30 is a photograph of the test envelope after sputtering. As can be seen, the sputtered quartz deposit in the test envelope cavity was discolored, probably from polymerization of epoxy materials present on the aluminum mask which was used to limit the sputtered film to the gas restriction areas. Also, considerable chipping of the test envelope resulted from interference between the aluminum mask and quartz envelope due to thermal expansion of the mask. Temperature monitoring facilities were not available in the sputtering chamber which was used; however, this mask had previously been used for d-c sputtering in quartz parts with no problems. Therefore, it can be assumed that the mask temperature exceeded 300°F, which had previously been measured in the d-c sputtering chamber.

Figure 31 is a roundness chart showing thickness and uniformity of the sputtered quartz deposit at three different latitudes of the test envelope.

The problems of discoloration and quartz chipping are not considered serious, as they could be resolved by fabrication of a new epoxy-free mask of a low expansion metal, such as Ni 36, a nickel iron alloy. The low sputtering rate and nonuniform thickness are, however, problems that make the sputtered quartz concept unusable for this application without further development which would be beyond the scope of this contract. Therefore, no further quartz sputtering work was done for this application.

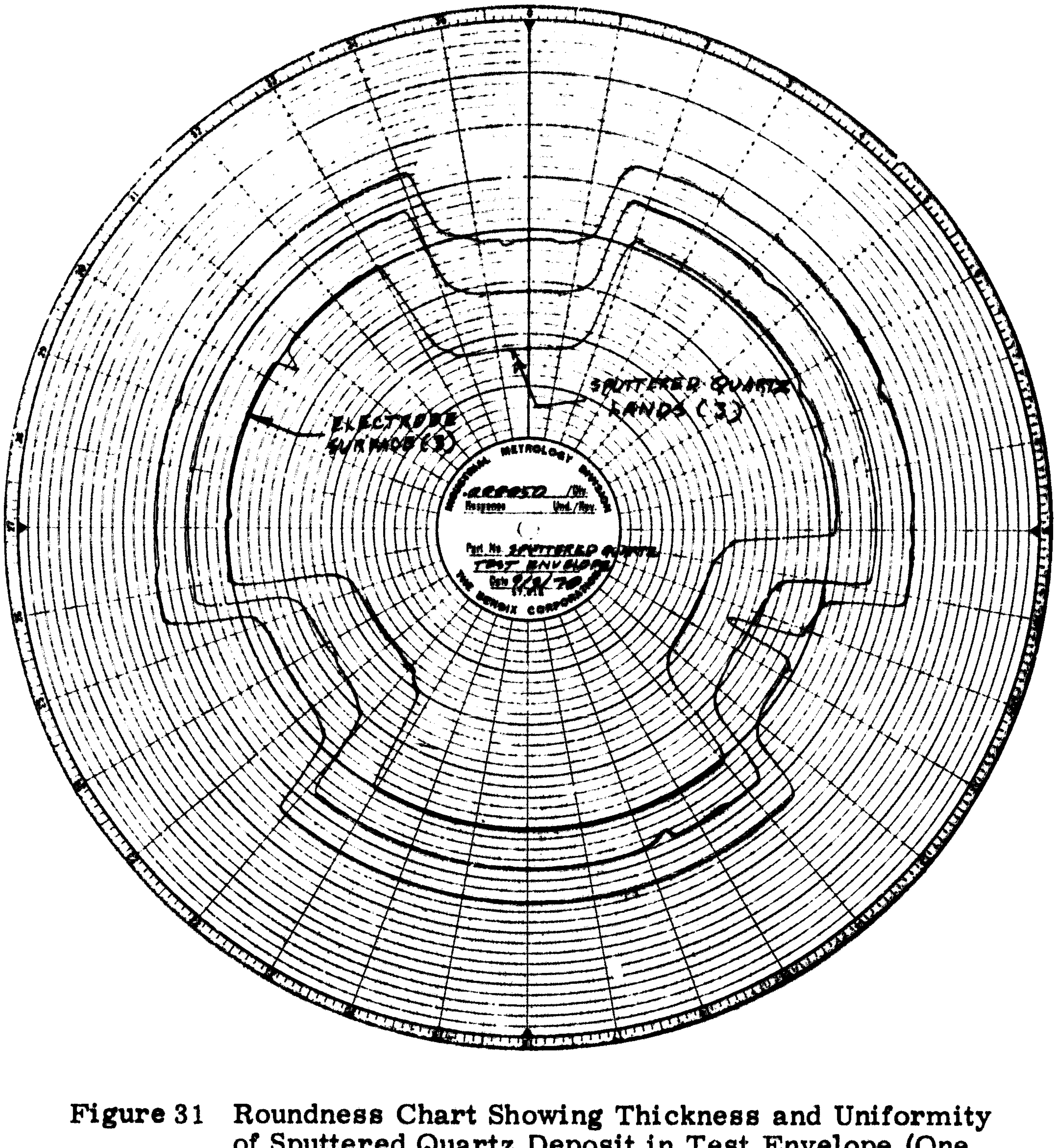
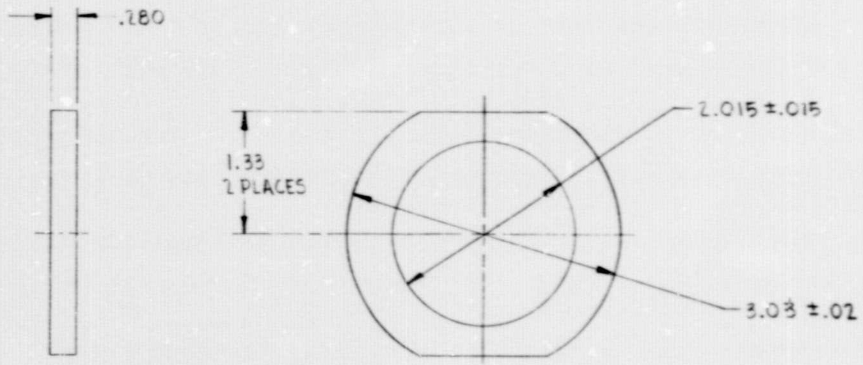


Figure 31   Roundness Chart Showing Thickness and Uniformity of Sputtered Quartz Deposit in Test Envelope (One Chart Division Equals 50 Microinches)

APPENDIX A
ENVELOPE MACHINING DRAWINGS

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
			7-30-70	
	2	2.015 ±.015 WAS 2.02" 3.03 ±.02 WAS 3.01; NOTE 1 WAS "MATL SPEC 7528 CERAMIC"	8-25-70	



3 - ALL EDGES .015 MAX RAD
UNLESS NOTED OTHERWISE

2 - NO CRACKS PERMISSIBLE BY STATIFLUX AND MICROSCOPE (10X-30X MAGNIFICATION) INSPECTION

1 - MAT'L ALUMINA CERAMIC (WESCO AL 300 OR EQUIVALENT)

1-69 V900 VELLUM

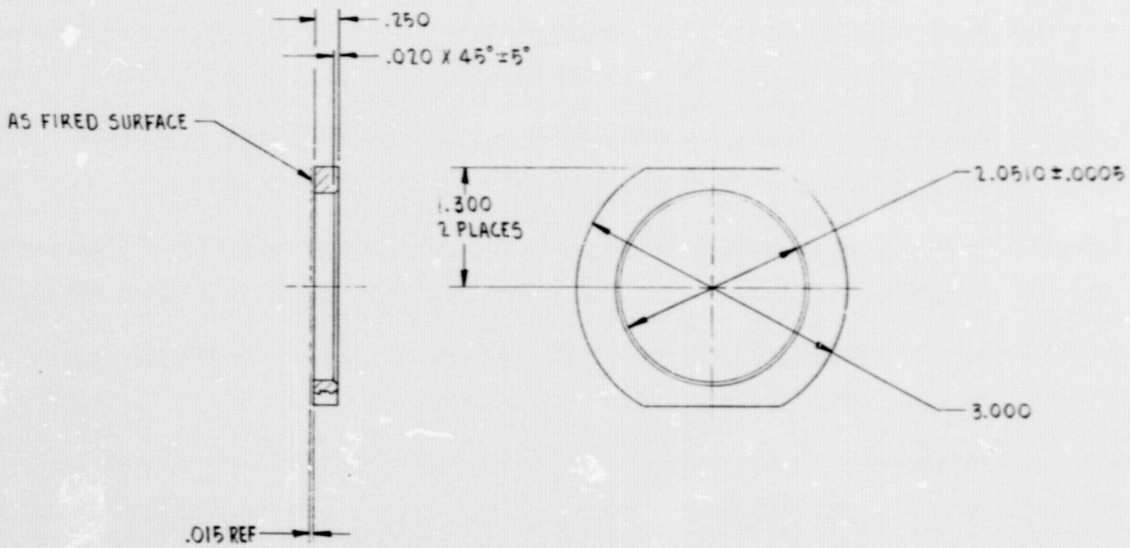
10034701	
NEXT ASSY	USED ON
APPLICATION	

TOLERANCES UNLESS NOTED OTHERWISE		DRAFTSMAN	[illegible]	7-30-70
.X ±	90° FORMED ANGLES +2° −1°	CHECK		
.XX ±.01		MATL & FINISH		
.XXX ±.008		APPL ENGR		
DEV 21600-30		DEV ENGR		
SUPSD		PROJ ENGR		
FINISH — SEE NOTE		PROD ENGR		
MATERIAL 1		RELIABILITY		
		INERTIAL COMPONENTS		

HONEYWELL INC. AEROSPACE AND DEFENSE GROUP
■ AERO MPLS □ AERO ST PETERSBURG □ ORD SEATTLE □ ORD HOPKINS
□ ORD MONTGOMERYVILLE □ S&R CTR MPLS □ RADIATION CTR BOSTON

RING, ENVELOPE —
AS FIRED

SIZE	CODE IDENT NO.	DRAWING NO.
C	94580	10034700
SCALE 1/1	WT	SHEET



2 - ALL EDGES .015 MAX RAD
UNLESS NOTED OTHERWISE

1 - NO CRACKS PERMISSIBLE BY STATIFLUX AND MICROSCOPE (10X-50X MAGNIFICATION) INSPECTION

NEXT ASSY	10034704
USED ON	
APPLICATION	

TOLERANCES UNLESS NOTED OTHERWISE	.X ± ; .XX ± ; .XXX ±.005 ; 90° FORMED ANGLES +2° −1°
DEV	21600-30
SUPSD	
FINISH — SEE NOTE	
MATERIAL	10034700-101

DRAFTSMAN	[illegible]	7-30-70
CHECK		
MATL & FINISH		
APPL ENGR		
DEV ENGR		
PROJ ENGR		
PROD ENGR		
RELIABILITY		

INERTIAL COMPONENTS

HONEYWELL INC. AEROSPACE AND DEFENSE GROUP
■ AERO MPLS □ AERO ST PETERSBURG □ ORD SEATTLE □ ORD HOPKINS □ ORD MONTGOMERYVILLE □ SAR CTR MPLS □ RADIATION CTR BOSTON

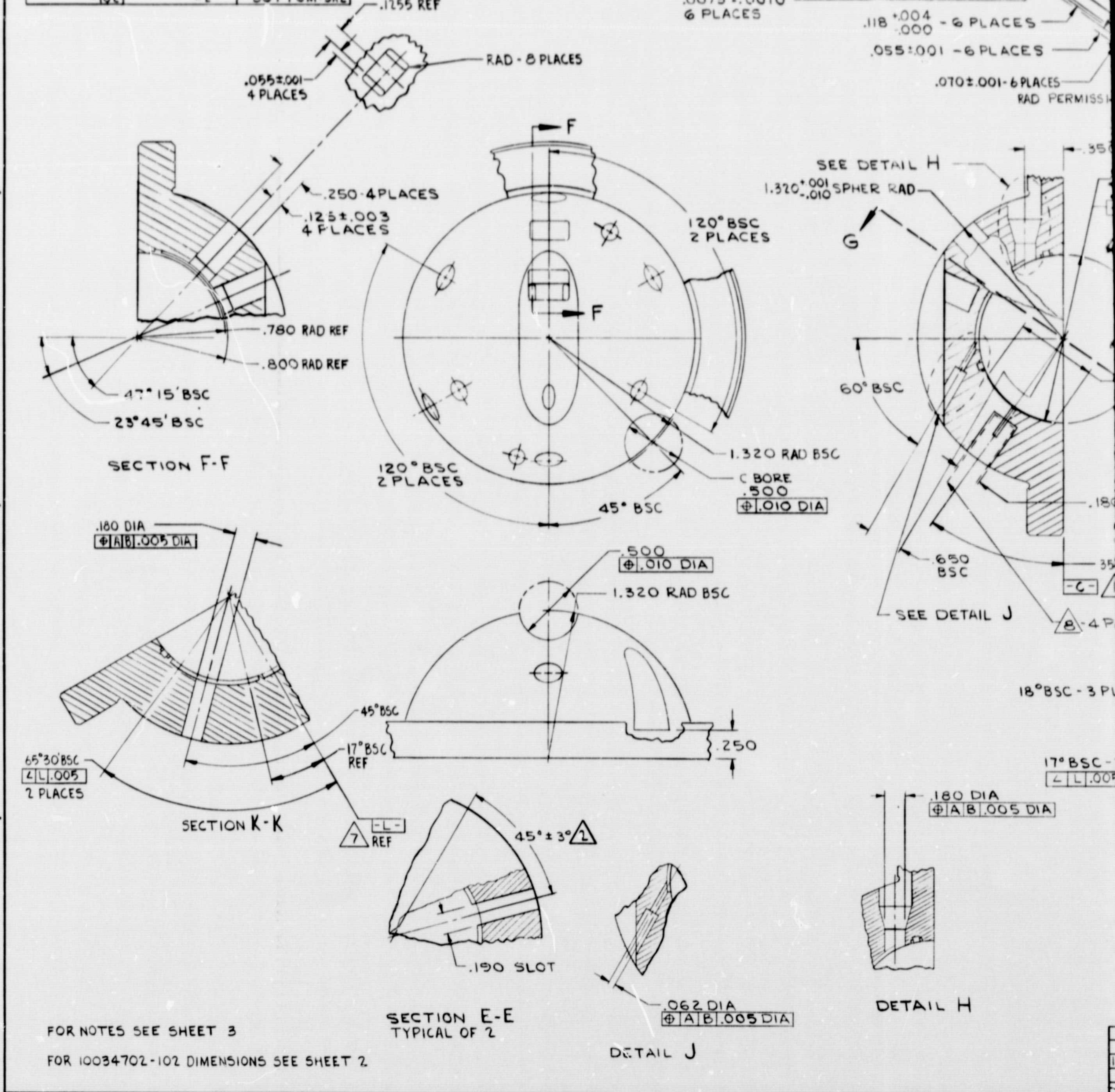
RING, ENVELOPE —
MACHINING

SIZE	CODE IDENT NO.	DRAWING NO.
C	94580	10034701

SCALE 1/1 WT SHEET

8 11-69 V000 VELLUM

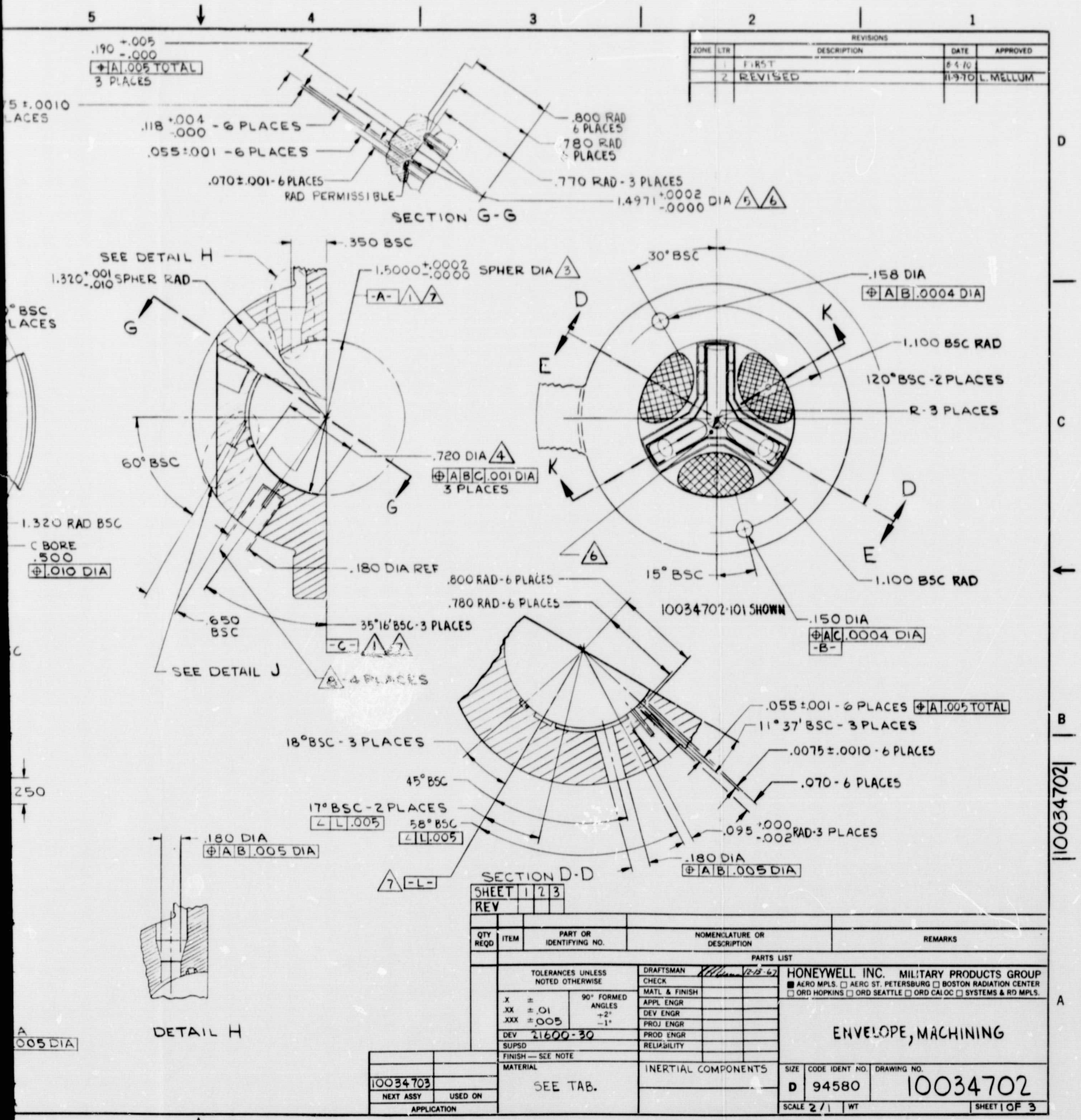
HONEYWELL PART NO	MATERIAL	ENVELOPE HALF
10034702-101	SK103117-1	TOP-SH1
-102	-2	BOTTOM-SH2



FOR NOTES SEE SHEET 3

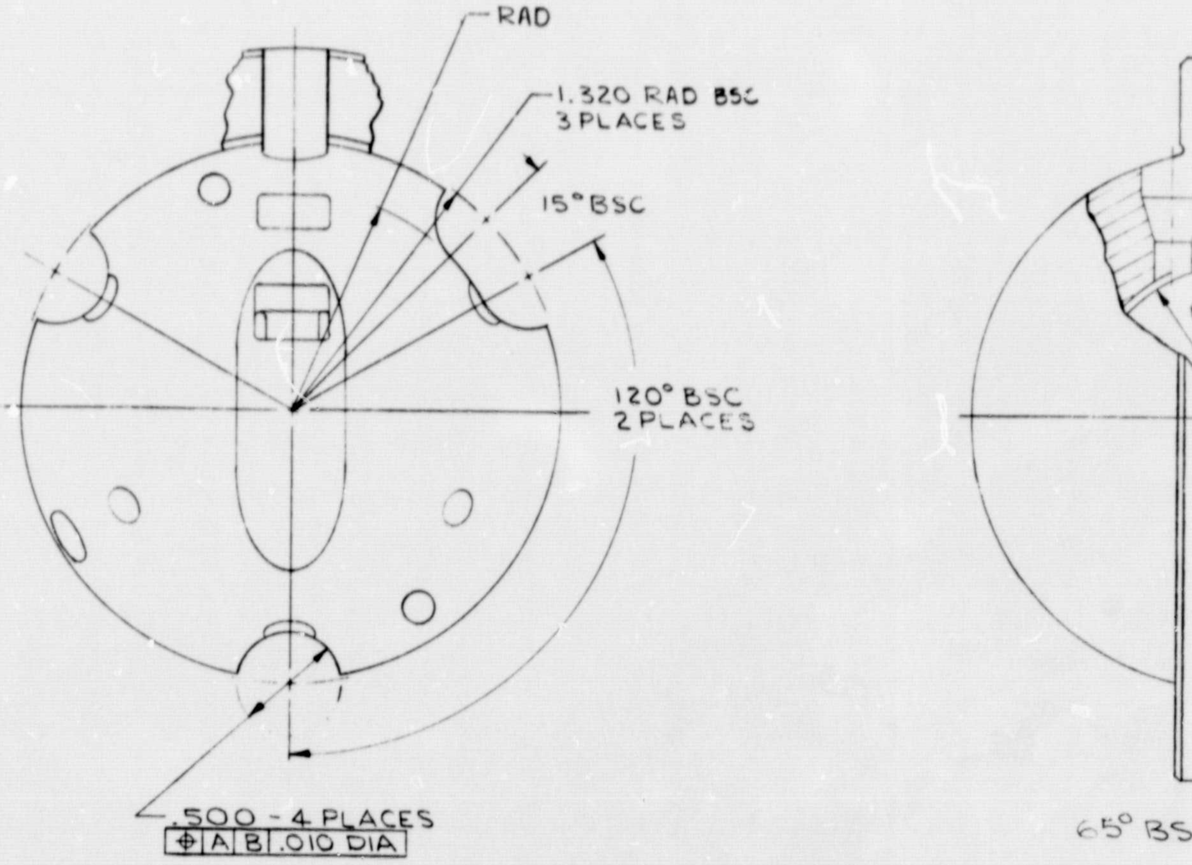
FOR 10034702-102 DIMENSIONS SEE SHEET 2

FOLDOUT FRAME 1



FOLDOUT FRAME 2

HONEYWELL PART NO.



1 - CENTER OF DATUM A TO BE IN THE PLANE OF DATUM C WITHIN .000050

2 - ANGULAR TOLERANCE APPLIES TO SLOT

3 - SPHERICAL WITHIN .000020 TIR

4 - DEPOSITED WITH TITANIUM-GOLD 5000 ANGSTROMS THICK

5 - DIMENSION APPLIES AFTER NOTE 6 ON GAS RESTRICTION LANDS

6 - GAS RESTRICTION LAND MATERIALS; ELECTRO-DEPOSTIED COPPER OVER SPUTTERED TITANIUM-COPPER METALLIZE FILM

7 - DATUM L IS DEFINED AS A LINE PASSING THRU THE ACTUAL CENTER OF DATUM A AND BASICALLY PERPENDICULAR TO DATUM C

8 - APPLY SILVER FILLED EPOXY (EPO-TEK 410)

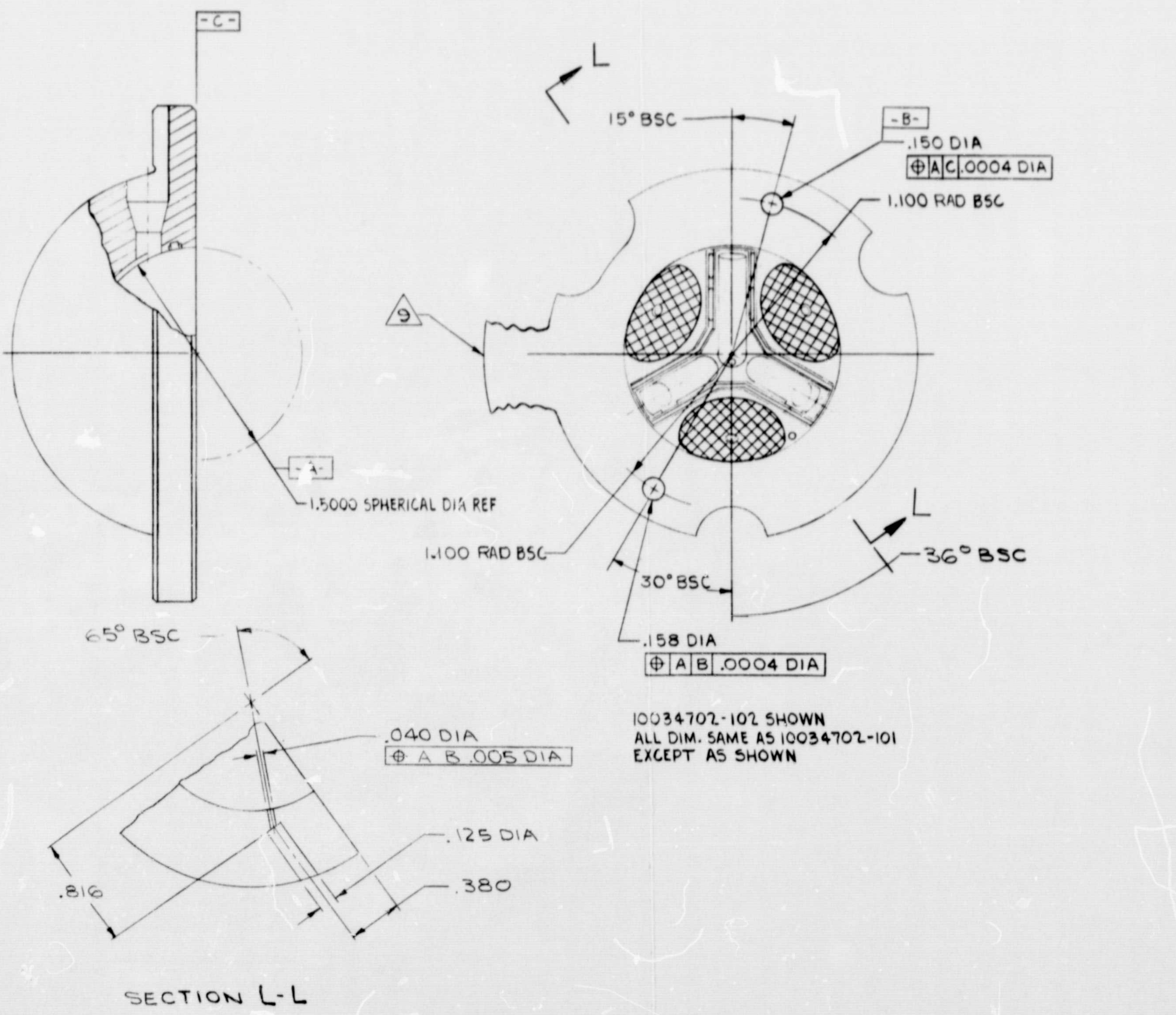
9 - FLANGE FOR TOOLING PURPOSES ONLY

FOLDOUT FRAME 1

INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-1000, FORM 3

DIMENSIONING AND TOLERANCING PER MIL-STD-8

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	FIRST	8-5-70	
	2	REVISED	11-3-70	L. MELLUM
	3	ADD SEC L-L	12-14-70	L. MELLUM



10034702-102 SHOWN
ALL DIM. SAME AS 10034702-101
EXCEPT AS SHOWN

10034702

QTY REQD	ITEM	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS
PARTS LIST				

TOLERANCES UNLESS NOTED OTHERWISE	.X ± ; .XX ±.01 ; .XXX ±.005 ; 90° FORMED ANGLES +2° −1°
DEV	21600-30
SUPSD	
FINISH — SEE NOTE	
MATERIAL	SEE TAB. SHEET 1
DRAFTSMAN / CHECK / MATL & FINISH / APPL ENGR / DEV ENGR / PROJ ENGR / PROD ENGR / RELIABILITY	SEE SH 1
NEXT ASSY	10034703
USED ON	
APPLICATION	

HONEYWELL INC. AEROSPACE AND DEFENSE GROUP
■ AERO MPLS. □ AERO ST. PETERSBURG □ BOSTON RADIATION CENTER □ ORD HOPKINS □ ORD SEATTLE □ ORD CALOC □ SYSTEMS & RD MPLS.

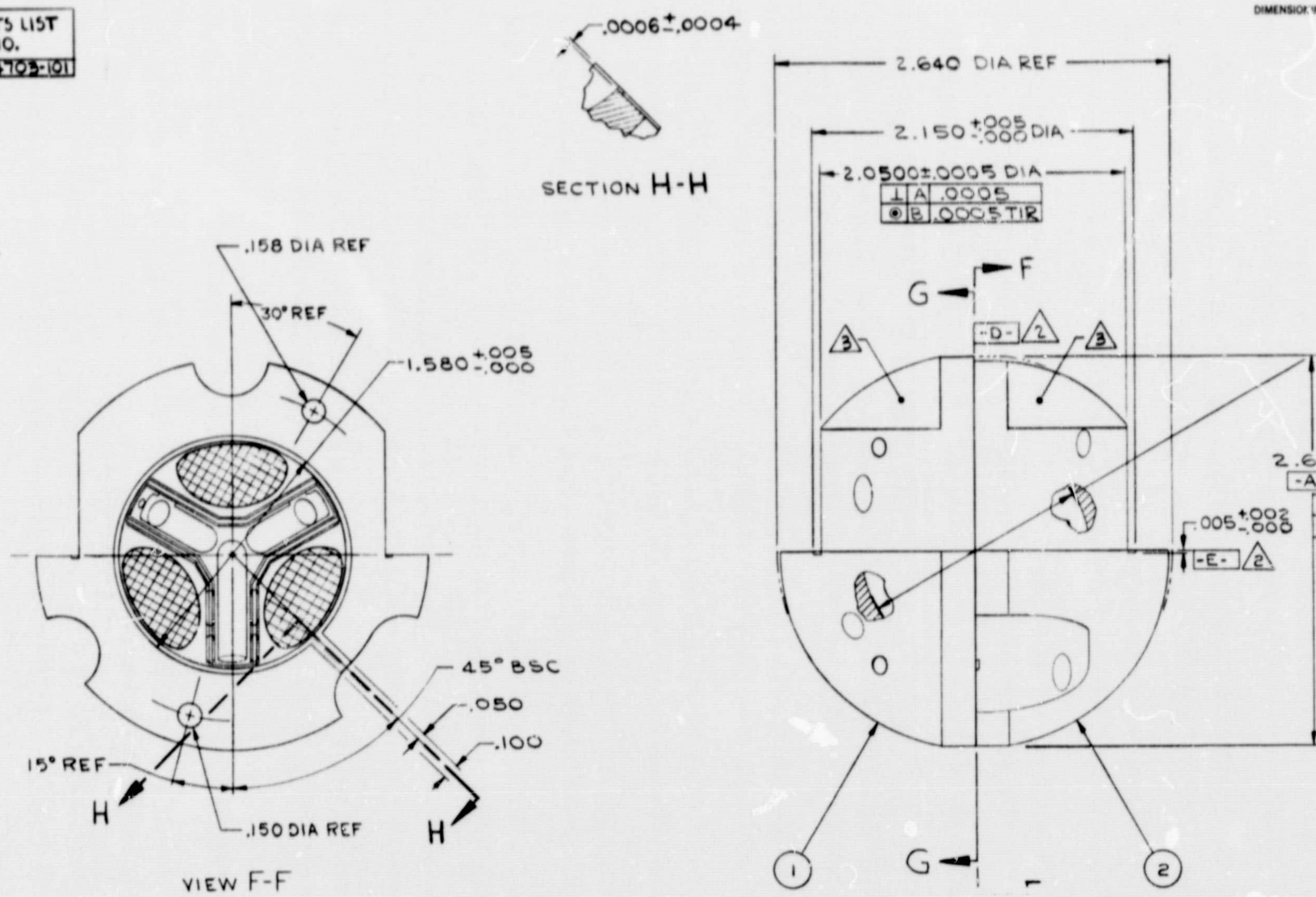
ENVELOPE, MACHINING

INERTIAL COMPONENTS

SIZE	CODE IDENT NO.	DRAWING NO.
D	94580	10034702
SCALE 2/1	WT	SHEET 2

FOLDOUT FRAME 2

HONEYWELL PART NO.	PARTS LIST NO.
10034703-101	PL10034703-101



PRELIMINARY PARTS LIST MPG-4007A — HONEYWELL INC. AEROSPACE AND DEFENSE GROUP, AEROSPACE DIVISION, MINNEAPOLIS

PPL 10034703-101 — ITEM CODE A — ISSUE NO. 01

LIST TITLE — TRANS CODE A — APPROVAL: PROJ ENGR, DSGN ENGR — DATE — PAGE

FIND NO.	QTY REQD	CODE IDENT	PART NUMBER	DESCRIPTION	REMARKS

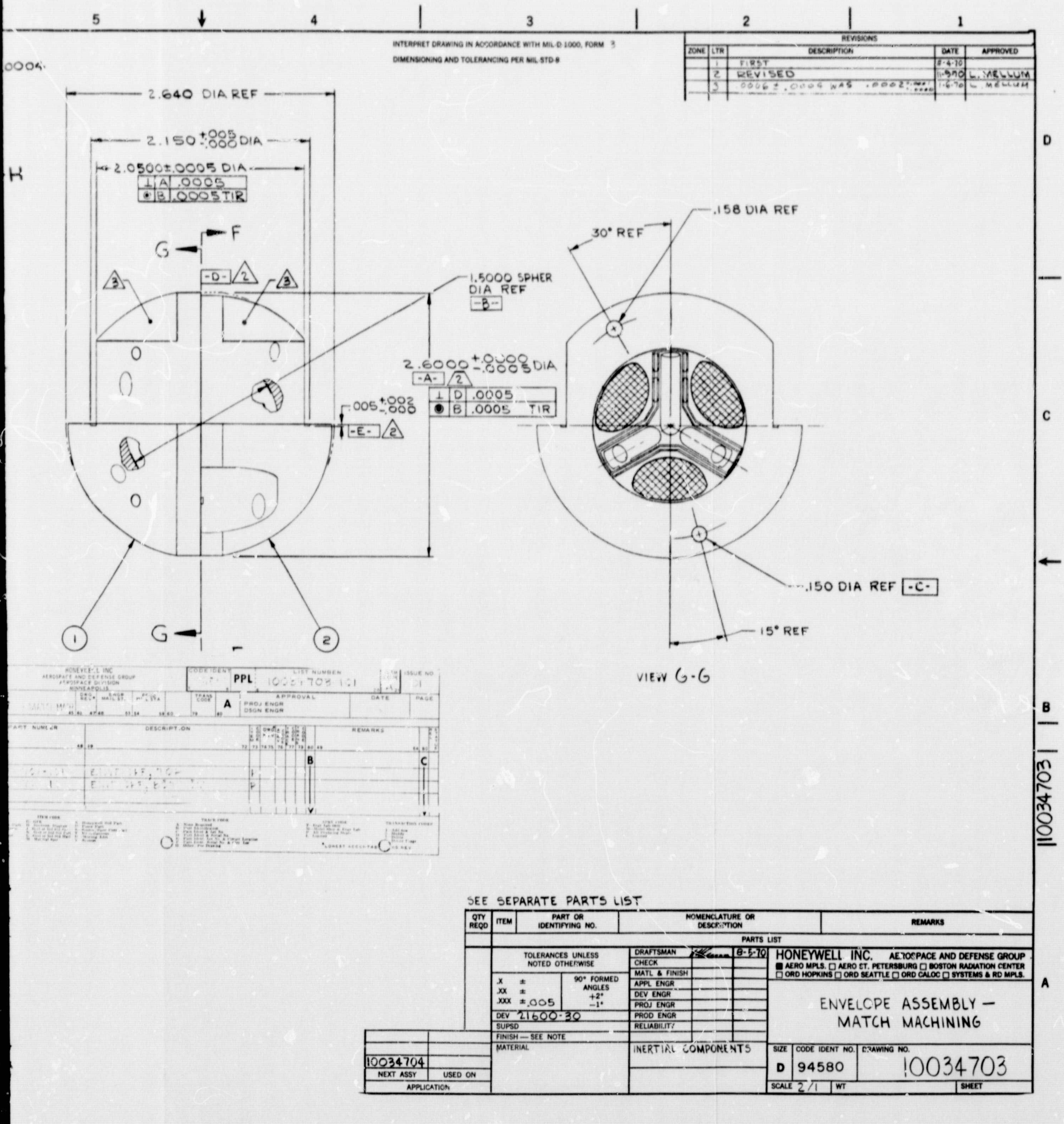
3 - GRIT BLAST IDENTIFICATION MARK THIS AREA

2 - PLANE OF DATUM E TO BE PERPENDICULAR TO DATUM D AND THRU THE CENTER OF DATUM A WITH IN .001

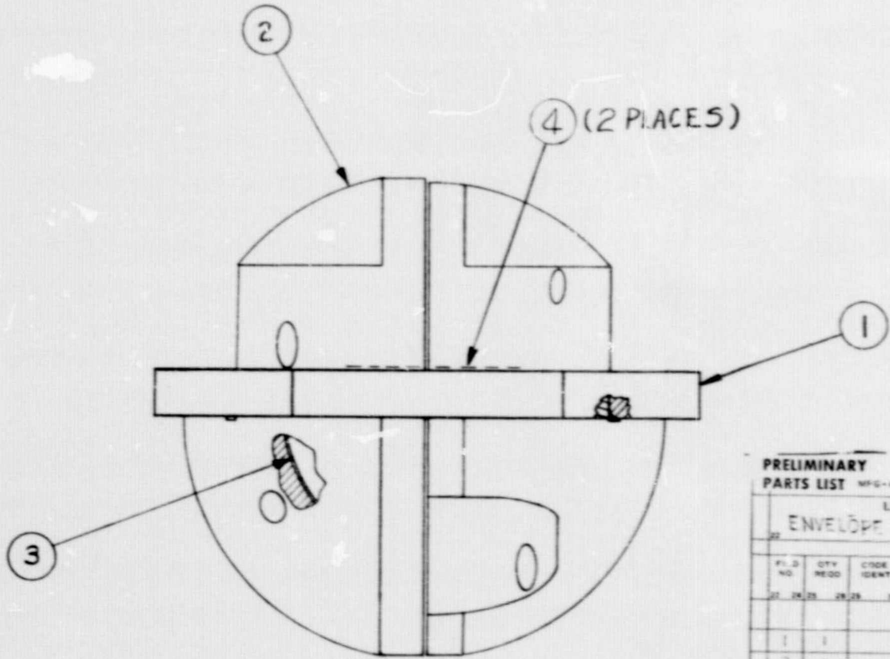
1 - THESE PARTS COMPRISE A MATCHED SET AND SHALL BE INDIVIDUALLY IDENTIFIED WITH IDENTICAL IDENTIFICATION MARKS. EACH MATCHED PAIR SHALL CARRY A DIFFERENT IDENTIFICATION MARK

10034704	
NEXT ASSY	
	APPLICATION

FOLDOUT FRAME 1



FOLDOUT FRAME 2



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	FIRST	8-5-70	
	2	ADD ITEM 4	3-18-70	LCH

PRELIMINARY PARTS LIST MFG-4002A

HONEYWELL INC
AEROSPACE AND DEFENSE GROUP
AEROSPACE DIVISION
MINNEAPOLIS

CODE IDENT 94580 PPL LIST NUMBER 10034704-101

LIST TITLE: ENVELOPE ASSY, ESG

TRANS CODE A

APPROVAL: PROJ ENGR, DSGN ENGR

FIND NO.	QTY REQD	CODE IDENT	PART NUMBER	DESCRIPTION		REMARKS
1	1		10034701-101	RING, ENVELOPE	P	B
2	1		10034703-101	ENVELOPE ASSY	A	
3	1		F9708-0-1	ROTOR	P	
3	ALT		10035016-101	RØTOR	P	
4	AR		MC6263	ADHESIVE	P	C

SEE SEPARATE PARTS LIST

QTY REQD	ITEM	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REMARKS

PARTS LIST

TOLERANCES UNLESS NOTED OTHERWISE		DRAFTSMAN [signature] 8-5-70	HONEYWELL INC. MILITARY PRODUCTS GROUP ■ AERO MPLS. □ AERO ST. PETERSBURG □ BOSTON RADIATION CENTER □ ORD HOPKINS □ ORD SEATTLE □ ORD CALOC □ SYSTEMS & RD MPLS.
.X ± .XX ± .XXX ±	90° FORMED ANGLES +2° −1°	CHECK MATL & FINISH APPL ENGR DEV ENGR PROJ ENGR PROD ENGR RELIABILITY	ENVELOPE ASSEMBLY, CRYOGENIC ESG
DEV 21600-30 SUPSD FINISH - SEE NOTE			
GOVT MATL SPEC		INERTIAL COMPONENTS	SIZE C · CODE IDENT NO. 94580 · DRAWING NO. 10034704
REF MATL (SPEC)			SCALE 2/1 · WT · SHEET

NEXT ASSY	USED ON
APPLICATION	

A

1 - MARKING REQ - NONE