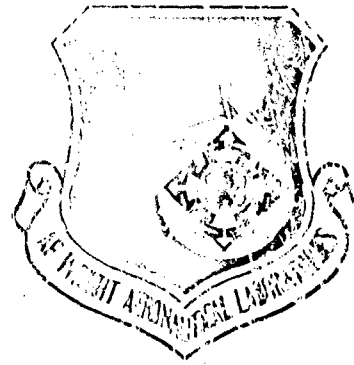


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AFWAL-TR-82-2049

ADVANCED HIGH-POWER GENERATOR FOR AIRBORNE APPLICATIONS

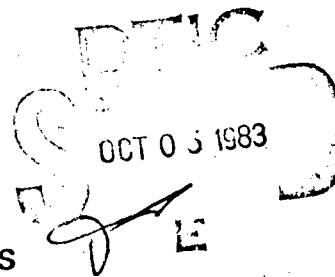
AiResearch Manufacturing Company
A Division of The Garrett Corporation
2525 West 190th Street
Torrance, California 90509



June 1983

Interim Report for Period March 1981 - February 1982

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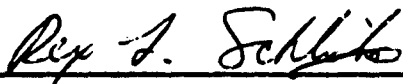
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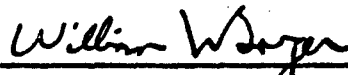
This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.



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FOR THE COMMANDER



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the work accomplished through Phase II of a four-phase program to design and build the stator and housing for a 5-Mw generator and test the complete 5-Mw generator. The PM rotor for this stator and housing is being built under a separate AF companion contract. This work is part of an Air Force exploratory program for high-power airborne electrical power supply technology. Phases I and II encompassed a 10-month period from April 1981 to January 1982.		

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In Phase I, a lightweight, high-power density stator/housing was designed and optimized with computer model BIGMAG for integration with a permanent magnet rotor into a 5-Mw alternator with a specific weight of 0.1 lb/kw or less.

Components with potential for significant weight reduction were identified for testing in Phase II. Among these critical components are a novel liquid-cooling scheme for the stator and an elastomer bore seal. Fabrication drawings were prepared for all individual parts of the stator and housing along with a detailed fabrication plan. A plan for testing the complete 5-Mw generator under full-load conditions at the AF Compressor Research Facility also was prepared. Fabrication and testing will be done in Phases III and IV, respectively.

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1. INTRODUCTION

This report describes work performed during Phase II of the stator/housing program for a 5-Mw permanent magnet generator currently being built under the Advanced High Power Generator Program, Contract F33615-80-C-2075, sponsored by the Powers System Branch, Aerospace Power Division, of the Aeropropulsion Laboratory at Wright-Patterson Air Force Base.

At Wright Patterson, the program is under the technical direction of Paul R. Bertheaud, and Capt. Rex Schlicher. At AiResearch, Fred B. McCarty is principal investigator, Frank E. Echolds is project engineer, and Andrew R. Druzsba is program manager.

As specified in Air Force CDRL 4, the report contains results of the critical component tests, a review of the design leading to a fabrication plan and long lead hardware definition, a no load test plan and a load test plan. All items presented require Air Force approval except the load test plan which was approved during a previous submittal.

2. CRITICAL COMPONENT TESTS

Critical component tests of the stator housing include the following:

Bore seal

Adhesives

Hairpin winding fabrication

Conductor impregnation and leach-out test

Conductor terminal fabrication

Conductor flow tests

2.1 VITON RUBBER BORE SEAL

A Viton rubber bore seal is used to exclude stator cooling fluid from the rotor cavity. It was estimated during the early part of the rotor program (F33615-76-C-2168) that a conventional type seal made of aluminum oxide would be 2 to 3 times as thick as the 0.020 thick Viton rubber bore seal that has been designed for use on the 5 MW alternator. A thin bore seal is highly desirable because it allows the air gap between rotor and stator to be as small as possible, thereby improving machine performance.

The Viton rubber bore seal is fabricated by repeatedly dipping a cylindrical tool into a container of liquid Viton. The result of this process is shown in Figure 2-1. After the Viton has air dried, air pressure is applied to the inside of the tool, forcing the cured Viton away from the tool surface as shown in Figure 2-2. The bore seal is then ready to be coated with adhesive and installed in the stator bore. Air pressure is applied to force the seal against the stator bore until the adhesive dries.

The fabrication details of the full size bore seal are shown on Drawing 500421. Final installation of the seal into the stator housing is described in Drawing 500400.

This concept is considered to be developed well enough to be included in the final design without further component testing beyond what was done in the rotor program critical component phase and described in technical report AFWAL-TR-80-2130.

2.2 ADHESIVES

A number of different adhesives are used in the stator/housing that come

TABLE 2-1

ADHESIVE COMPATIBILITY TEST RESULTS

	<u>Bonded Materials</u>	<u>Adhesive</u>	<u>Application</u>
1.	Nomex - Nomex	PLV 2000	Matrix conductor insulator
2.	Silicon steel - silicon steel	Cycleweld	Stator stack
3.	Viton rubber - G10 epoxy glass	PLV 2000	Bore seal end support

Test Exposures	Bonded Materials		
	1	2	3
Methylene chloride 4 hrs, rm. temp.	Disolved bond	No effect	No effect
Air (baseline) 96 hrs, 350°F	No effect	No effect	No effect
Coolanol 25 96 hrs, 350°F	No effect	No effect	No effect
DC 200 96 hrs, 350°F	No effect	No effect	No effect

PLV 2000 is a Viton rubber based adhesive

Cycleweld is a nitrile phenolic adhesive

into contact with potentially reactive fluids. Sample testing was done during Phase II to determine what reaction, if any, takes place between the important adhesives used in the stator and three different fluids. The results of this testing are shown in Table 2-1. All of the bonded materials retained their strength after being exposed to the various fluids at temperature with the exception of the Nomex-Nomex bonded with PLV2000. This bond was completely degraded when exposed to the methylene chloride at room temperature for 4 hours. The Nomex to Nomex bond is formed in the process of fabricating the matrix conductor insulating jacket. Three sides of the jacket are formed in the winding fixture, the wire strands are layed in place, and the jacket is closed by fo'lding over opposite sides of the Nomex and bonding with PLV2000. This bond is only required to hold until the conductors are inserted in the stator stack, after which they are held closed by the tightness of fit in the slot. Methylene chloride is flushed through the conductor to leach out the winding impregnant after this fit is accomplished.

2.3 HAIRPIN WINDING FABRICATION

The stator of the 5 MW generator incorporates hair pin windings, each terminating in specially designed terminals. The windings are formed from a multi strand conductor comprising 36 strands of #26 A.W.G. magnet wire bonded together with an adhesive and jacketed with Nomex insulation. After the hair pin is formed and the conductor is installed in the stator or the test fixture, the adhesive is leached out with methylene chloride.

Fabrication of the hair pin winding was a major portion of the Phase II development and testing effort. The winding was fabricated in the fixture shown in Drawing 500434. The fixture has the dimensions and special features to fabricate windings that will fit the final stator and the test fixture.

Before use of the final hairpin winding fixture, tests (experimental fabrication) were conducted on a prototype fixture to develop fabrication methods. Views of the conductor feeder used and the prototype winding fixture are shown in Figures 2-3 and 2-4. The prototype was used to fabricate the first hair pin conductors. In the fabrication, the 36-strand conductor was wrapped four-in-hand using adjustable tension blocks to assure equal tension in each strand, and a swivel guide was used to assure the proper sequencing and guiding of each strand. After measurement to verify proper dimensions the assembled conductor was sprayed and wiped to apply the adhesive (wiping produced the best results, and schemes to mechanize the procedure are being investigated).

The final hairpin winding fixture is shown in Figures 2-5 and 2-6. Figure 2-5 shows the winding fixture with the side plates attached, capturing a fully-bonded, 36-strand conductor impregnated with the stiffening cohesive agent VPE-5571, and Figure 2-6 shows the hairpin or knuckle end of the winding as wound and impregnated in the winding fixture.

Using the completed fixture, conductors were fabricated for the ensuing tests. Figures 2-7, 2-8, 2-9, 2-10 and 2-11 show the completed conductor. Figure 2-7 is an overall view of the hairpin. Figure 2-8 shows the coolant hole in the Nomex insulation jacket. Figure 2-9 depicts the lead extensions for terminating the conductors. Figure 2-10 shows the hairpin winding knuckle and Figure 2-11 shows the cross section of a conductor. Figures 2-12 and 2-13 are views of the hairpin winding showing the terminals attached for test.

The bending qualities which make for a useable conductor were demonstrated during specific bending and forming experimentation and by use of the conductors in flow and other test setups. Work to improve conductor fabrication technique is continuing. These include precut, preformed insulators to achieve a more accurate conductor matrix and facilitate conductor manufacture. For example a special punch was designed to form cooling holes in the conductor insulation. Figure 2-14 shows the tool designed to punch holes in the cooling jacket, and Figure 2-15 shows the punched conductor as installed in the coolant test fixture. Face dimensions of the punch are 0.060 by 0.100 inch.

2.4 CONDUCTOR MATRIX IMPREGNATION AND LEACH-OUT TEST

To develop techniques for leaching out the conductors, two sample conductors 16-in. long were fabricated. They simulated the actual stator configuration with top and bottom coil sides, and proper oil passages in the insulation jackets were used. The bonding impregnant was successfully leached out of the conductors, AiResearch Memo 19318-45609-019 detailing the technique is included as Exhibit A.

2.5 CONDUCTOR TERMINAL FABRICATION

Conductor terminals were fabricated for use in the flow test and the final stator. The assembly is designed to hold pressure, provide dielectric capability, and accommodate thermal expansion. The design utilizes double O-rings, Nema grade C11 insulator (machined from spiral wrapped stock for coolant seepage protection) and a high-conductivity, zirconium and copper terminal element. These components are shown in Figure 2-16.

2.6 FLOW TESTING

Flow testing was conducted in the test rig shown in Drawings 94-38-0434 and LSK 17367. Figures 2-17, 2-18 and 2-19 show the test fixture unassembled, a closeup of the coolant relief at the conductor inlet, and the assembled components. Figures 2-20, 2-21 and 2-22 are various views of the flow test setup. An important part of setting up for the flow test was insertion of the hairpin into the test fixture, a function verification of the hairpin winding dimensional and bending characteristics. Figure 2-23 shows the conductor in the test setup. Figure 2-24 shows the crimped ends of the conductor in the test setup. Prior to installation, the ends of the conductor strands were dipped in MeCl solvent to remove the forming adhesive and the insulating enamel was stripped from the strands. End-lacing of the Nomex insulation jackets was provided so that coolant oil would enter the conductor matrix at the end of the insulation jacket (see Figure 2-25). The figure also shows the thermocouple installation for the tests.

For the tests flow meters were installed to measure the flow in each section of the conductor and the differential pressure across each inlet-to-outlet was measured. Oil viscosity measurements were made at various temperatures.

<u>Temperature °F</u>	<u>Viscosity, CV</u>
70	2.18
100	1.73
130	1.45
150	1.25

Resistances of the conductor and the insulation were measured. At 20°C conductor reactance was 0.00732Ω (within 1 percent of the calculated value). Insulation resistance measured at ambient temperature and 500 vdc was $150 \times 10^9\Omega$ without cooling oil and $3 \times 10^{12}\Omega$ with cooling oil.

Initial flow testing yielded extremely low pressures and high flows as compared to those measured during previous conductor segment tests.*

<u>Section No.</u>	<u>Flow, gpm</u>	<u>Delta Pressure Across Section, psid</u>
1-2	0.0220	10.89
2-3	0.0220	10.50
3-4	0.0220	11.60
4-5	0.0220	14.79

Coolant flow was then adjusted to occur in all sections simultaneously as in the final stator configuration. The following results were obtained.

<u>Section No.</u>	<u>Flow, gpm</u>	<u>Delta Pressure Across Section, psid</u>
1-2	0.0227	10.65
2-3 } Common inlet	0.0432	10.29
3-4 }		10.60
4-5	0.0226	15.90

Section 4-5 required a greater pressure than other sections; subsequent back flushing and retesting revealed improper leach-out of the conductor. The conductor was replaced and a more extensive leach-out is being performed at the time of this writing. Uniform coolant flow through each stator section and each conductor must be maintained in order to prevent the formation of local hot spots and possible conductor burn out. This preliminary testing illustrates the effect of incomplete leach out on coolant flow. Once a completely leached out conductor is fabricated, as evidenced by equal section flows, testing at current density will begin.

*See AFWAL-TR-80-2130 for details.

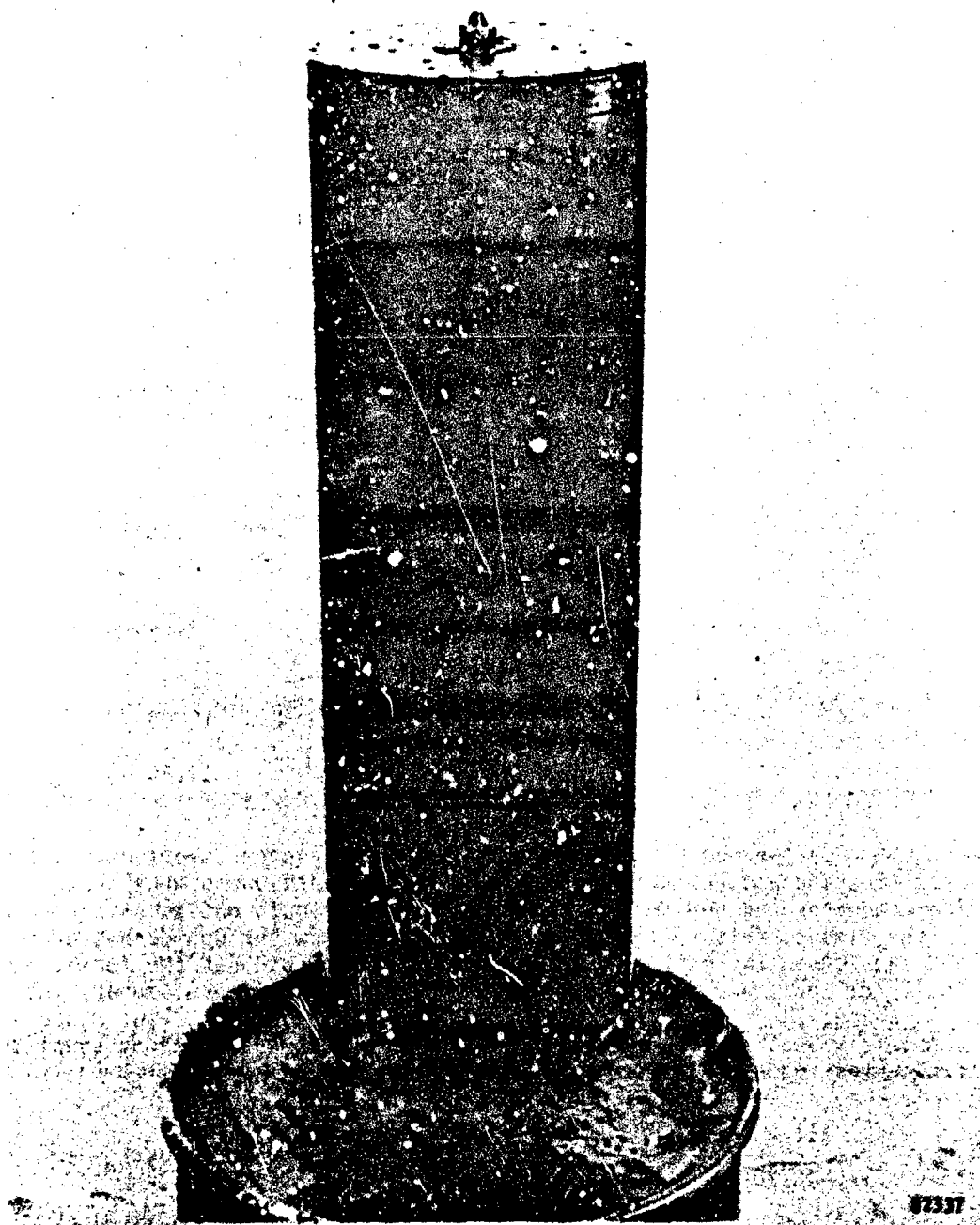


Figure 2-1. Bore Seal Tool Coated With Viton

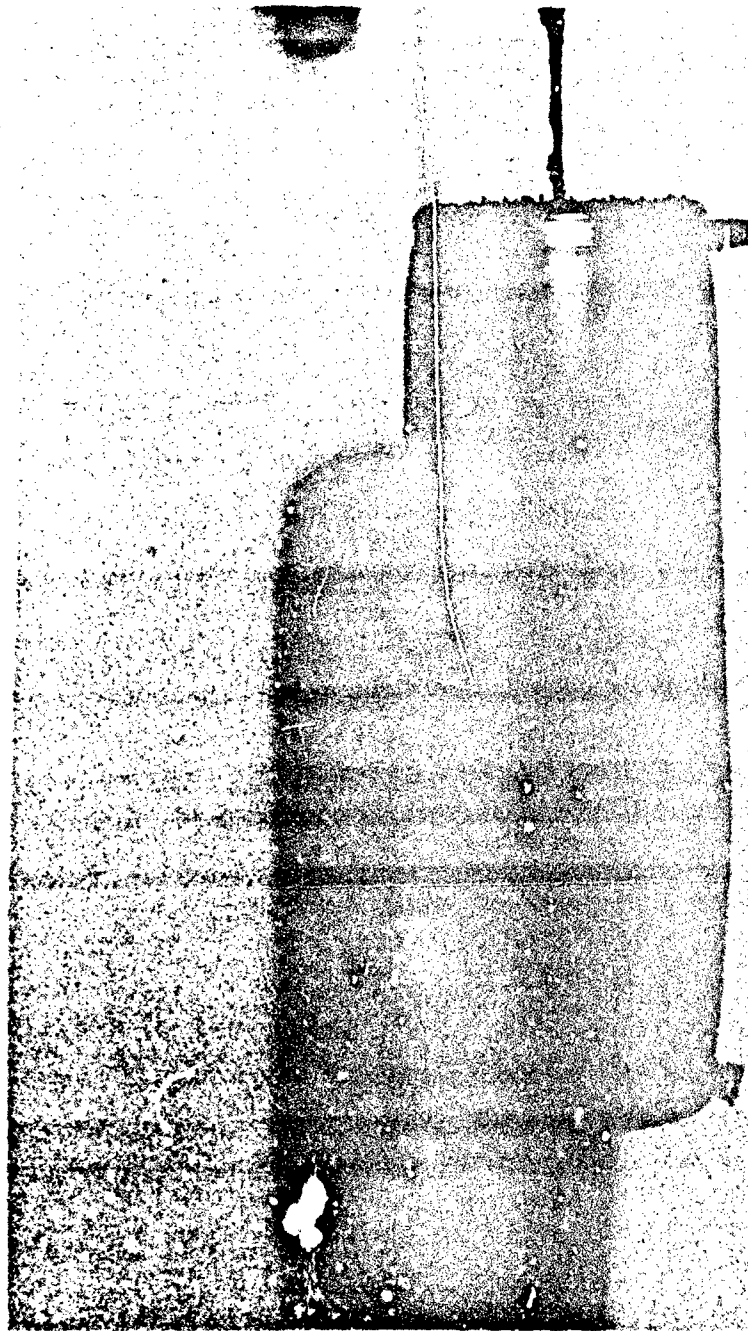


Figure 2-2. Inflated Bore Seal on Tool



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Figure 2-3. Conductor Feeder

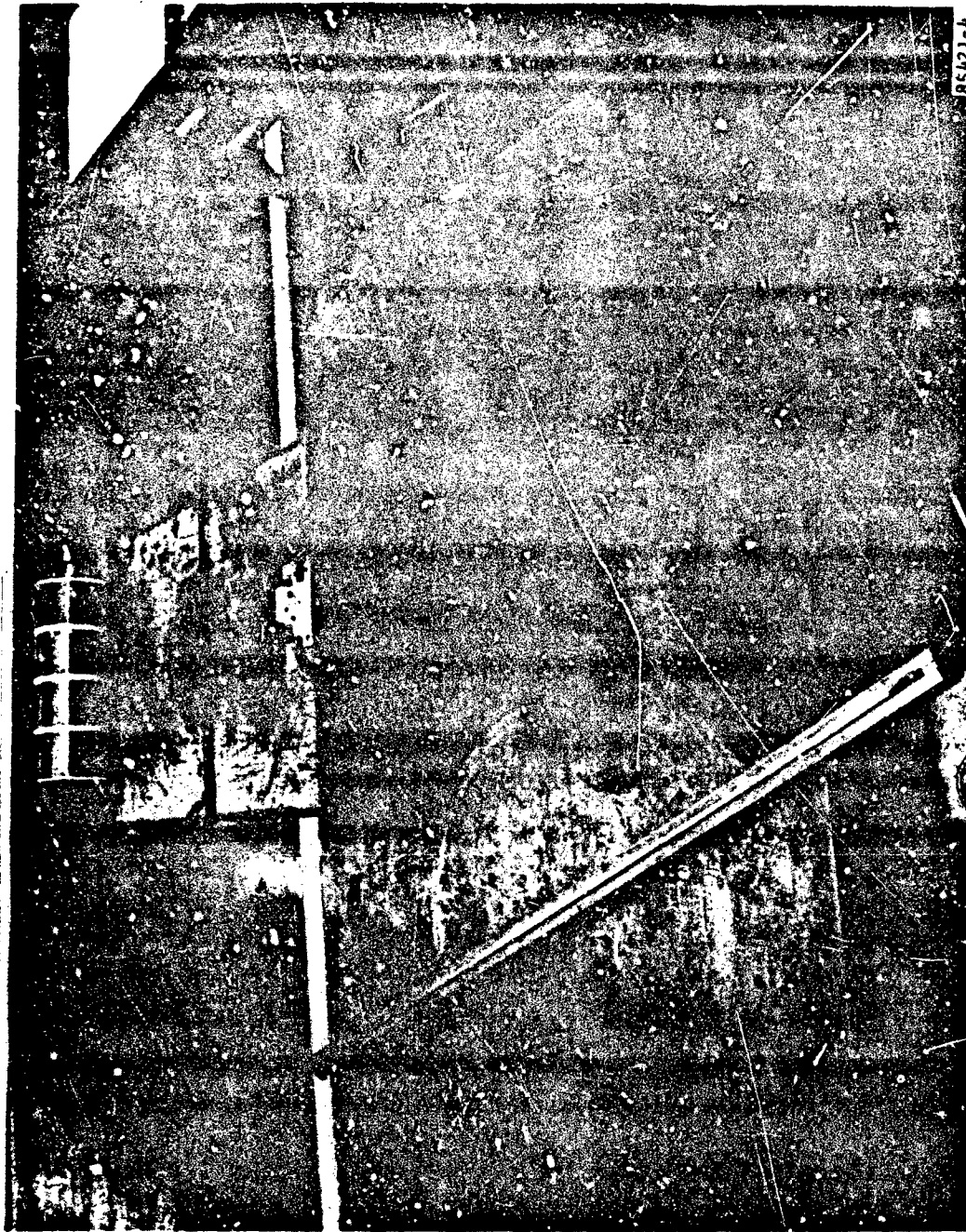


Figure 2-4. Prototype Winding Fixture

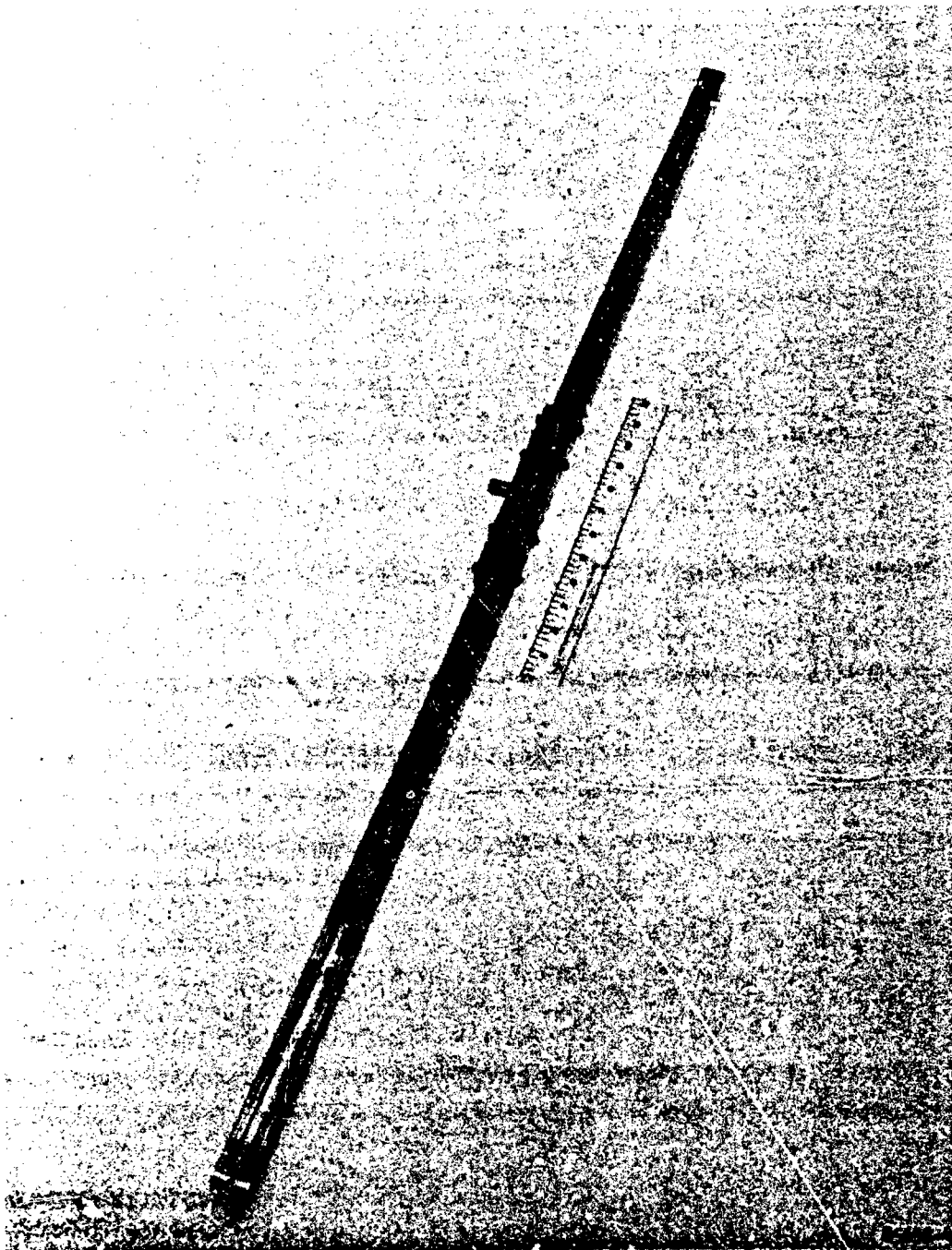


Figure 2-5. Hairpin Winding Fixture

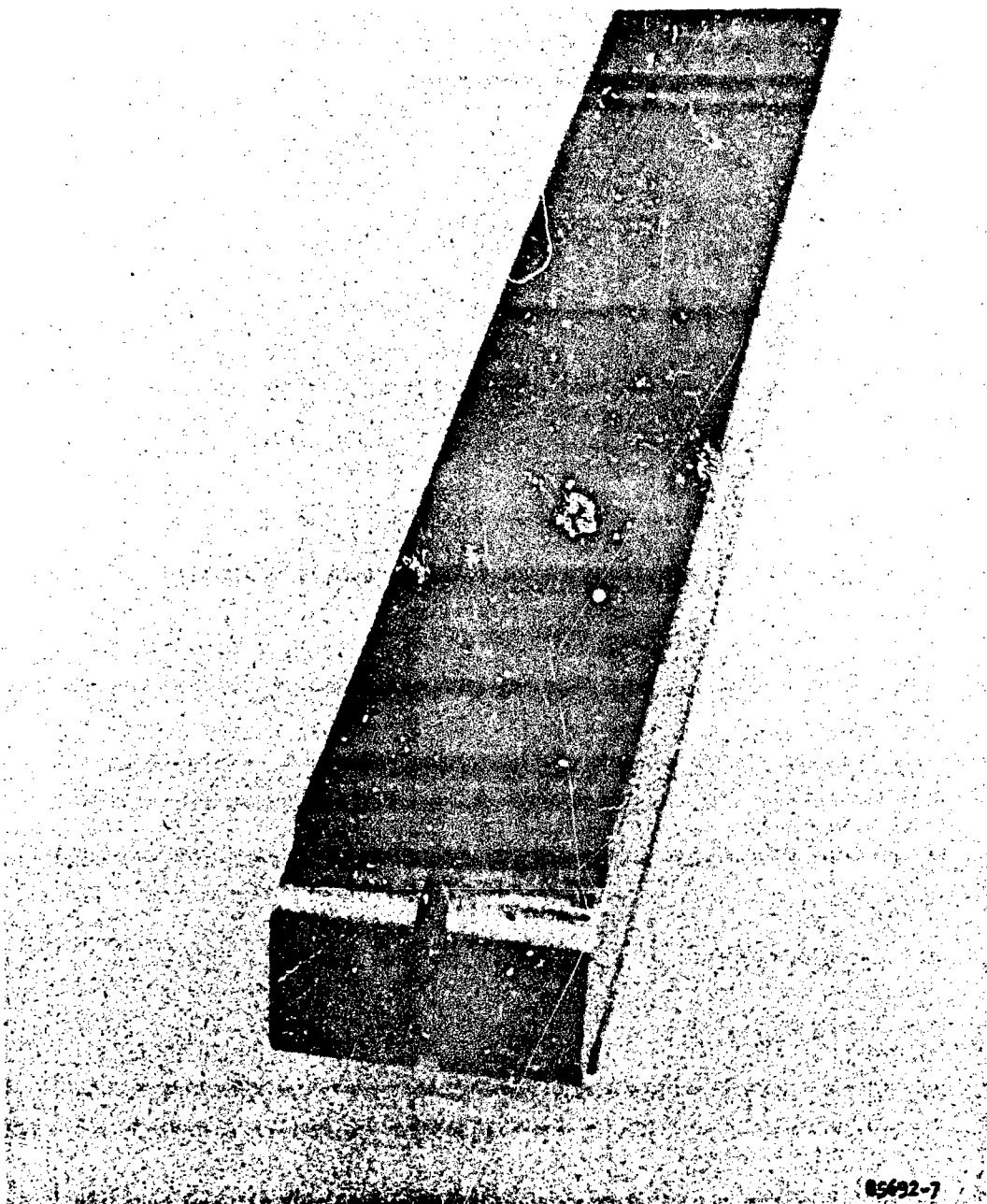
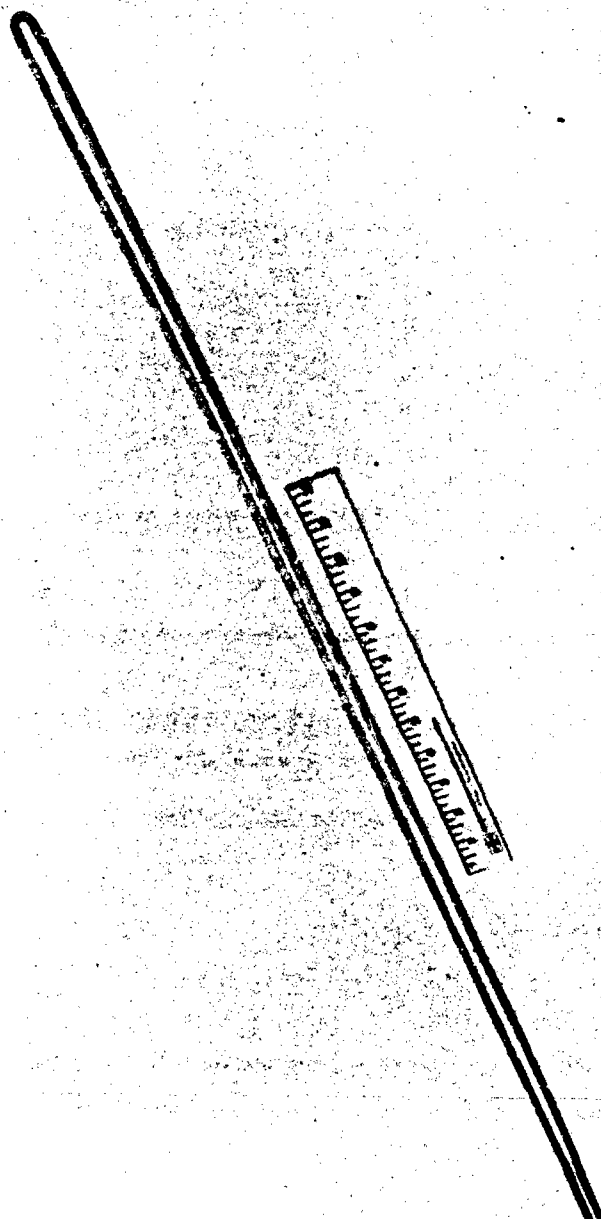


Figure 2-6. Winding Knuckle End in Fixture



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Figure 2-7. Hairpin Winding



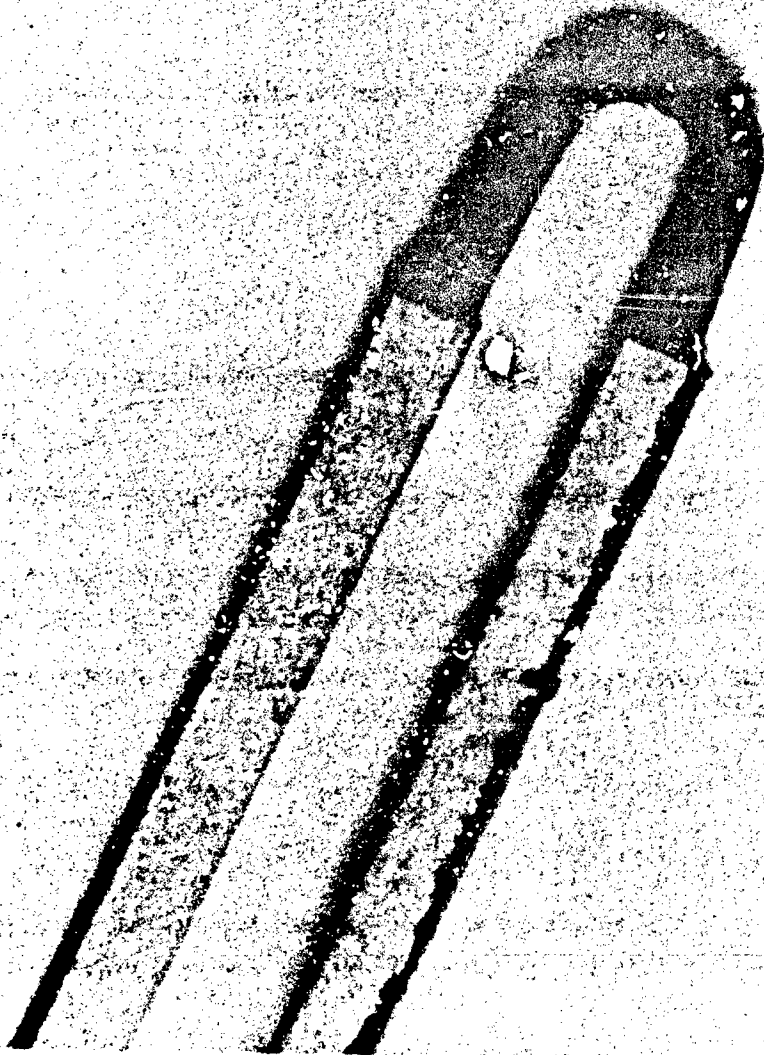
85692-10

Figure 2-8. Coolant Hole in Nomex Jacket



35692-9

Figure 2-9. Winding Lead Extensions



85692-8

Figure 2-10. Winding Knuckle End

85781-1

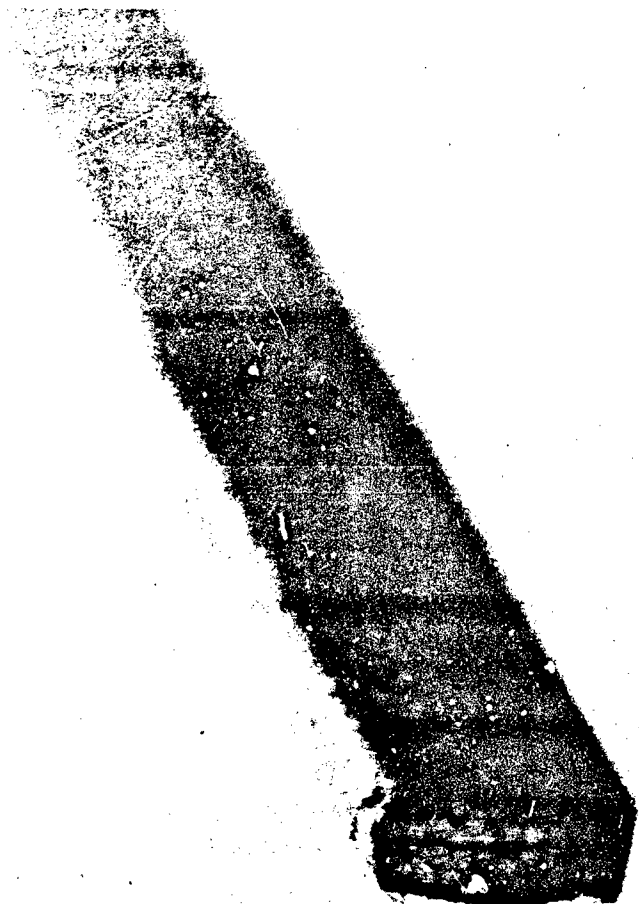
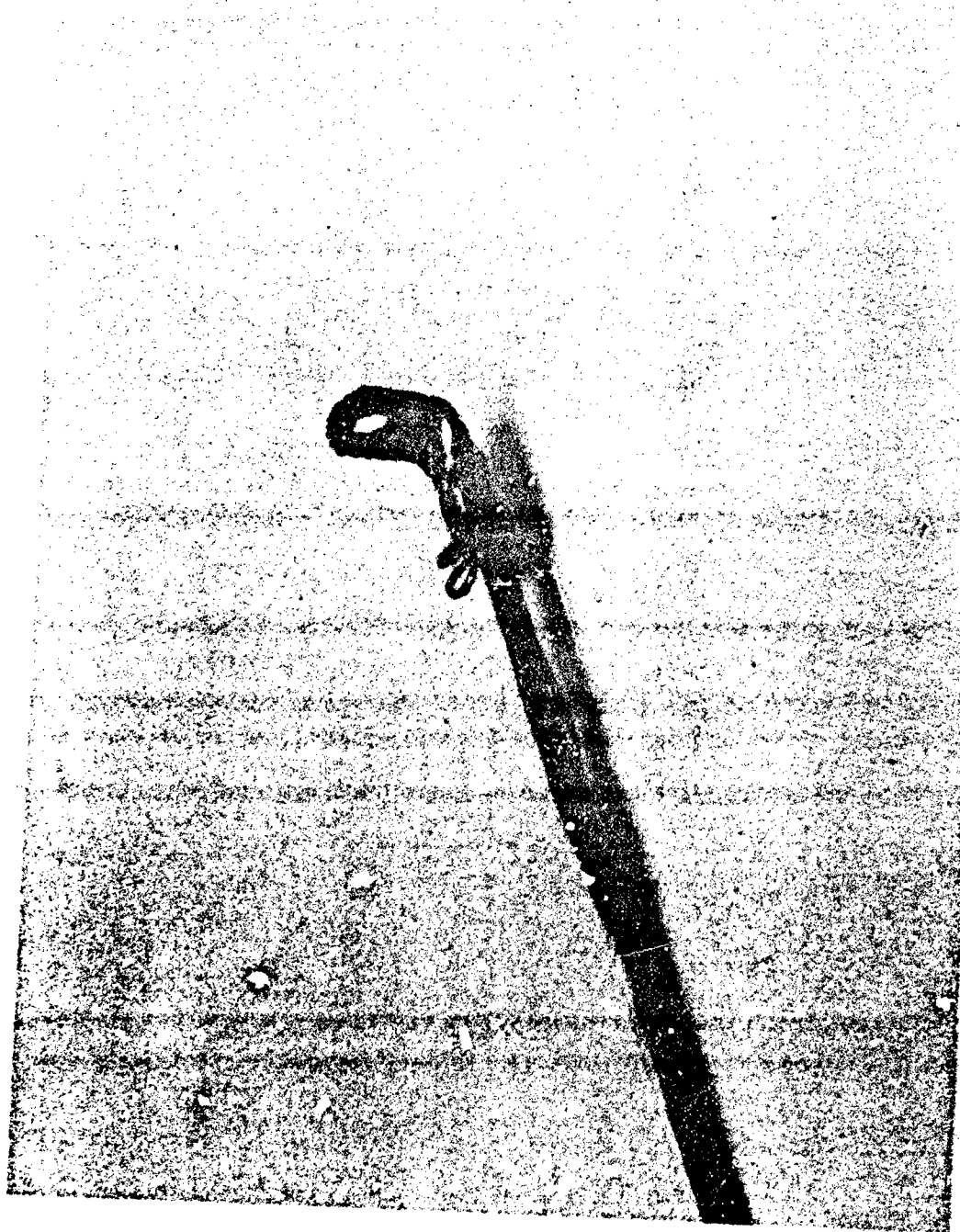


Figure 2-11. Cross Section of Conductor

Figure 2-12. Winding With Terminal Attached



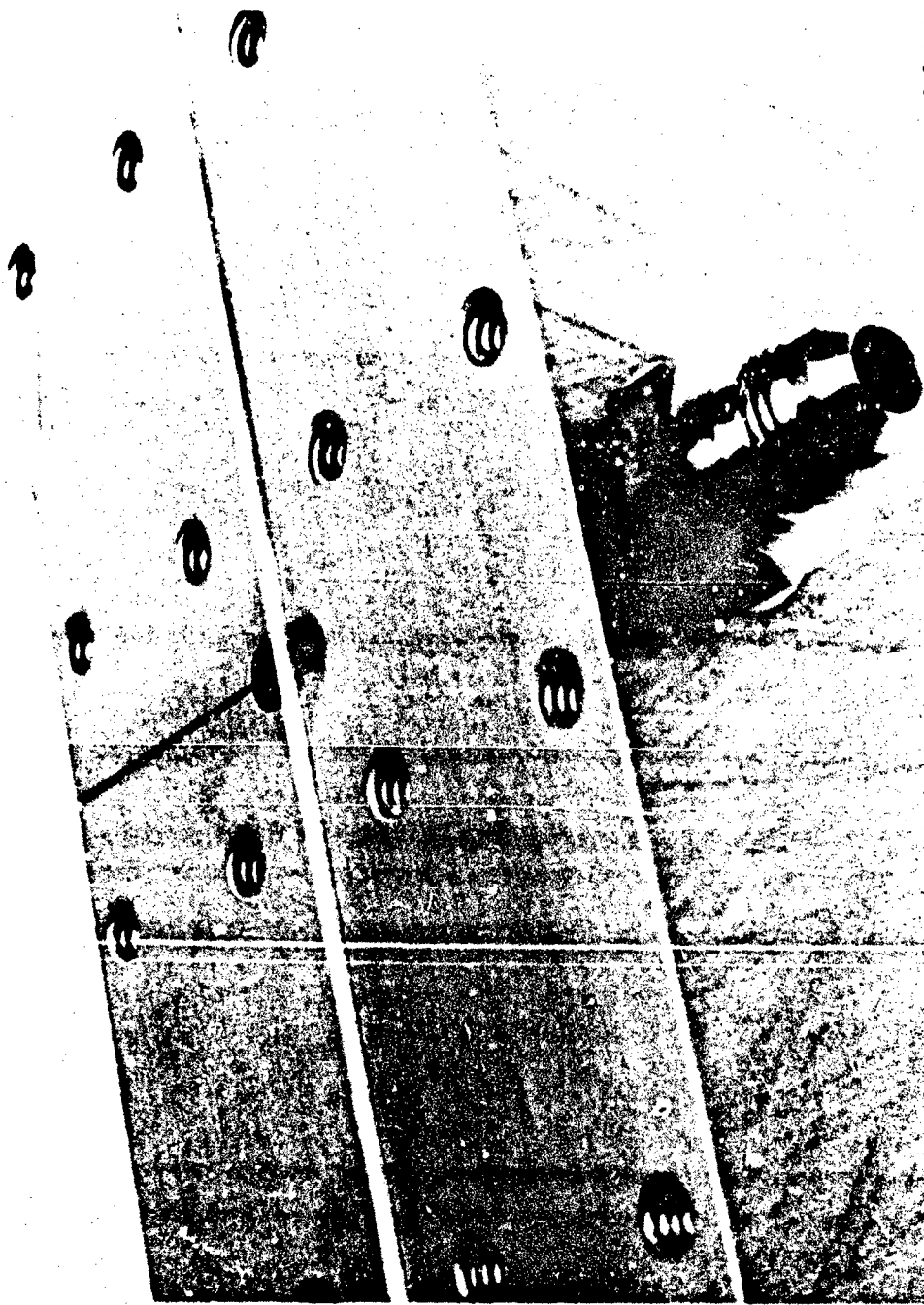


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Figure 2-13. Winding With Terminal Attached (Detail)

85821-1

Figure 2-14. Punch for Cooling Holes in Conductor Insulation



85821-2

Figure 2-15. Punched Conductor in Test Fixture

85692-6

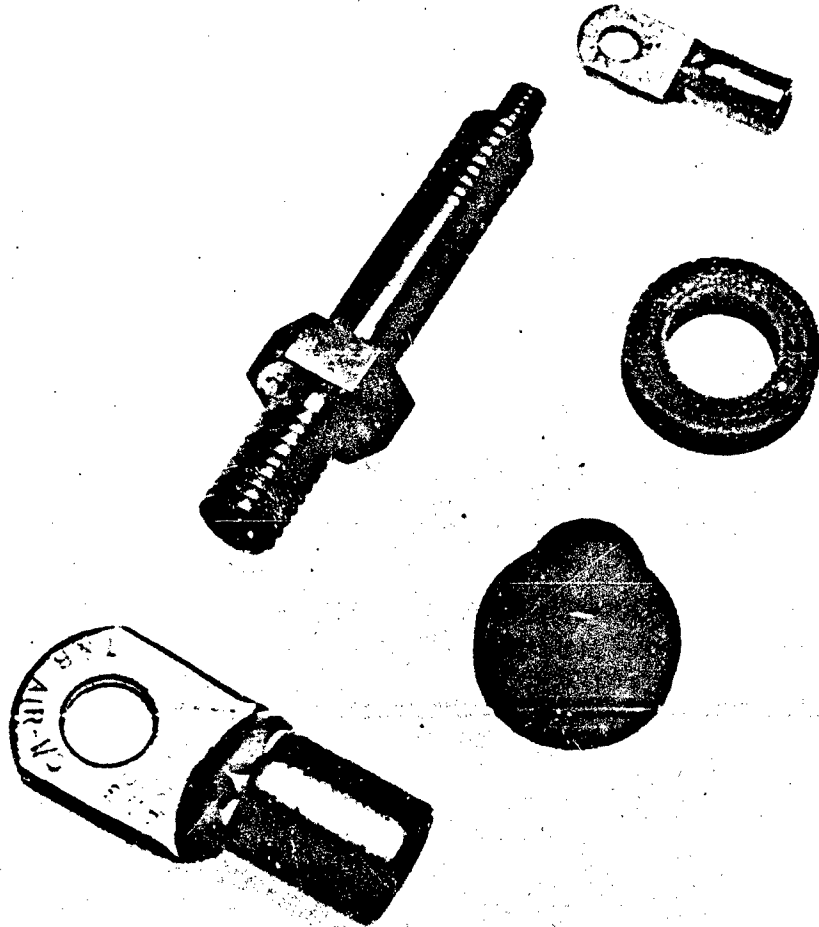
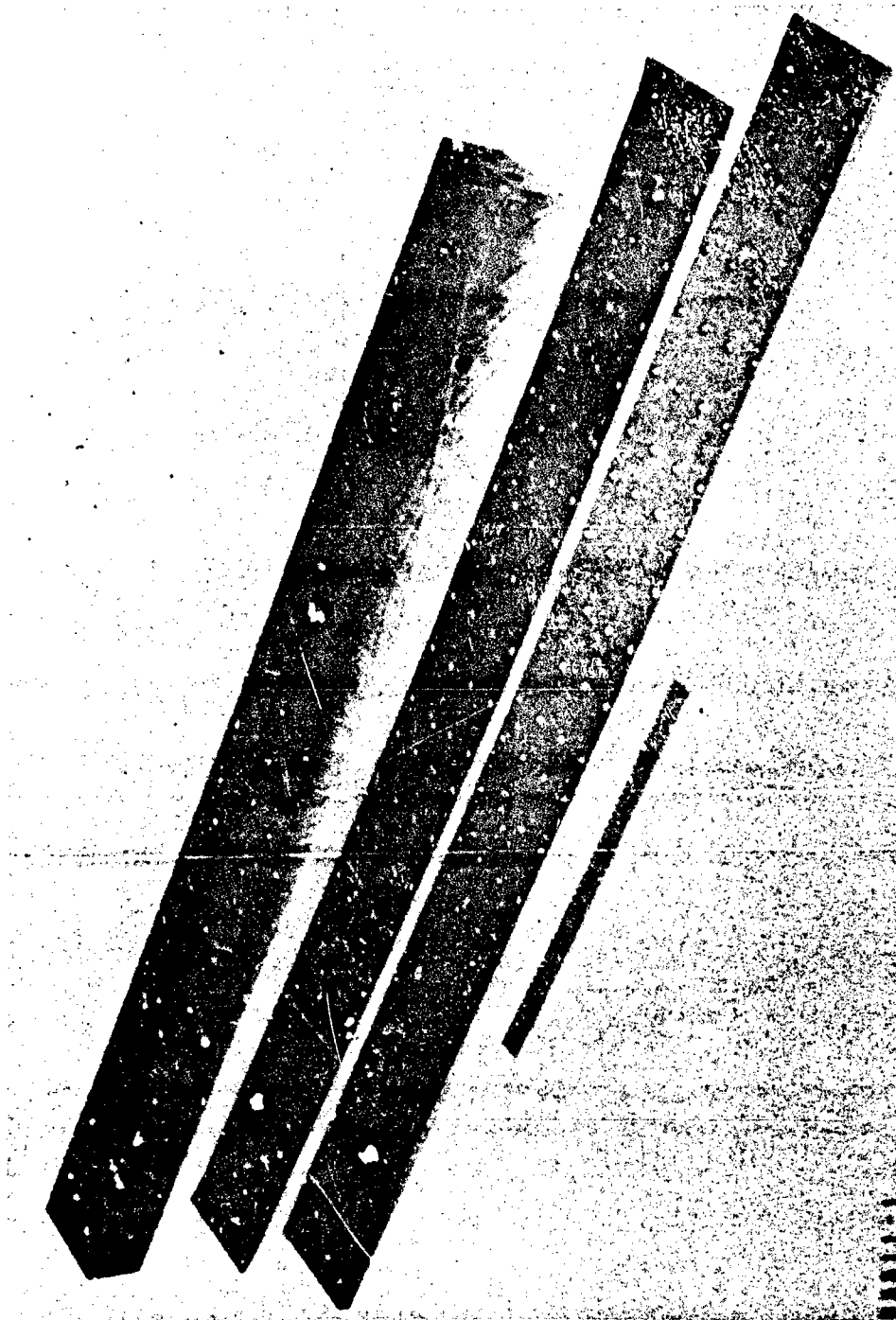
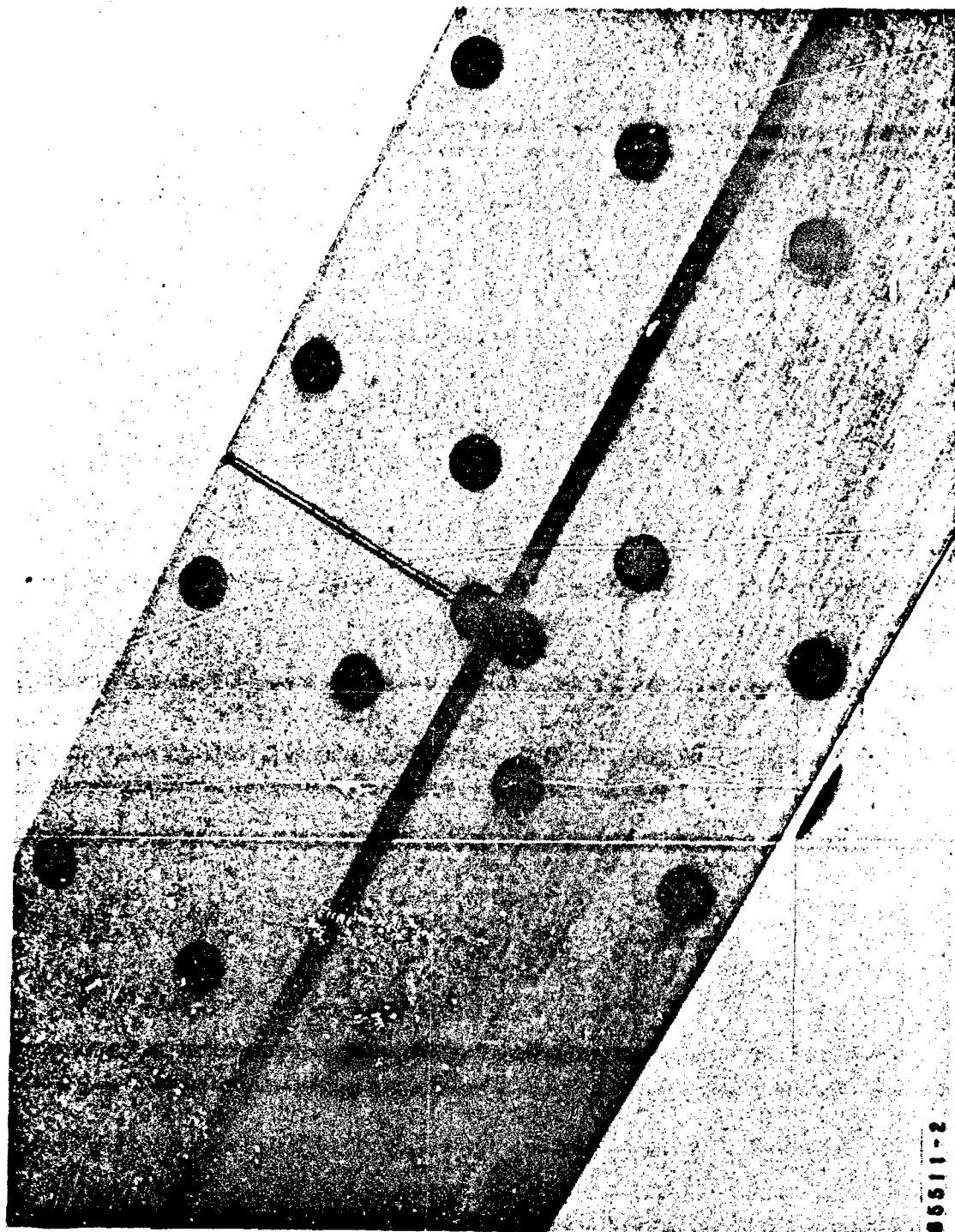


Figure 2-16. Conductor Terminal Assembly



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Figure 2-17. Unassembled Hairpin Winding Test Fixture



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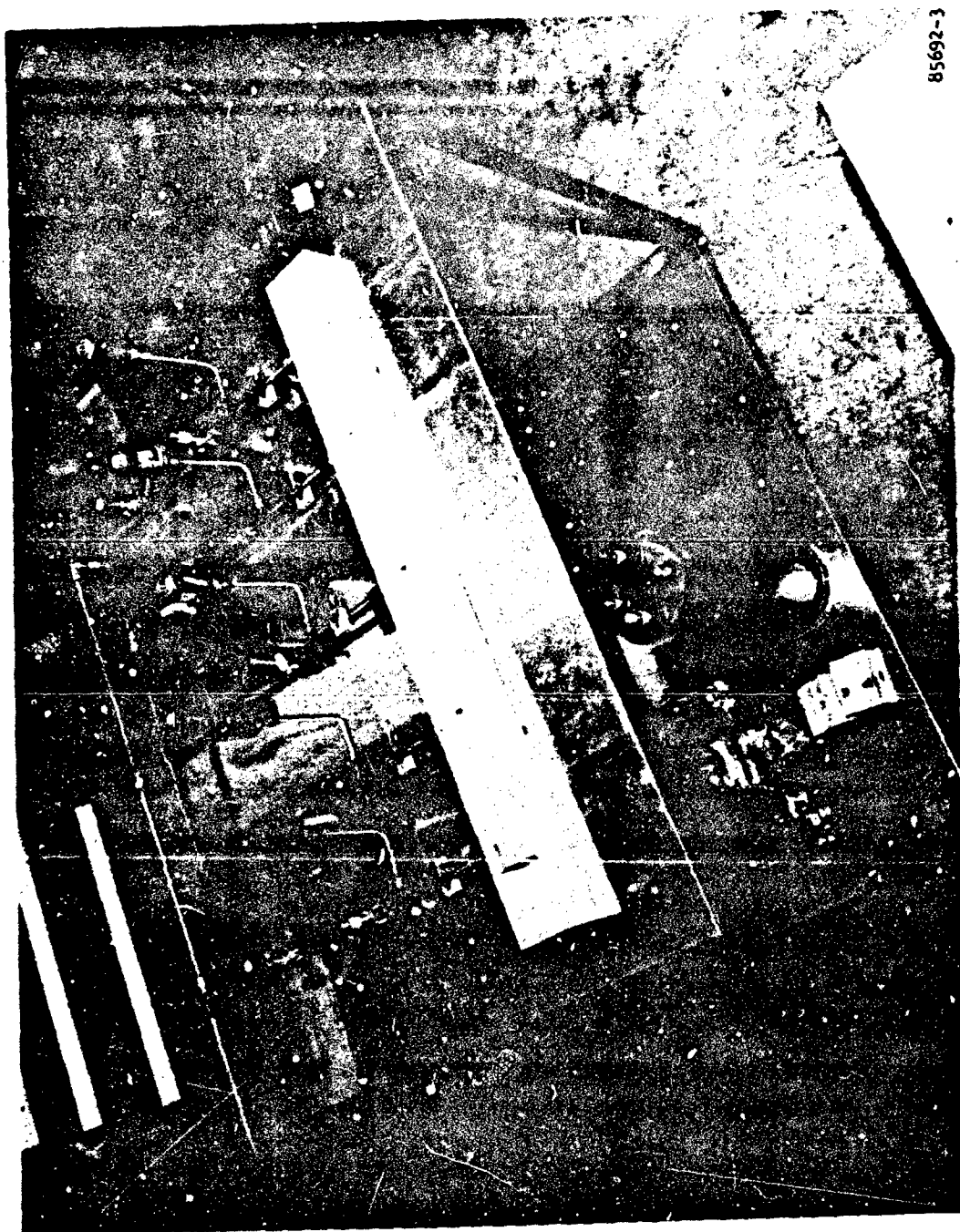
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Figure 2-18. Coolant Inlet Relief of the Conductor Slot Location



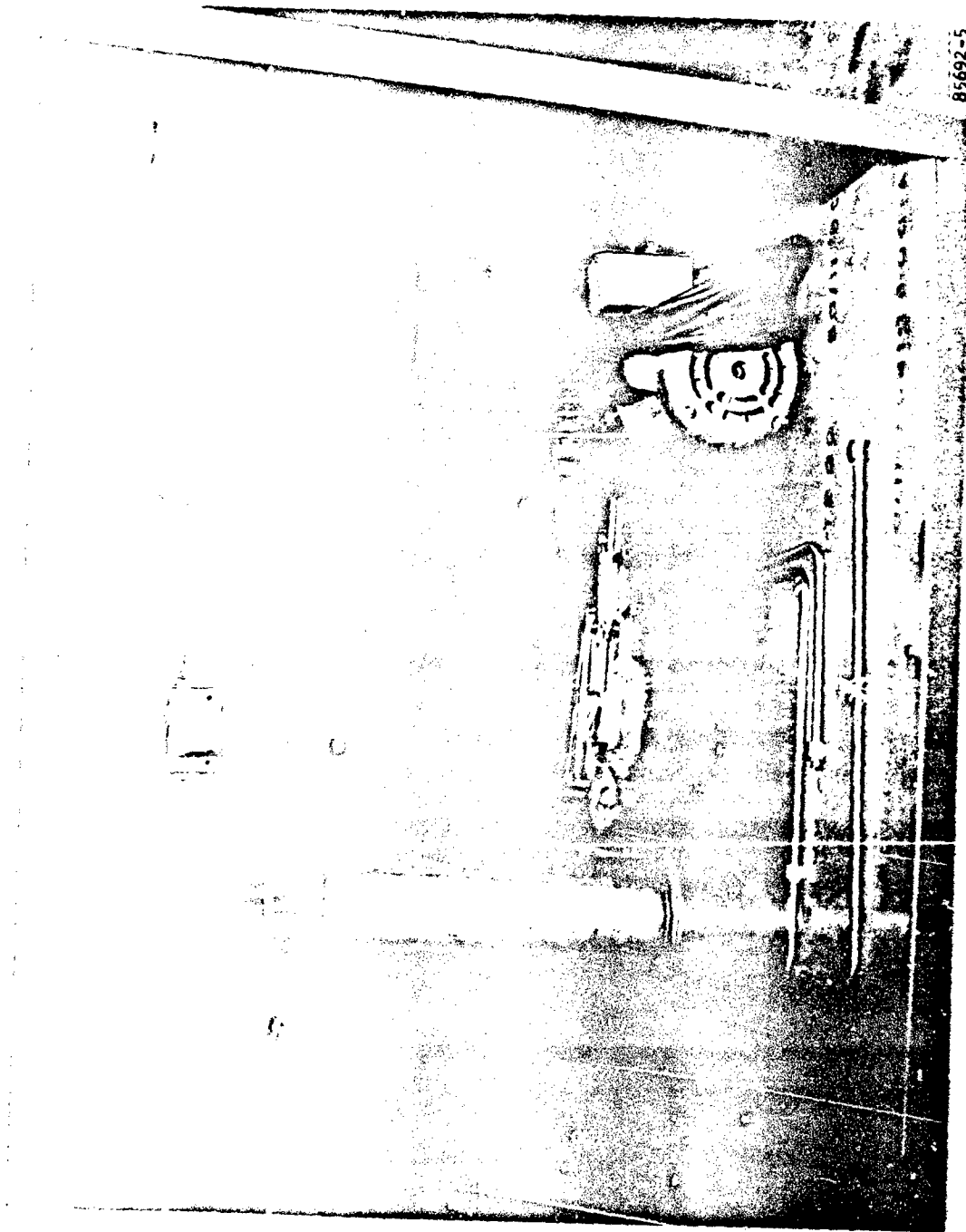
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Figure 2-19. Assembled Hairpin Winding Test Fixture



85692-3

Figure 2-20. Flow Test Setup Overview



85692-5

Figure 2-21. Flow Test Setup Detail

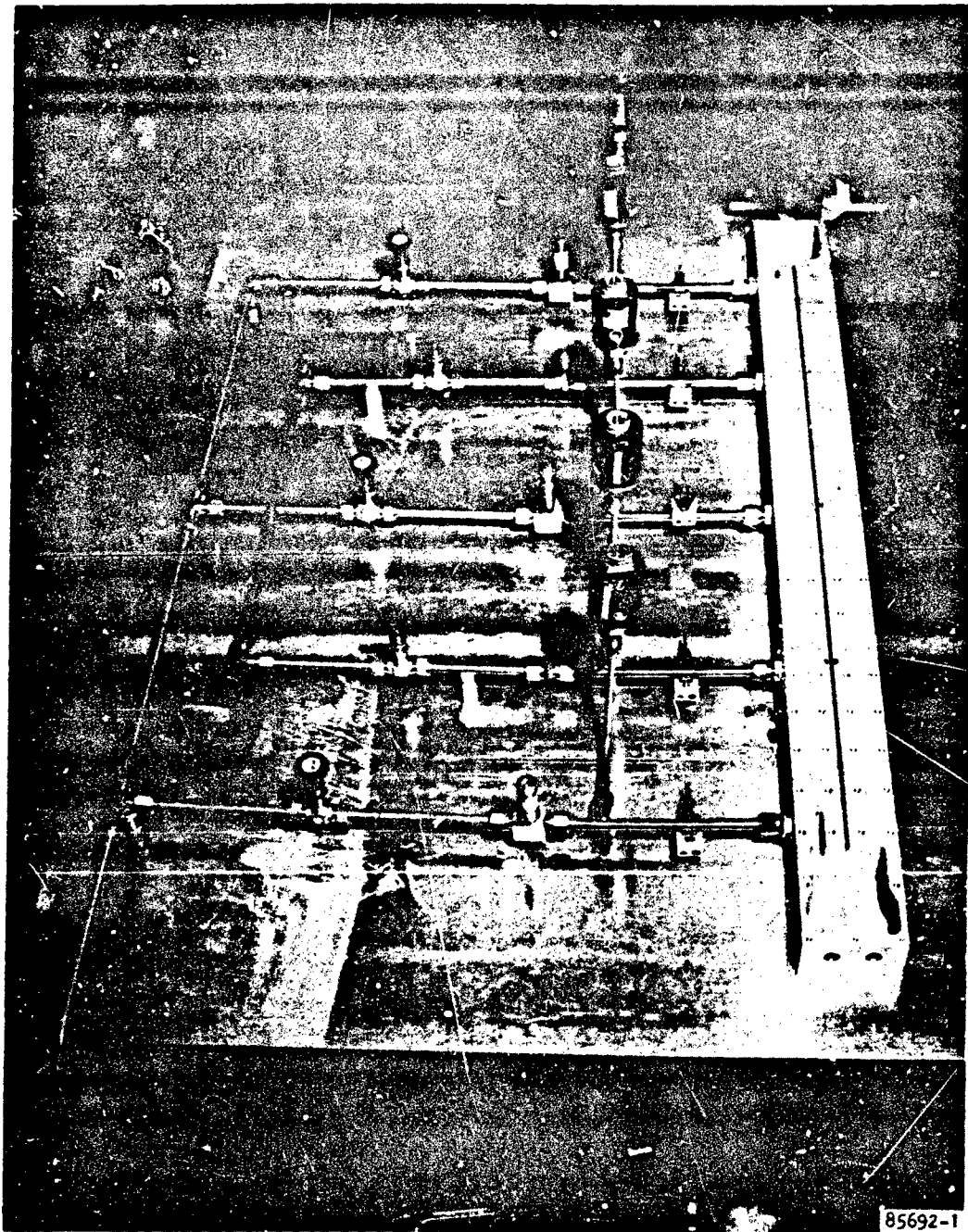
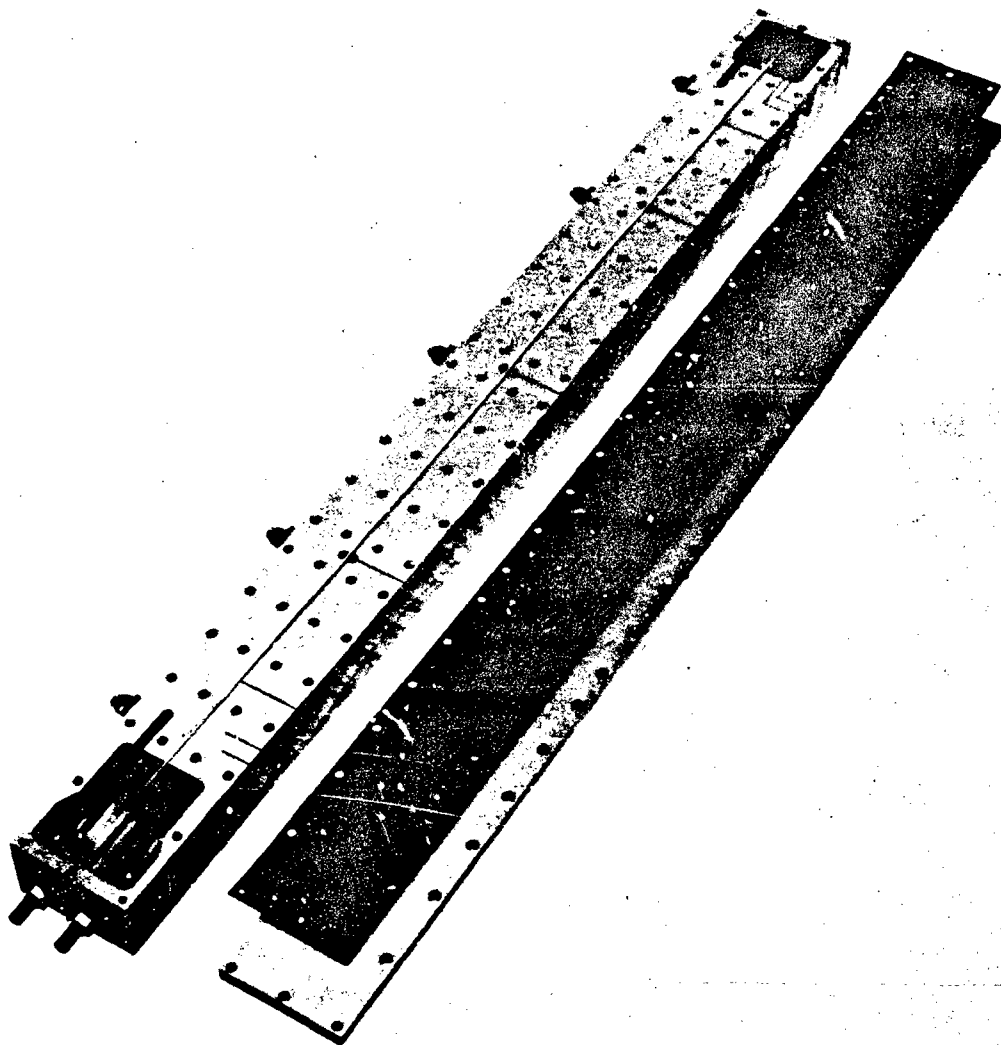
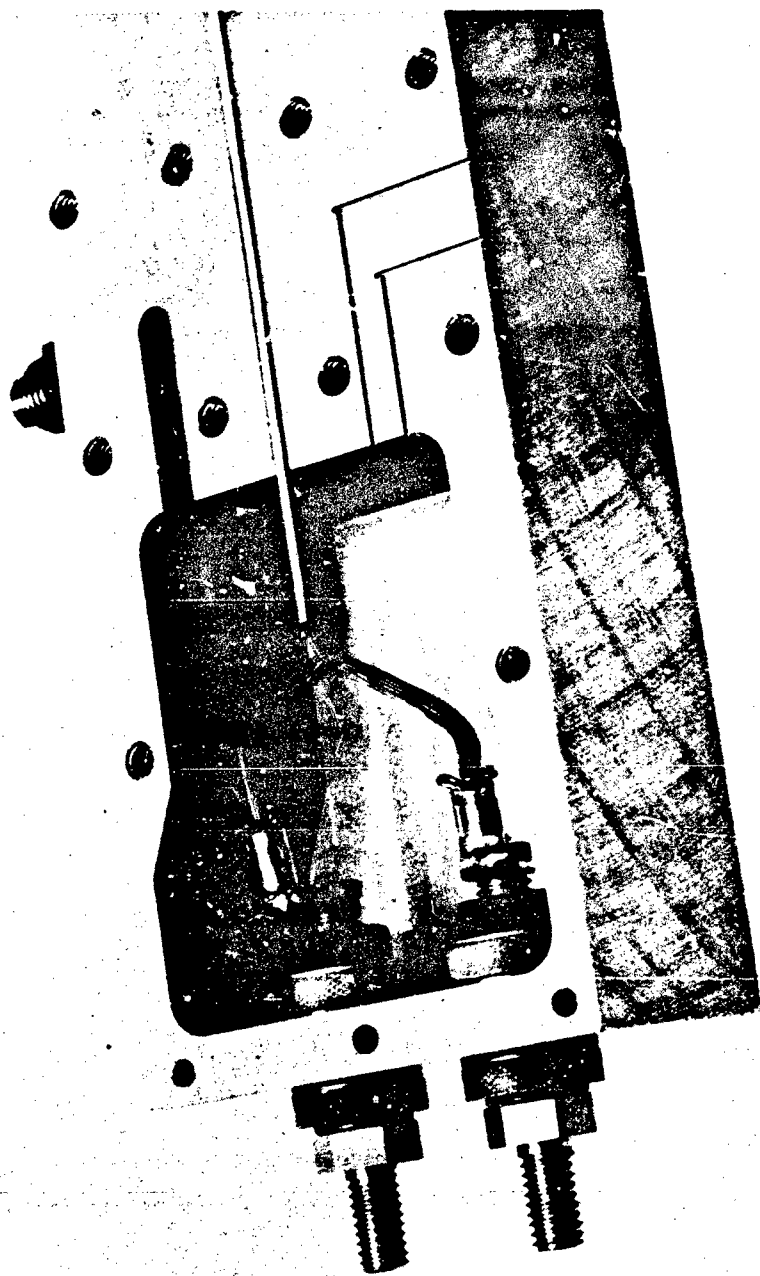


Figure 2-22. Flow Test Setup



85821-5

Figure 2-23. Conductor Installed in Flow Test Fixture



85821-4

Figure 2-24. Conductor Terminals

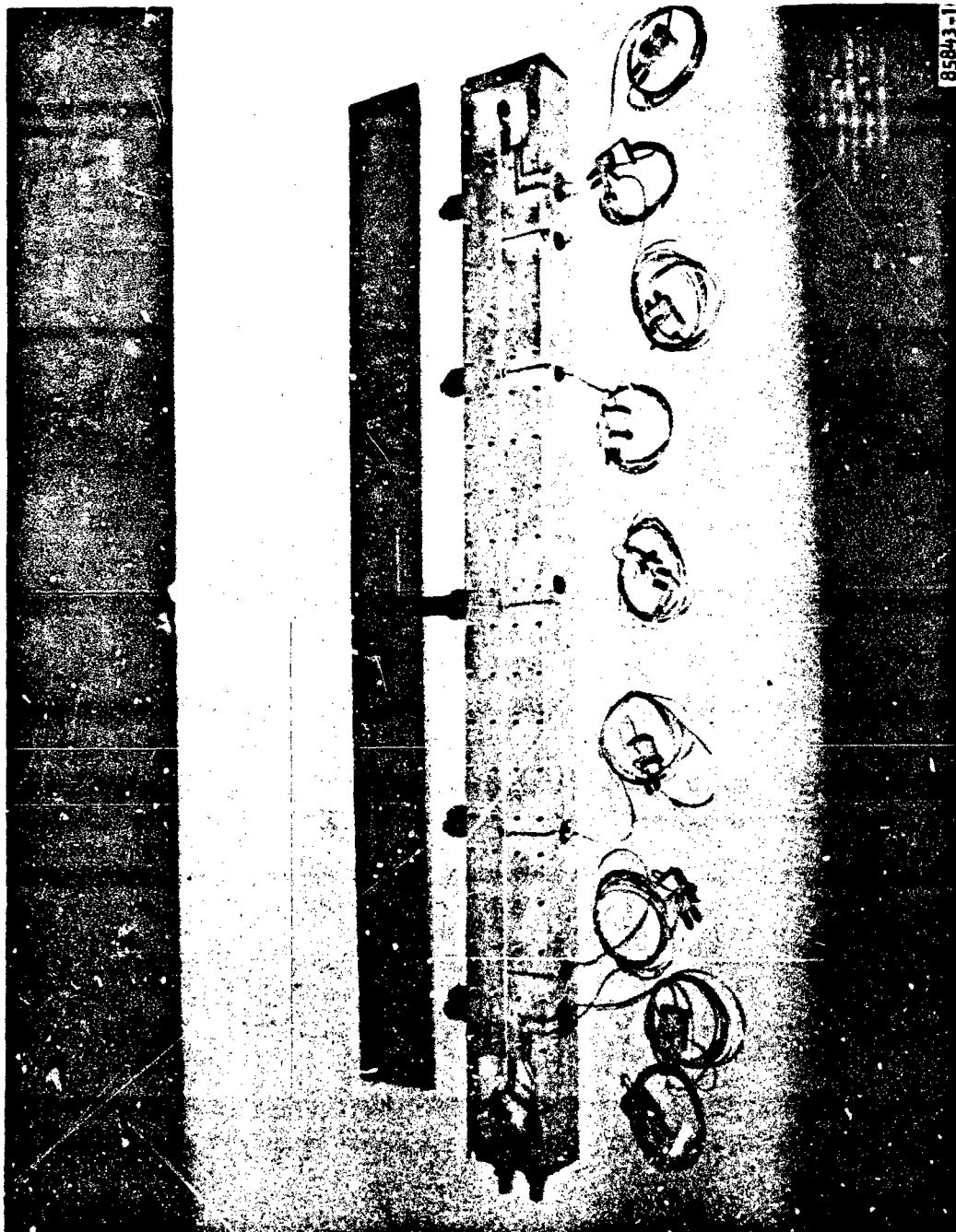


Figure 2-25. Test Fixture Showing Jacket End-Lacing and Thermocouple

EXHIBIT 2A

AIRESEARCH MEMO 19318-45609-019



AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA

IN REPLY REFER TO:

19318-45609-019

OFFICE MEMO

TO: A. Druzbsa DEPT. 93-8 DATE: Oct. 15, 1981
FROM: C. Gibson DEPT. 93-18 EXT. 3505 COPIES TO: P. Fizer
F. McCarty
K. Ramezani
SUBJECT: Assembly of the Advanced SMW Permanent Magnet
Generator Conductors into Insulating Jackets.

Introduction

The materials used to bond the conductors together for assembly were the following:

Material	Source
Vitel VPE-5571	Goodyear Tire and Rubber Co., Chemical Division
Methylene Chloride	Commercial
Trichloroethane	Commercial
Perchloroethylene	Commercial

Typical Adhesive Formulation	
Vitel VPE-5571	450 grams
Methylene Chloride	3.00 liters
Trichloroethane	.75 liters
Perchloroethylene	.25 liters
Total	4.00 liters

Vitel VPE-5571 is a polyester resin that exhibits high specific adhesion to various substrates, the most important being polyethylene terephthalate film (e.g. Mylar). Its excellent chemical and thermal stability, flexibility, and cohesive strength make it a good candidate for bonding polyester films to copper foils and wires for the electronics industry. In addition, it has high solubility in chlorinated organic solvents and will also melt flow at temperatures below 450° F. For these reasons, it was chosen as the bonding agent for assembling the conductors into the Nomex paper insulating jackets.

Procedure (See Figure 1)

Assembly (performed by P. Fizer and K. Ramezani).

The conductors were aligned, coated with the Vitel-5571 bonding solution and allowed to air dry at room temperature for approximately 10 to 20 minutes in band widths of four strands each. The banded conductors were then placed nine layers high into an insulator jacket that was coated with the Vitel adhesive on its internal walls. A grooved metal fixture was used to assist in the holding of the insulator jacket during the stacking of the conductor bands. This procedure was repeated to produce two Nomex paper jacketed, 4 x 9 conductors each 16 inches long.

Vitel VPE-5571 Removal

The conductor samples each had a small (approx 0.1 inch in diameter) oil flow passage cut through the insulating jacket at their mid sections. They were then placed into the grooved metal fixture in a slot sample configuration (as defined by P. Fizer) with both ends open.

FORM 756-1 (11-75)

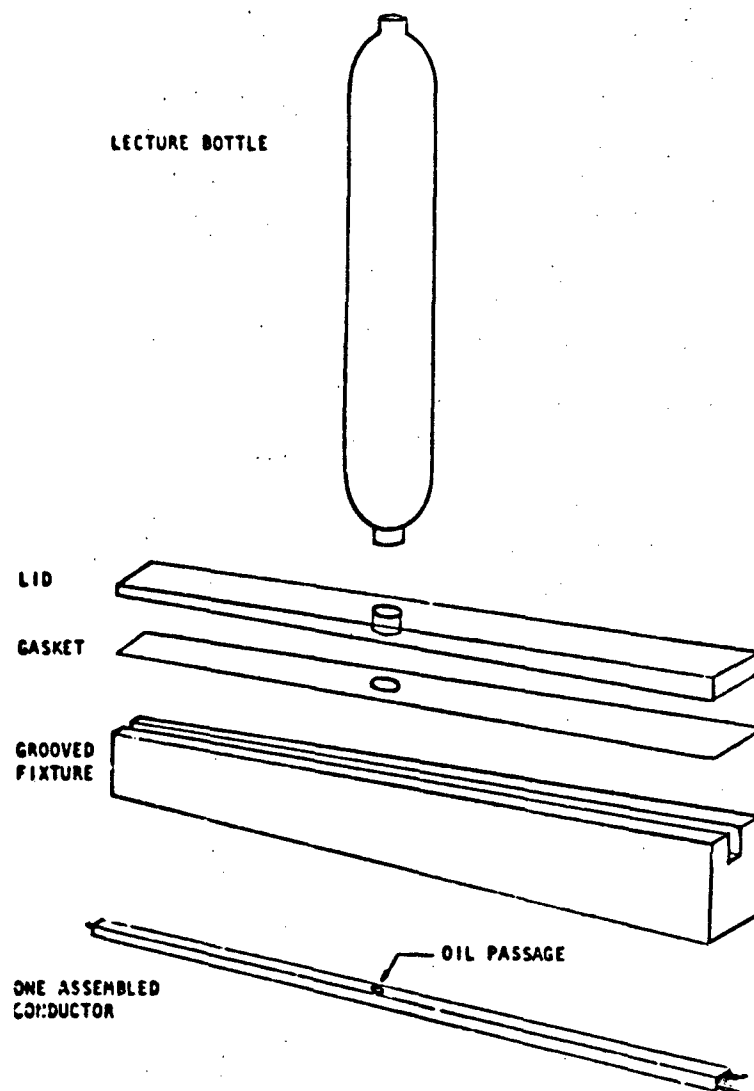


Figure 1. Fixture Components for Conductor Assembly

Ref: 19318-45609-019

October 15, 1981

The metal fixture was then fitted with a rubber gasketed lid that sealed the open groove to form an enclosed channel around the conductors. A pressurized nitrogen line was fitted at a threaded opening in the lid over the conductors' oil passages. This assembly was then heated to 450° F in an air circulating oven and a low flow of nitrogen was passed through the conductors.

After the dripping of the Vitel adhesive from the open ends appeared to stop, the assembly was removed from the oven and prepared for solvent extraction. A 250 ml, metal lecture bottle reservoir was fitted to the assembly in place of the nitrogen line. Approximately 1 liter of fresh methylene chloride was passed through the assembly by gravity addition. This was followed by an approximately 1 liter methylene chloride power flush by applying a low nitrogen pressure to the top of the lecture bottle. The cleaned conductors were then dried by allowing a low flow of nitrogen to pass through the system at room temperature for 10 minutes.

The conductors were then removed from the assembly, sectioned, and visually inspected at 30 x for cleanliness. No adhesive was noted.

Conclusions

The procedure used in this first, cursory study was the best that could be conceived without extensive testing. Additional study is needed to minimize pressure, temperatures and solvent volumes before the development unit is assembled.

Chris Gibson

Chris Gibson
Materials Engineering

Approved

D. W. McGrath

D. W. McGrath
Materials Engineering

mn

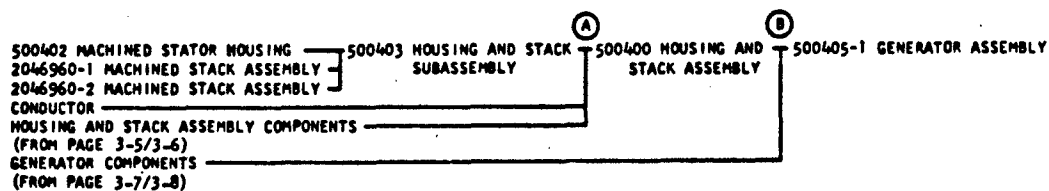
3. DETAIL DESIGN REVIEW

During Phase II the final detail designs were completed. These designs are fully compatible with the rotor scheduled for delivery early in 1982. These designs were incorporated into the fabrication drawings which form the basis for the rotor fabrication plan.

3.1 FABRICATION PLAN

AtResearch manufacturing engineering participated in the detail design process; each detail was reviewed for producibility and was approved by the cognizant manufacturing engineer before it was released to production. In preparation of the fabrication plan, the manufacturing operations were determined by the manufacturing engineer. These operations are presented in Figure 3-1. This figure shows the sequence of operations; the time span required is reflected in Paragraph 3.2, Long Lead Item Descriptions.

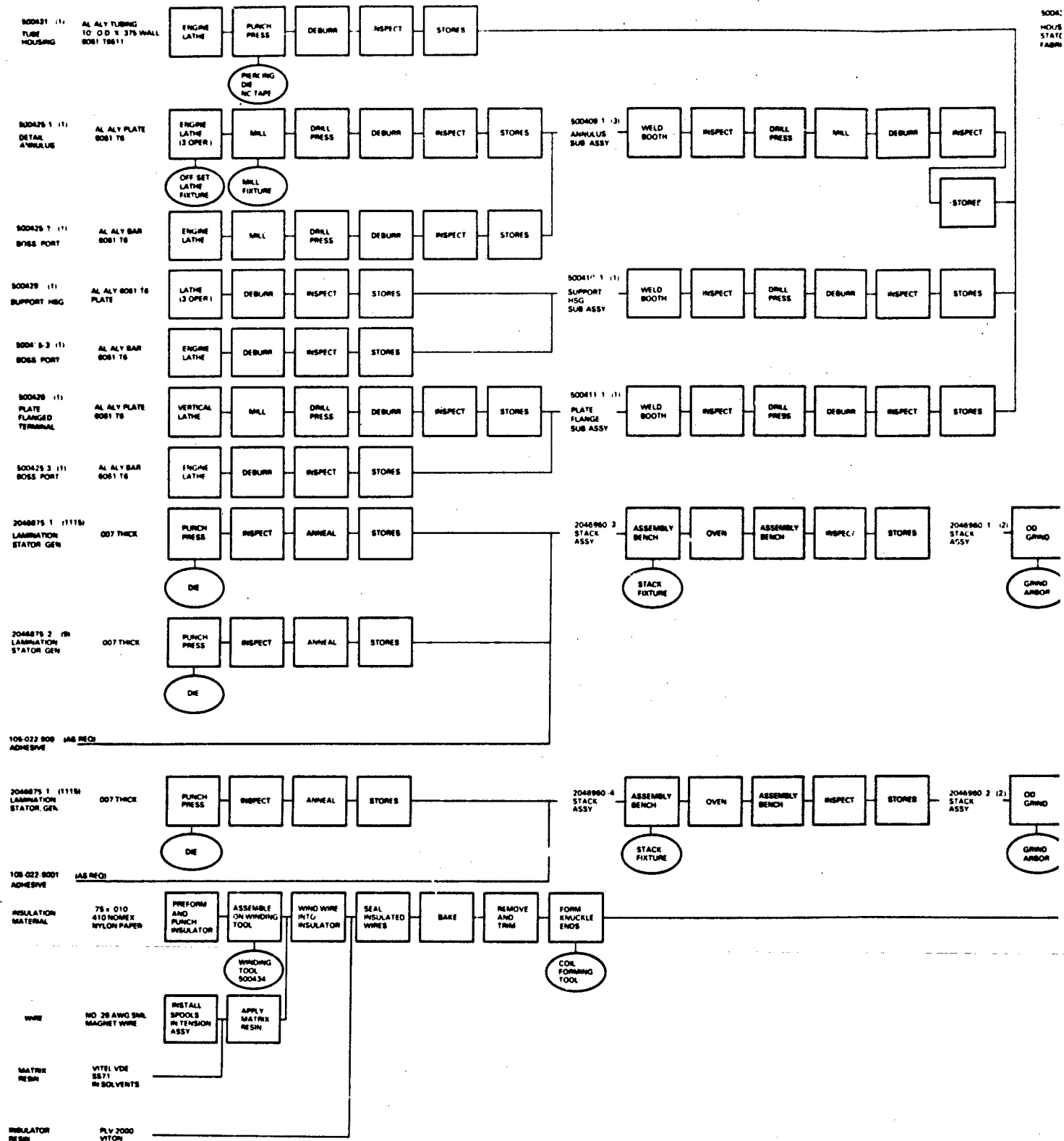
The figure is presented in three parts; parts 2 and 3 are keyed to the assembly sequence by the letters A and B as indicated below:



Drawings used in determining the manufacturing operations are included in numerical order at the end of this section.

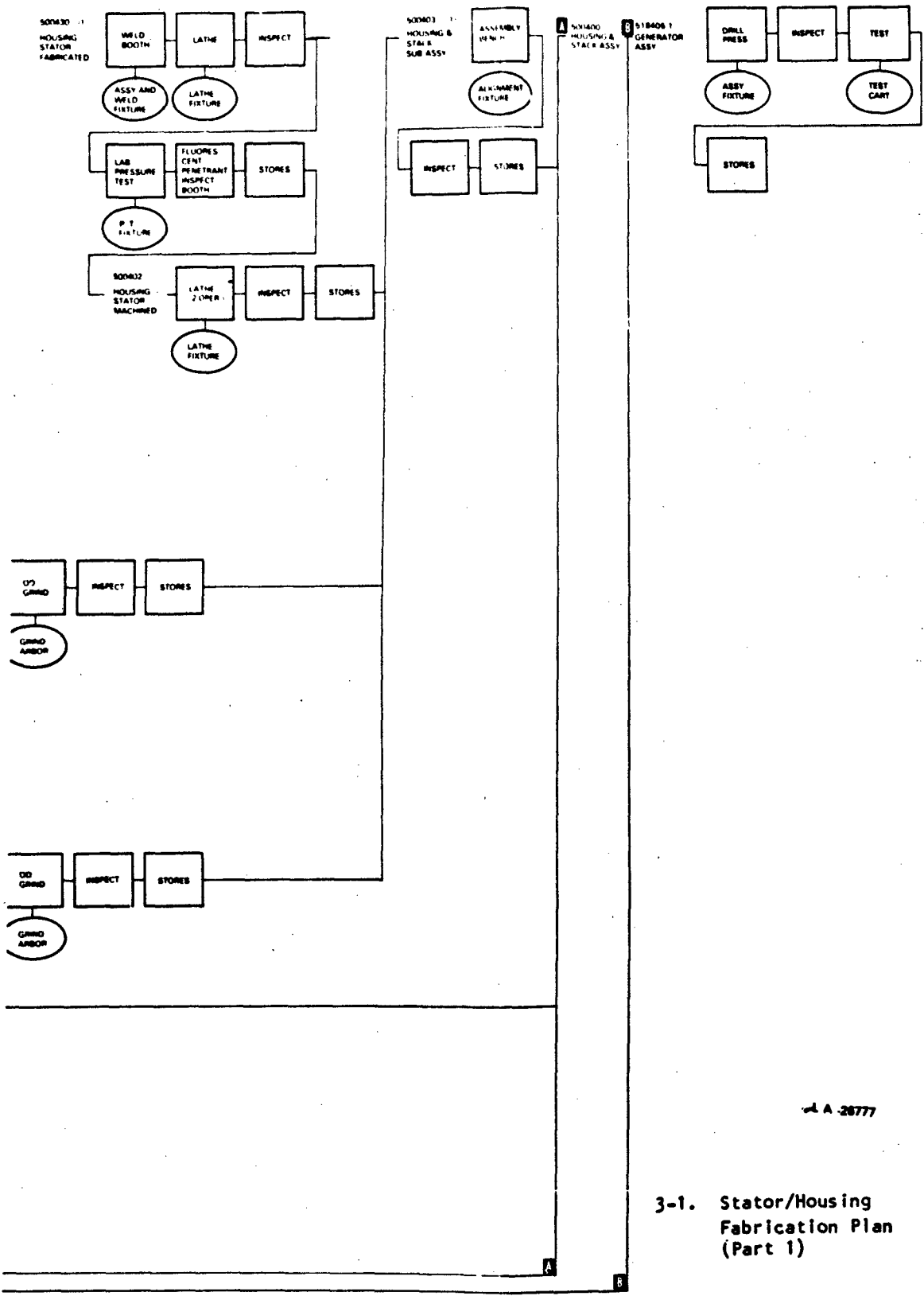
3.2 LONG LEAD ITEM DESCRIPTIONS

Long lead is readily determined from the fabrication schedule presented in Figure 3-2. As shown in the figure, overall fabrication and assembly of the complete generator is 13 months.



HOUSING AND STACK COMPONENTS (FROM PART 2, PAGE 3-3)

GENERATOR COMPONENTS (FROM PART 3, PAGE 3-4)



A 28777

3-1. Stator/Housing
Fabrication Plan
(Part 1)

3-3/3-4

2

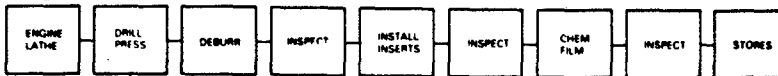
S00433 (2)
SUPPORT
WIRING

NEMA GRADE G11
EPOXY GLASS
LAMINATED



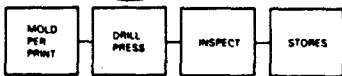
S00438 (1)
RING NEUTRAL

AL ALY PLATE
8081 T8



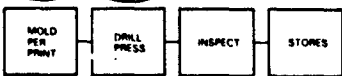
S00438 1 (10)
INSULATOR
NEUTRAL RING

NEMA GRADE G11
EPOXY GLASS
LAMINATED



S00438 2 (2)
INSULATOR
NEUTRAL RING

NEMA GRADE G11
EPOXY GLASS
LAMINATED



S00401 1 (21)
INSULATOR

S00422 (1)
BORE SEAL
ASSY



GLASS
CLOTH

MISC
DETAILS (1)

S00427-1 (42)
H2 RECD
TERMINAL
ELEC

635 HEX BAR
ZIRCONIUM COPPER
CDA-180 (HARD)



S00428-1 (42)
SLEEVE

NEMA GRADE
G11 1.00 DIA BAR



S00428-2 (42)
WASHER

NEMA GRADE
G11 1.00 DIA BAR



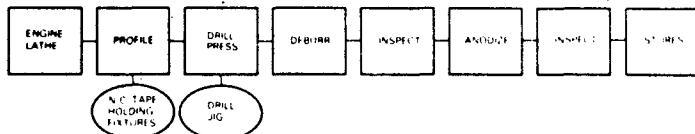
TERMINAL
DETAILS (42) PURCHASED

500437
ROLLER BEARING

PURCHASED

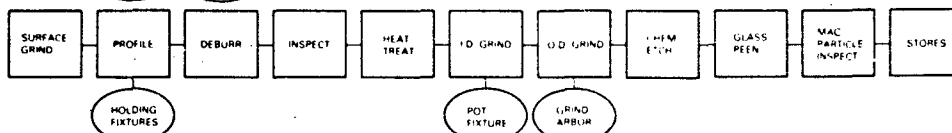
500401
RETAINER
BEARING

AL ALY PLATE
7075 (COND 735)



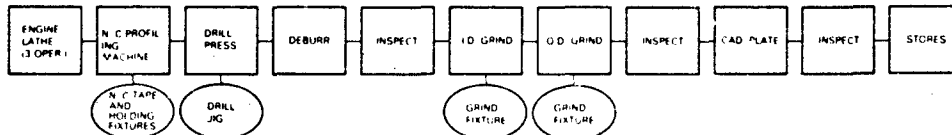
2047324
MOUNT RESILIENT
BEARING

4340 STEEL
ANALYSIS
6.50 O.D. TUBING
X 5.0 WALL



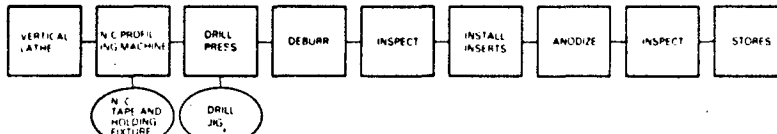
500435 (1)
SUPPORT ASSY
BEARING

10" O.D. X 4" I.D.
1015 STL TBG



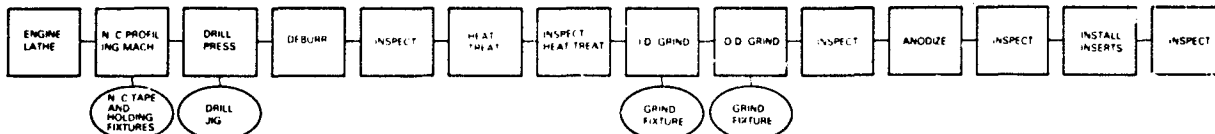
500430 (1)
END BELL ASSY
(LEAD END)

AL ALY PLATE
7075 (735)



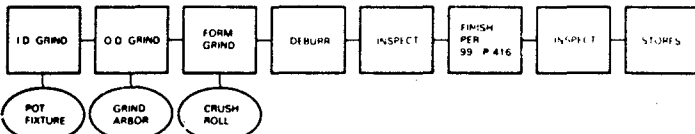
500432 (1)
END BELL ASSY

1.50" THICK PLATE
AT ALLOY
7075 (735)



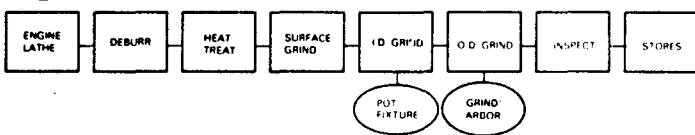
2046874 (1)
SPACER

4.25 O.D. X 3/8"
WALL TUBING
1015 STL



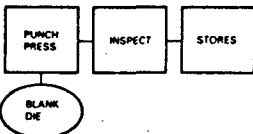
2047326 (1)
SPACER

6.00 DIA BAR
4340 STL
MIL S 5000



2047328 (1)
WASHER SHIM

0.10 STL STRIP
99 S 690
1010 OR 1020 STL



DUCT* (1)

FINAL CONFIGURATION OF DUCT IS NOT DEFINED

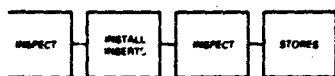
DUCT* (1)

FINAL CONFIGURATION OF DUCT IS NOT DEFINED

MSC
DETAILS

2048960
ROTOR ASSY

B



LA-26779

Figure 3-1. Stator/Housing Fabrication Plan
(Part 3 Inserts at B of Part 1)

3-7/3-8

2

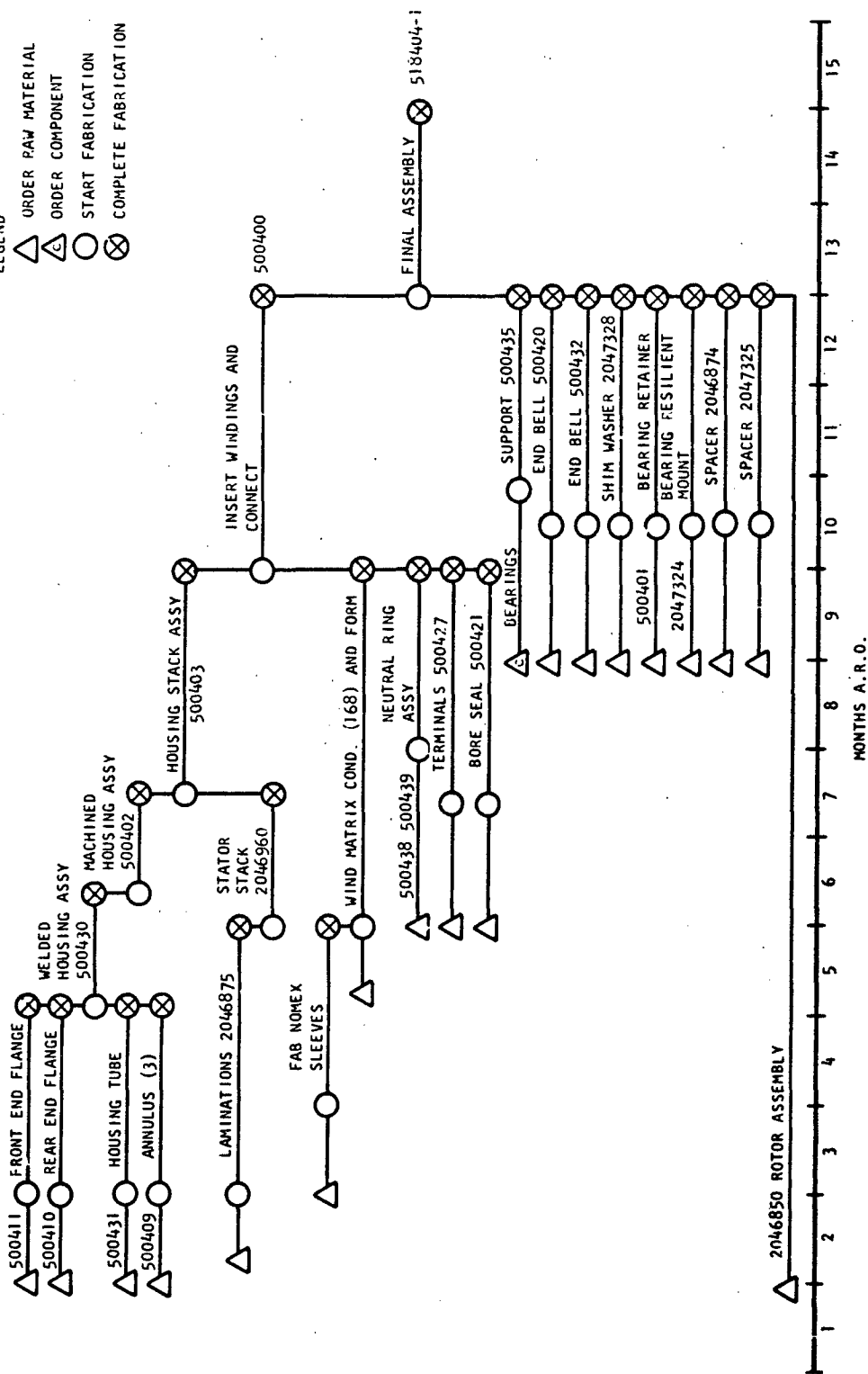
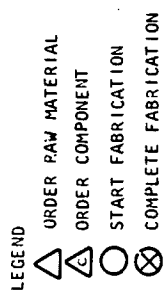
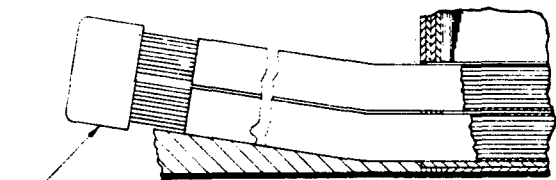


Figure 3-2. Fabrication Schedule

INDEX OF DRAWINGS

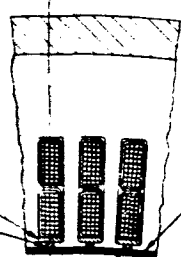
500400	Stator and Housing Assy
500401	Bearing Retainer
500402	Machined Stator Housing
500403	Housing and Stack Assy
500409	Annulus Subassy
500410	Housing Support Subassy
500411	Plate Flange Subassy
500420	End Bell Assy (Lead End)
500421	Bore Seal Fabrication
500422	Bore Seal Assy
500425	Annulus Details
500426	Terminal Insulator
500427	Electrical Terminal
500428	Flanged Terminal Plate
500429	Housing Support
500430	Fabricated Stator Housing
500431	Housing Tube
500432	End Bell Assembly
500433	Bore Seal Support
500434	Winding Assy Form
500435	Bearing Support Assembly
500436	Ball Bearing (Purchased part--not included)
500437	Roller Bearing (Purchased part--not included)
500438	Neutral Ring Insulator
500439	Neutral Ring
518402	Generator System, 10MW
2046855	Balance Weight
2046874	Spacer
2046875	Lamination
2046960	Stator Stack Assy
2047040	Bore Seal Tool End Cap
2047043	Spacer
2047176	Bore Seal Tool Body
2047324	Resilient Bearing Mount
2047325	Spacer
2047328	Shim Washer
2047329	Warning Label
94-38-0434	Stator Cooling Test
LSK 17367	Stator Cooling Test Rig

H
G
F
E
D
C
B
A



LEEVE, ELECT
TBD

DETAIL E
SCALE 5/1 (SEE SHT 1)

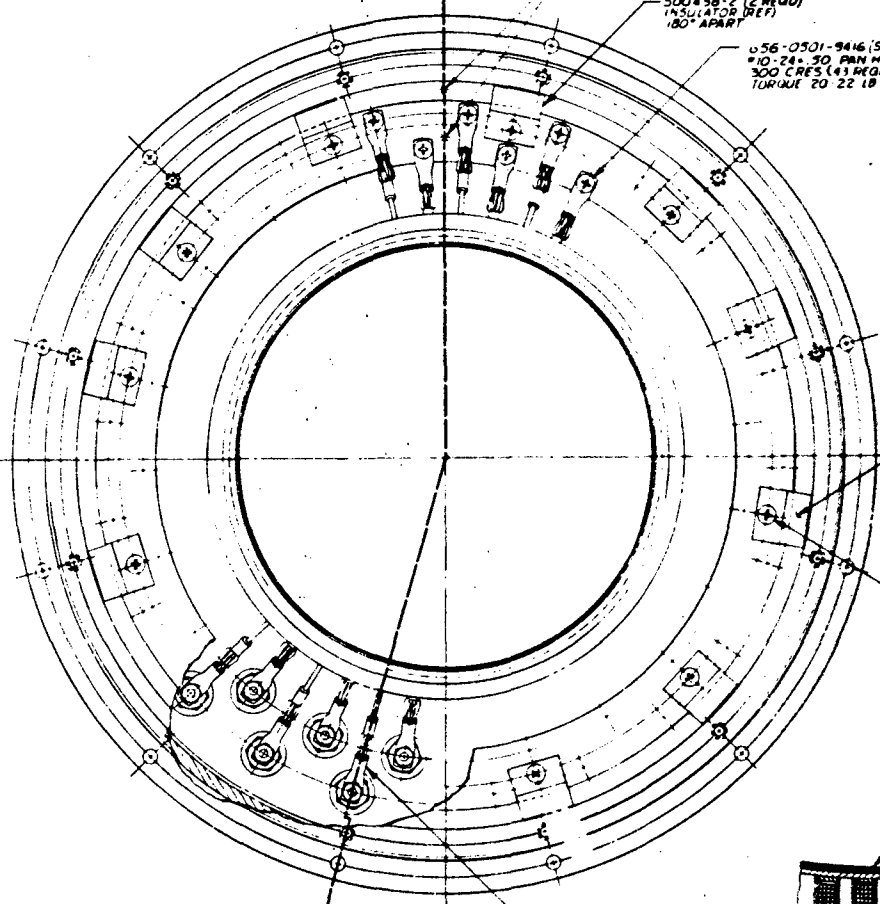


0.2 THICK SLOT WEDGE
NEMA GRADE (GII) MATERIAL

SLOT FILLER
NEMA GRADE (GII) MATERIAL

500422-1

DETAIL D
SCALE 5/1



CENTER PUNCH
REF MARK

500438-2 (2 REQD)
INSULATOR (REF)
180° APART

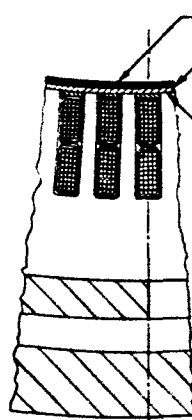
U56-0501-9416 (SCREW;
#10-24 x .50, PAN HD,
300 CRES (41 REQD)
TORQUE 20-22 LB IN

500438-1 (8 REQD)
INSULATOR REF

U56-0511-9420 (12 REQD)
#10-24 x .63 FL HD 300 CRES
TORQUE 20-22 LB IN
(3 SCREW)

SEE SHT 1 A

MS 25036-115
ELECT LUG (84 REQD)



BORE SEAL (REF)

CLASS CLOTH (REF)

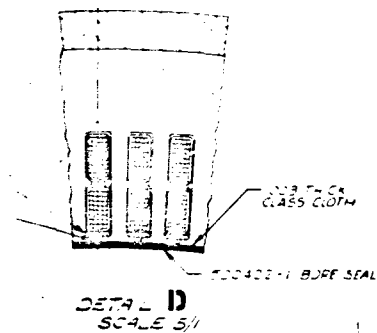
0.20 x .25 STACK SPACE FILLER
NEMA GRADE (GII) MATERIAL
3 REQD

DETAIL B
SCALE 5/1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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100	REVISED		



500498-1 (REGD)
INSULATOR REF

5-0511-9810 (12 REGD)
54" x 63" FLM 300 CRES
5 JUE 22 22 LB IN
S. RFW

- BORE SEAL REF

CLASS CLOTH REF

1/4" OF PASTE FILLER
VIA UNDER (OH) MATERIAL
REGD

SECTION F - F

NOTES UNLESS OTHERWISE SPECIFIED

E 70210 500498
SHEET 1 OF 2

3-13/3-14

H

G

F

E

D

C

B

A

59055F18-400
SLEEVING

OIL IN

500403-1 HSG & STACK ASSY
(1 REQD)INK STAMP ARE
USING WHITE
.25 MIN HIGH
TYP 5 PLACE:DETAIL E
SEE SHT 2M83248/1-260
2 REQD500433-1
SUPPORT (2 REQD)F
(SEE SHT 2)OIL
OUTOIL
IN500412-1
CONDUCTOR
3TY 168500439-1 RING
(1 REQD)

656-0501-9416 (REF)

656-0511-9420 (REF)

500438-2
INSULATOR (2 REQD)500438-1
INSULATOR (10 REQD)S8157CY77-032 WASHER
(43 REQD)F
(SEE SHT 2)

SECTION A-A

MS 35649-205 NUT
(43 REQD)MS 35333-107 WASHER
(43 REQD)S8157CY63-032 WASHER
(43 REQD)MS 35649-2355 NUT
(129 REQD)500427-1 TERMINAL
(43 REQD)NAS 1523C8E O-RING
(43 REQD)NAS 1523C8E O-RING
(43 REQD)500426-1 INSULATOR
(43 REQD)500426-2 INSULATOR
(43 REQD)

△ SLEEVE WIRE WITH 59055F18 (TEFLON SLEEVE)
INTERNALLY (DO NOT BRING SLEEVING THROU)

△ COVER JOINT WITH MS-A-46050 APPROX.

△ THERMOCOUPLE WIRE (TYPE K, 36 GA, 40 IN)
WINDING AS SHOWN, 5 PLACES 270°
ADD ONE DROP PER RS184E05

NOTES: UNLESS OTHERWISE SPECIFIED

8

7

6

5

4

A	3-15-59	C	D	E	F	G	H
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- PART NO. **500400-1**
 THIS DRAWING IS THE PROPERTY OF THE GOVERNMENT OF THE UNITED STATES OF AMERICA. IT IS TO BE USED FOR THE PURPOSES OF THE CONTRACT UNDER WHICH IT WAS PREPARED. IT IS NOT TO BE REPRODUCED OR TRANSMITTED IN ANY FORM OR BY ANY MEANS, ELECTRONIC OR MECHANICAL, INCLUDING PHOTOCOPYING, RECORDING, OR BY ANY INFORMATION STORAGE AND RETRIEVAL SYSTEM, WITHOUT PERMISSION IN WRITING FROM THE GOVERNMENT OF THE UNITED STATES OF AMERICA.

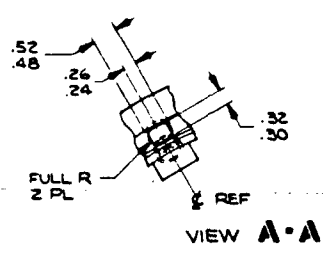
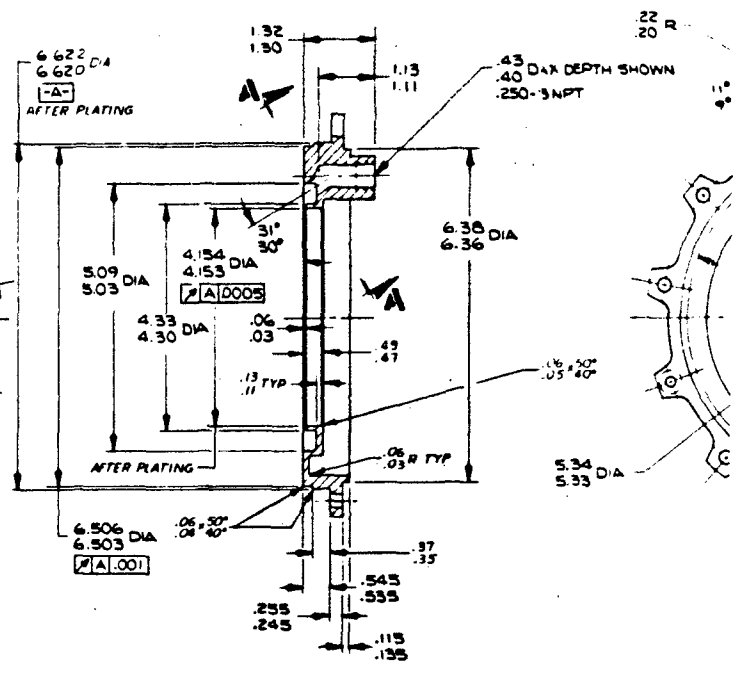
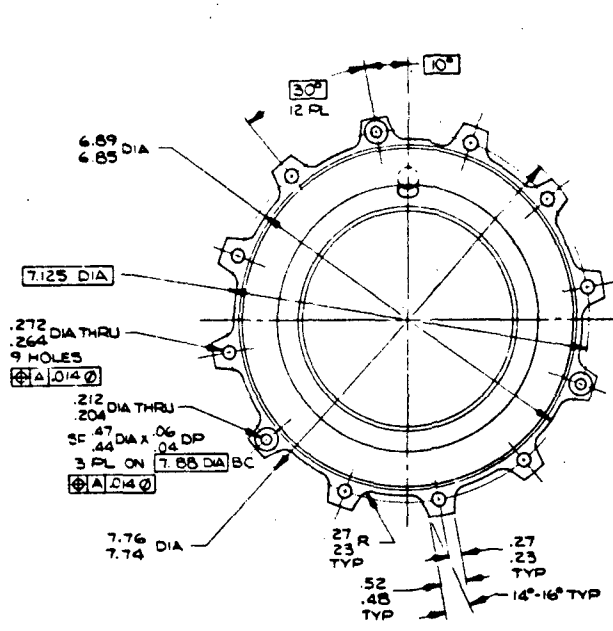
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 REV. **1**
 DATE **10-1-64**
 BY **10150-001-001**
 CHECKED BY **10150-001-001**
 APPROVED BY **10150-001-001**
 APPLICATION

TITLE **STATOR & HSG ASSY**
 PART NO. **500400**
 SCALE **1/1**
 SHEET **1** OF **1**

2

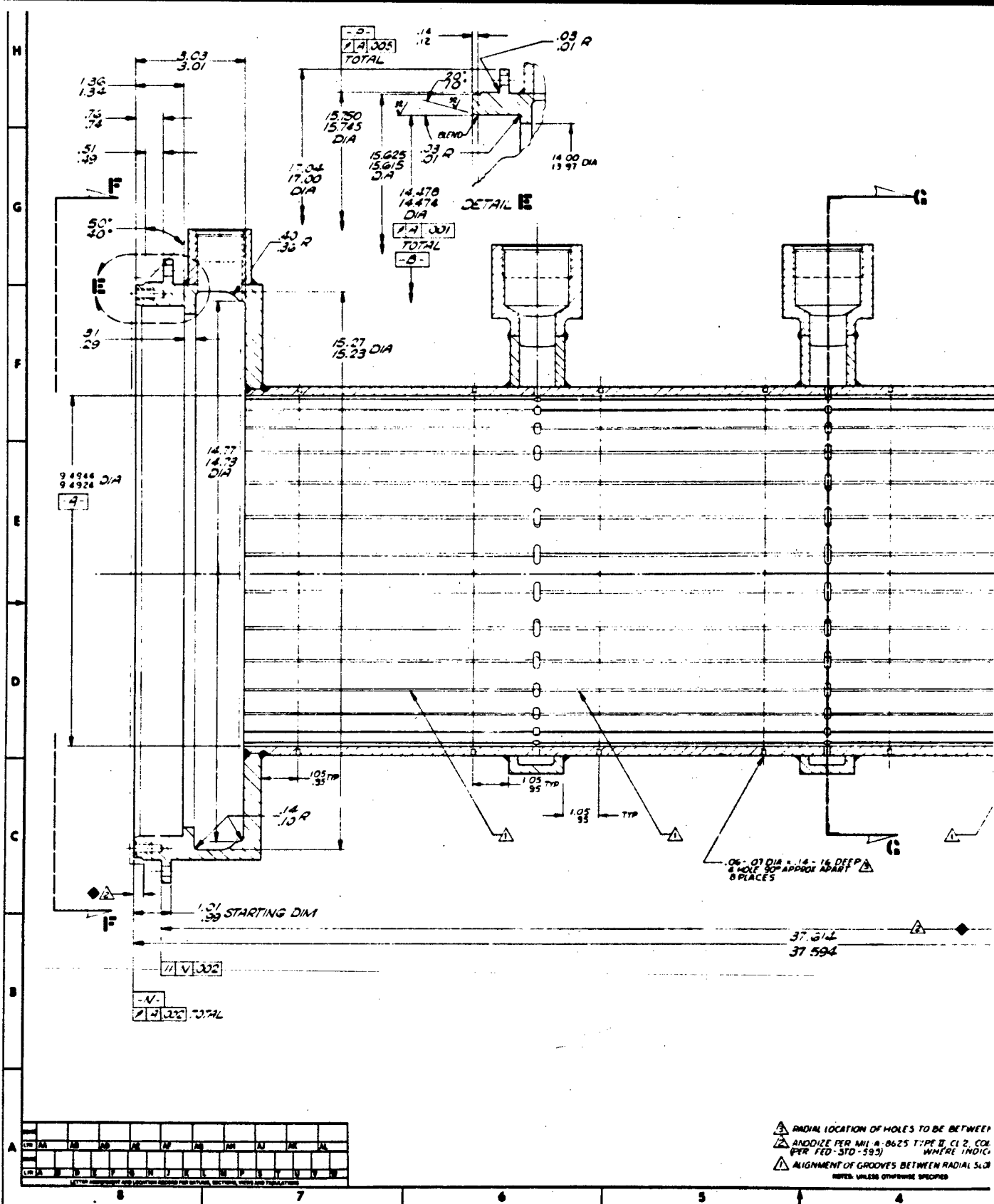
3-11/3-12

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A

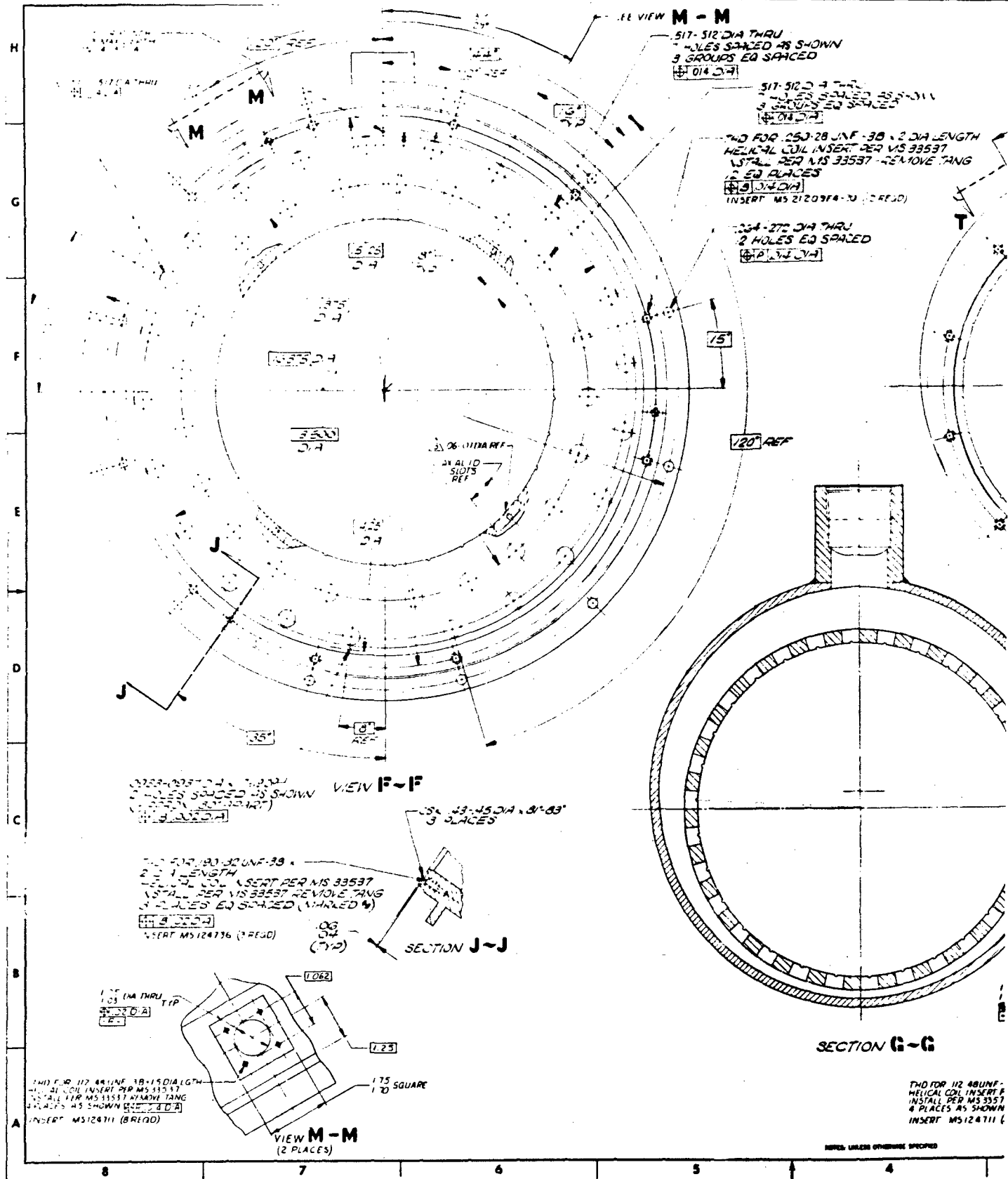


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ANODIZE PER MIL A 8625 TYPE II CL
(COLOR BLUE TED STD 595 NQ 23100)
FINES UNLESS OTHERWISE SPECIFIED



3. RADIAL LOCATION OF HOLES TO BE BETWEEN AXIAL LD. SLOTS 2. ANODIZE PER MIL-B-8625 TYPE II CL 2, COLOR BLUE (#23180) PER FED-STD-593 WHERE INDICATED BY  1. ALIGNMENT OF GROOVES BETWEEN RADIAL SLOTS AS SHOWN NOT RECD. NOTES: UNLESS OTHERWISE SPECIFIED		PART NO 500402 1 THIS DRAWING IS THE PROPERTY OF THE GOVERNMENT AND IS NOT TO BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT PERMISSION OF THE GOVERNMENT	DRAWING NO. 500402 1 REV. 1 DATE 10-1-60 BY 1010 CHECKED BY 1010 APPROVED BY 1010 TITLE 500402 1 1010	HOUSING STRUCTOR INCH-NEED 70210 500402 SCALE 1/1 SHEET 1 OF 1
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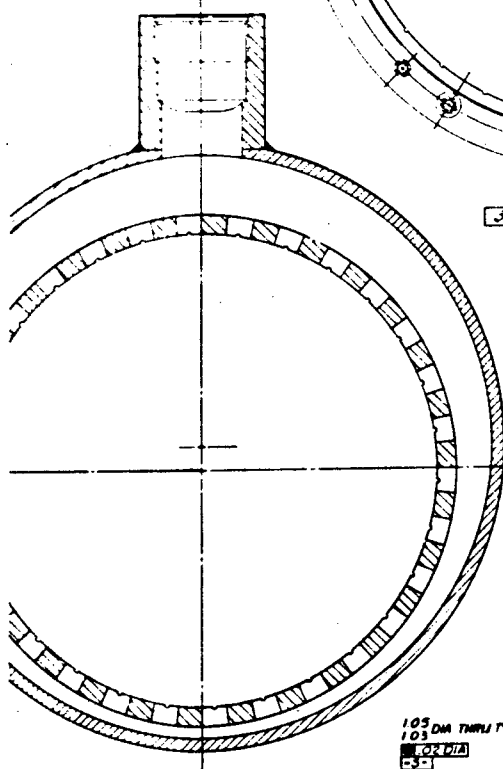
DIA THRU
SPACED AS SHOWN
AS ED SPACED

517-510-4-20
517-510-4-20
517-510-4-20
517-510-4-20

TWO FOR 250-28 UNF-35
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537-REMOVE TANG
3 EQ PLACES
INSERT MS 2124711 (B REQD)

250-28 UNF-35
2 HOLES ED SPACED
250-28 UNF-35

250-28 UNF-35

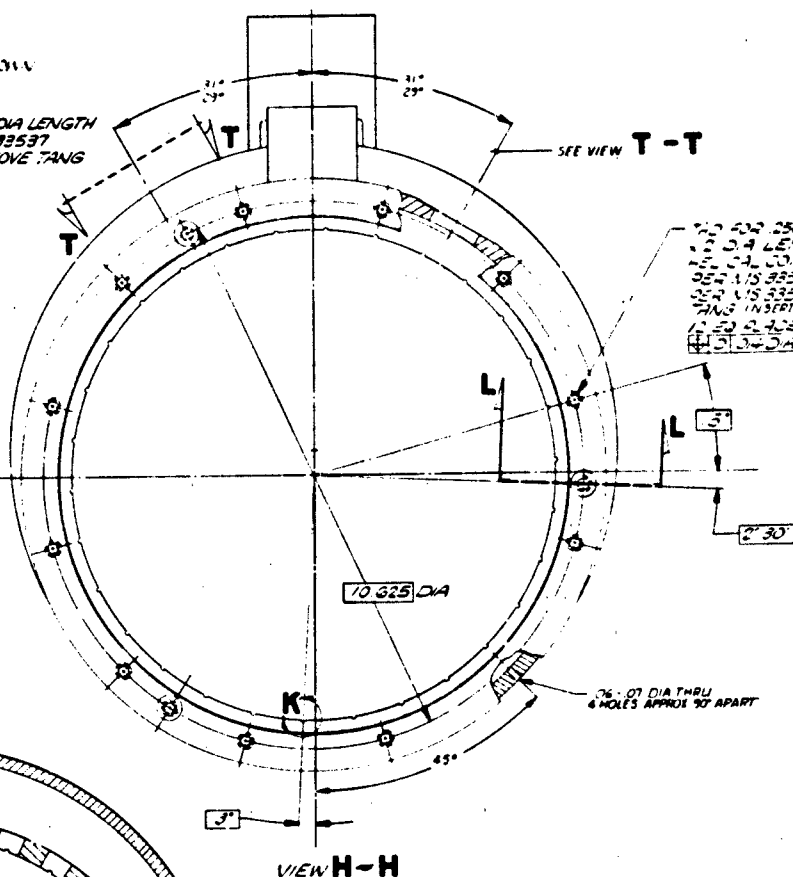


SECTION G-G

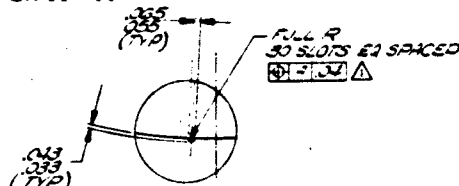
TWO FOR 112-48 UNF-35
HELICAL COIL INSERT PER MS 33537
INSTALL PER MS 33537-REMOVE TANG
4 PLACES AS SHOWN
INSERT MS 2124711 (B REQD)

VIEW T-T
(2 PLACES)

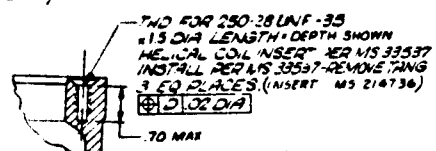
NOTE: VALUES OVERSHOWN LISTED



VIEW H-H



DETAIL K
SCALE 2/1



SECTION L-L

E 70210		500432	
SCALE 1/1		SHEET 2	

2

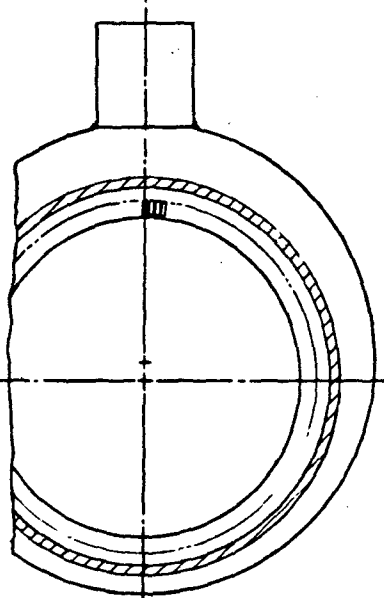
3-19/3-20

D

C

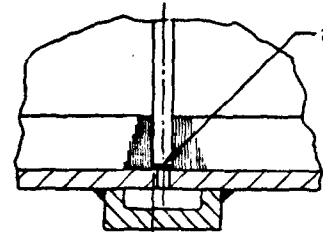
B

A



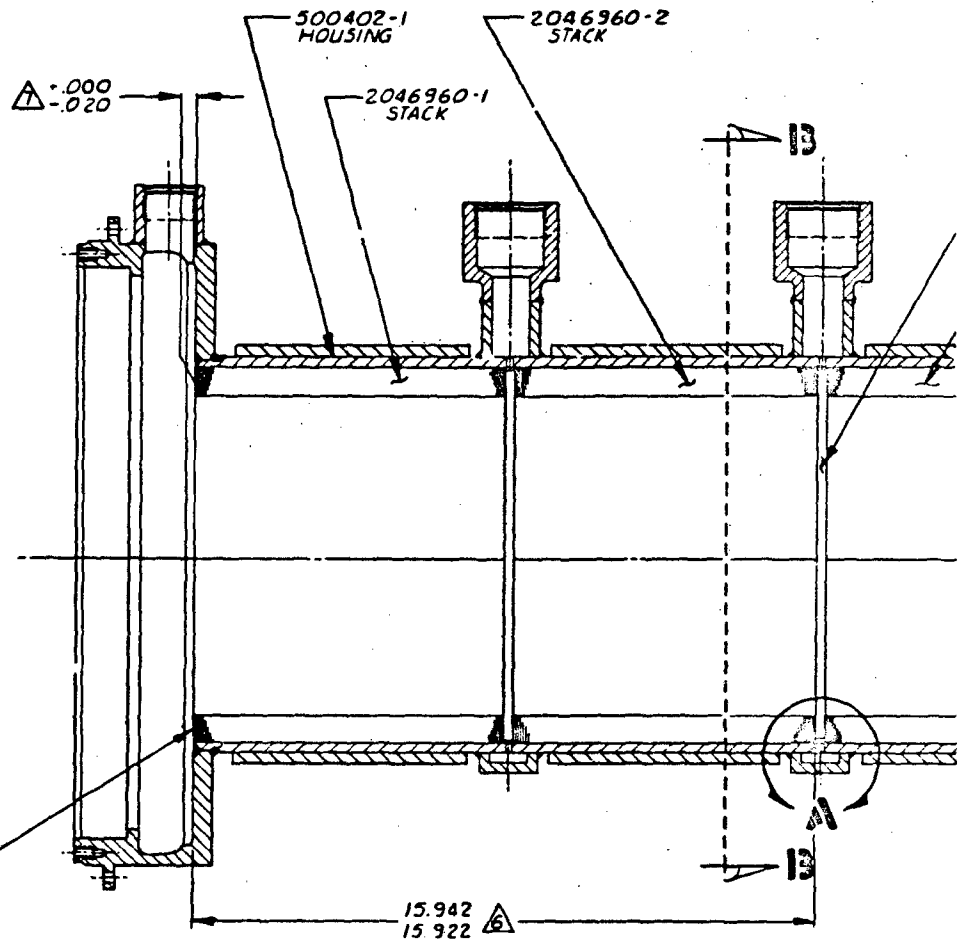
SECTION 13-13

END LAM MUST BE THIS SIDE



15.932(REF)

DETAIL A
SCALE 1/1



- 7 IF ALL 4 STACKS ARE INSTALLED AT ONE TIME THIS DIMENSION MUST BE USED.
- 6 IF ONE STACK AT A TIME IS INSTALLED LOCATING DIMENSION MUST BE USED.
- 5 A BLANKET MAY BE USED TO COVER THE HEATERS TO RETAIN THE HEAT.
- 4 STATOR SLOTS MUST BE IN LINE THRU ALL 4 STACKS. A DRILL ROD OR CENTERLESS GRINDING CAN BE USED FOR ALIGNING TOOL. A MIN OF 3 RODS MUST BE USED.
- 3 HEATING THE HOUSING (DYN 5, X1402-1) 310°F ± 20°F BY USING STRIP HEATERS & CONTROLLING THE TEMP WITH A THERMOSTAT.
- 2 FOR VISUAL INSPECTION OF STACK ALIGNMENT IN RESPECT TO THE OIL SLOTS IN THE HOUSING CAN BE SEEN THRU THE PORTS.
- 1 PARTS MUST BE SET UP AND PRE-ALIGNED IN FIXTURE PRIOR TO ASSY.

NOTES UNLESS OTHERWISE SPECIFIED

8

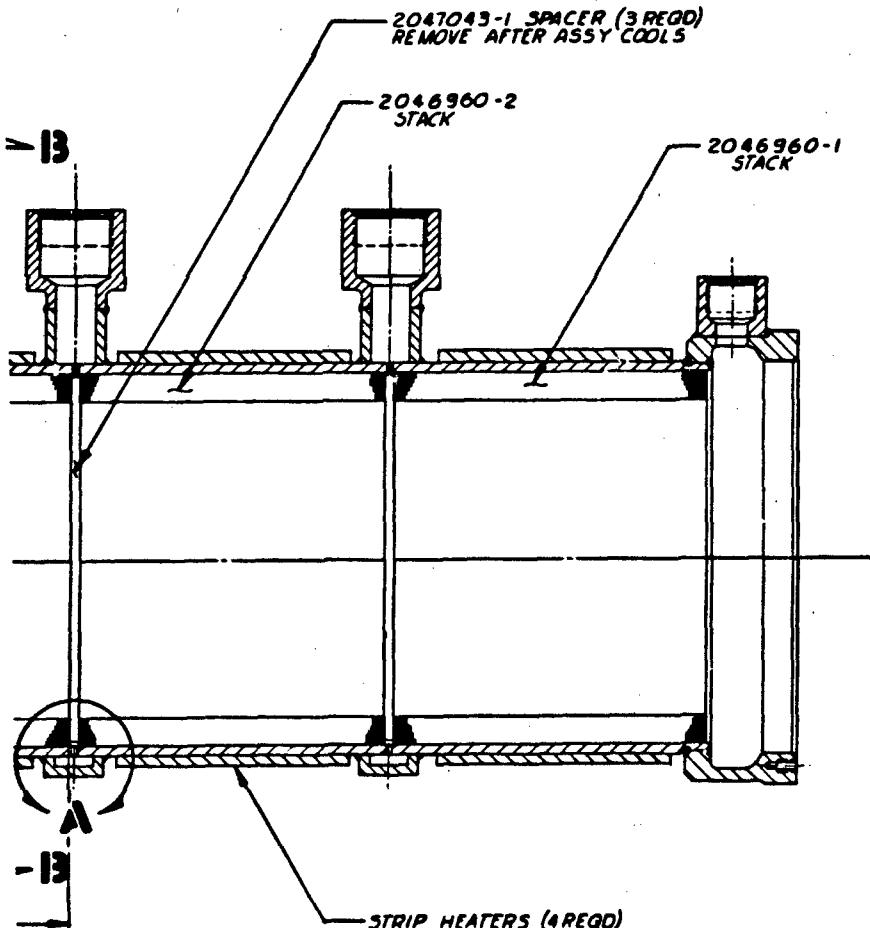
7

6

5

4

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NO. 500403	
SHEET	



INSTALLED AT ONE TIME
T BE USED.
E IS INSTALLED THIS
MUST BE USED.
SED TO COVER THE
THE HEAT.
IN LINE THRU ALL 4
CENTERLESS GROUND ROD
ING TOOL, A MIN.
USED.

STRIP HEATERS (4 REQD)
REMOVE AFTER ALL 4 STACKS
ARE INSTALLED AND THE ASSY
HAS BEEN COOLED TO 200°F MIN.

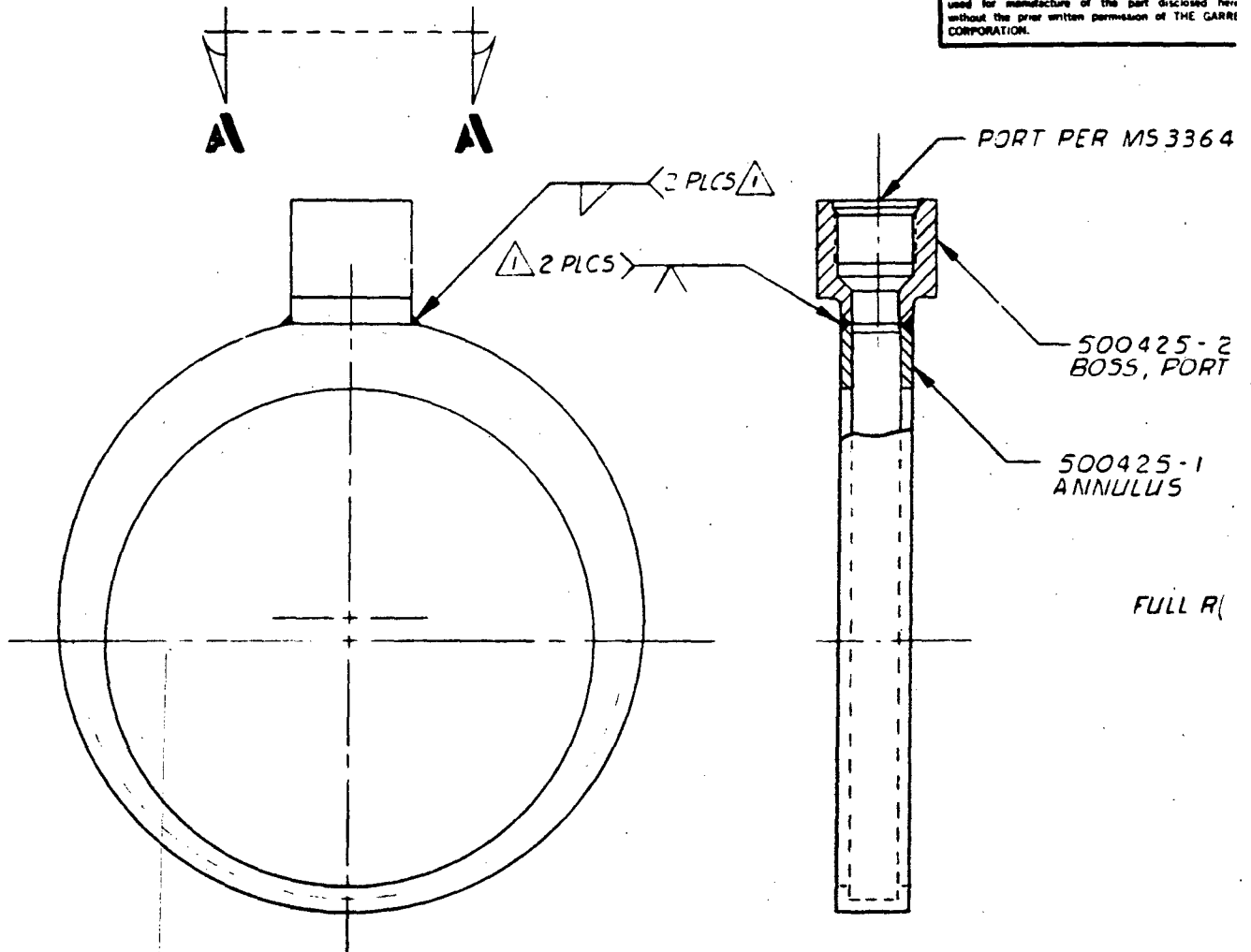
PART NO. 500403-1

UNLESS OTHERWISE SPECIFIED: DIMENSIONS IN INCHES DIMENSIONS IN MILLIMETERS DIMENSIONS IN FEET AND INCHES		 ANDREASSEN MANUFACTURING COMPANY A DIVISION OF THE BARRETT CORPORATION TORRANCE, CALIFORNIA	
HOUSING & STACK SUB ASSEMBLY		D 70210 500403	
SCALE 1/2"=1"		SHEET 1 OF 1	

3-21/3-22

2

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⚠ LOCATE BOSS ON FLAT PROVIDED ON MATING PART 1 WELD AS SHOWN.
 ⚠ WELD PER AIRSEARCH SPEC WBS 18
 NOTES: UNLESS OTHERWISE SPECIFIED

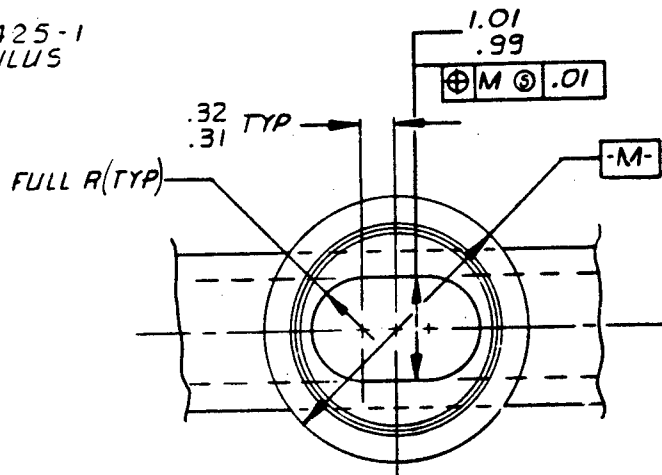
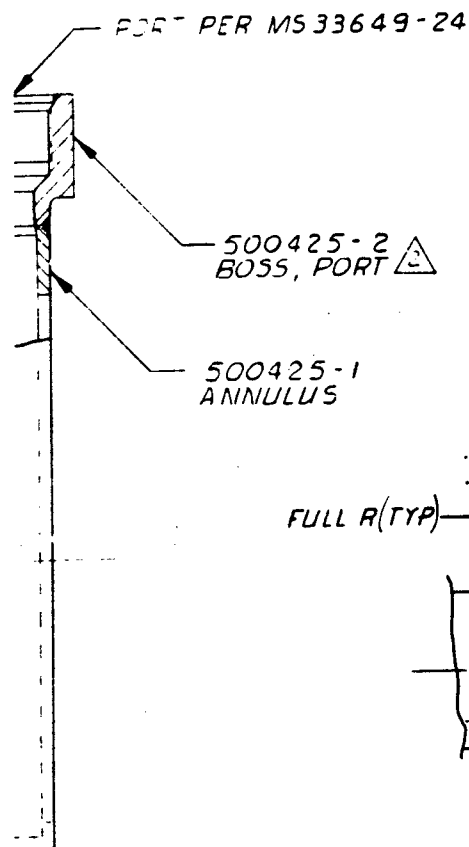
PART NO. 500409-1

3(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC883 <i>CLB</i> STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER MCS	
MATERIAL	PREPARE
FINISH PROCESS	CHE
	DESIGN
	VALUE
HEAT TREATMENT	MATL
	SYMB
	APVD
	DESIGN
	3
	COVER

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ZONE		LTR	DESCRIPTION	DATE	APPROVED



VIEW A-A

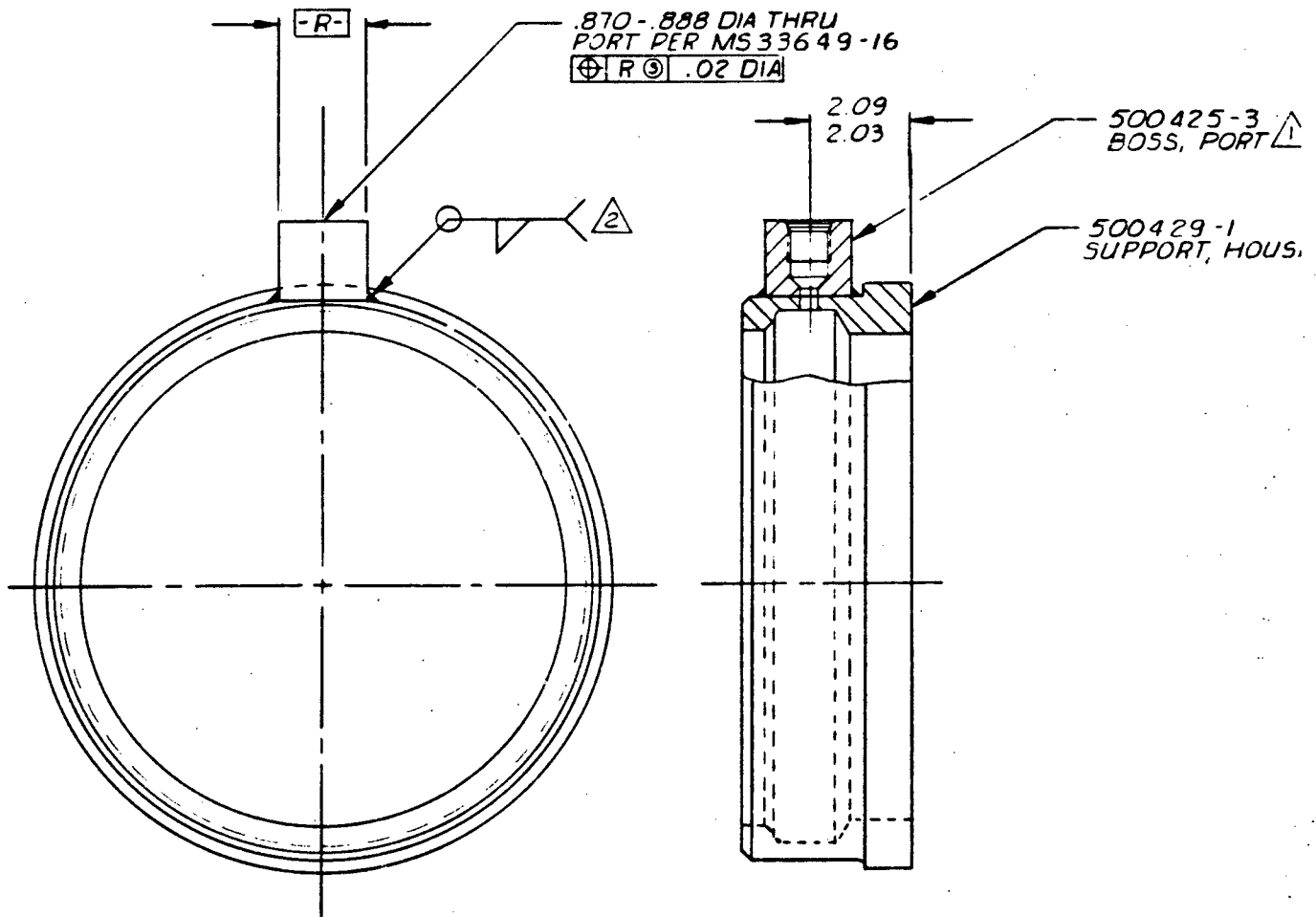
PART NO. 500409-1

UNLESS OTHERWISE SPECIFIED: BURN CONTROL PER SC883 CL8 STD INTERPRETATIONS PER PDS IDENTIFICATION MARKING PER MC18		CONTRACT NO.		AIRSEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL		PREPARED BY <i>Ryan G. 820114</i>		ANNULUS. SUB. ASSY	
FINISH PROCESS		CHK			
HEAT TREATMENT		DESIGN			
		VALUE ENGR			
		MAYL			
		STRESS			
		APVD		SIZE CODE IDENT NO DWS NO	
		DESIGN SUPERVISOR PROJECT ENGINEER <i>J. J. Sullivan</i> 1-18-82		C 70210 500409	
		GOVERNMENT APVD		SCALE 1/2 SHEET 1 OF 1	

2 3-23/3-24

500409

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- △ LOCATE BOSS ON FLAT PROVIDED ON MATING PART & WELD AS SHOWN.
- △ WELD PER AIRESEARCH SPEC WBS18
- NOTES: UNLESS OTHERWISE SPECIFIED

PART NO. 500410-1

1(-1)	500430-1	518404-1
REQD	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER S-383 C/LB STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER MCS		PREPARED BY
MATERIAL	DESIGN	CHK
	VALUE ENGR	
	MATL	
	STRESS	
	APVD	
	DESIGN SUPERV	
	J. J. S.	
	1-18-72	
	GOVERNMENT	

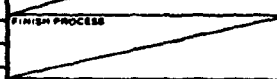
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

09
03

500425-3
BOSS, PORT 

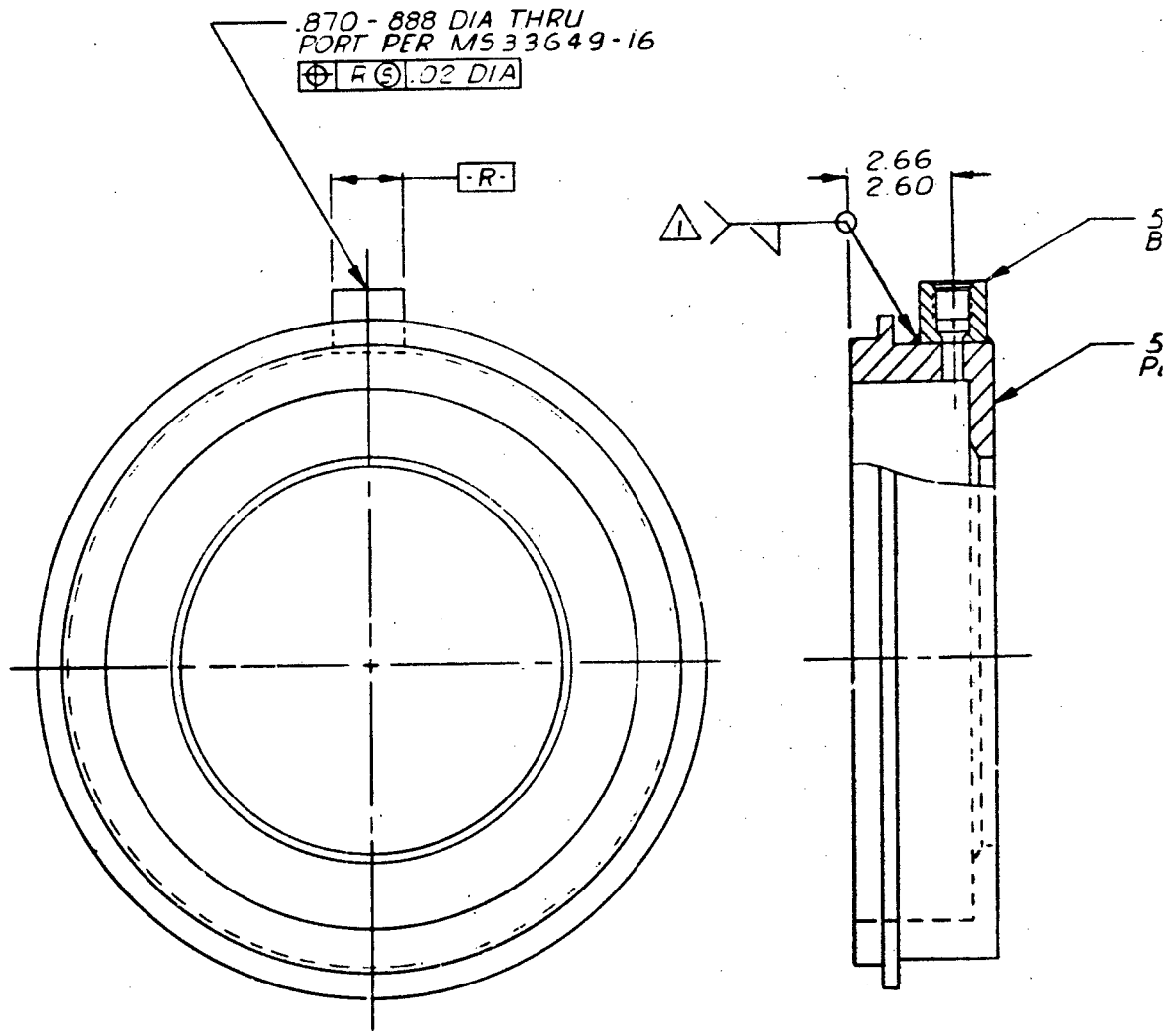
- 500429-1
SUPPORT, HOUSING

500410

UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SCQS CLB STD INTERPRETATIONS PER PMS IDENTIFICATION MARKING PER MC16		CONTRACT NO.		 GARRETT A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA		
MATERIAL		PREPARED BY Handy 020114		SUPPORT, HOUSING SUB. ASSY		
		CNE				
		DESIGN				
		VALVE ENGR				
		MATL				
FINISH PROCESS		STRESS				
APVD						
DESIGN SUPERVISOR		PROJECT ENGINEER				
33 J. J. [Signature] 1-573		HA 1-573				
HEAT TREATMENT		GOVERNMENT APVD		SIZE	CODE IDENT NO	DWG NO
				C	70210	500410
ION				SCALE	SHEET / OF	
				1/2		

3-25/3-26

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PART NO. 500411-1

UNLESS OTHERWISE SPECIFIED:
BURR CONTROL PER SC883 **CLB**
STD INTERPRETATIONS PER PMS
IDENTIFICATION MARKING PER
MC13

MATERIAL	PREPARED
DESIGN	CHE
VALUE	DESIGN
MATL	DESIGN
STRENGTH	DESIGN
APPROVED	DESIGN
DESIGN	DESIGN
1-1	GOVERNMENT

11-1	500430-1	518404-
REQD	NEXT ASSY	USED ON
APPLICATION		

2. LOCATE BOSS ON FLAT PROVIDED ON MATING PART & WELD AS SHOWN.

1. WELD PER AIRSEARCH SPEC. WBS 18

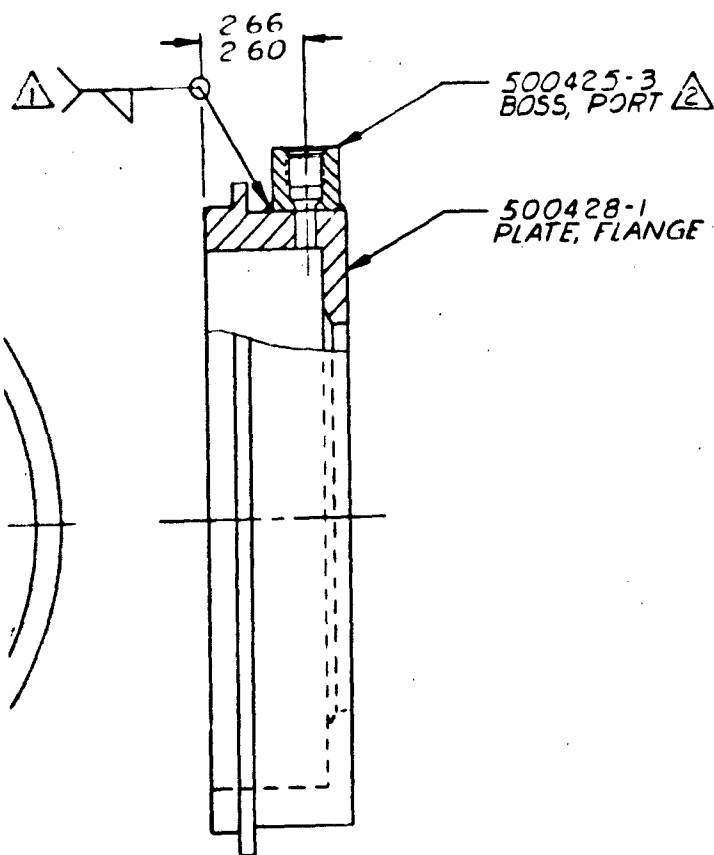
NOTES: UNLESS OTHERWISE SPECIFIED

which are the property of THE GARRETT CORPORATION
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 CORPORATION.

REVISIONS			DATE	APPROVED
ZONE	LTR	DESCRIPTION		

R

5



500411

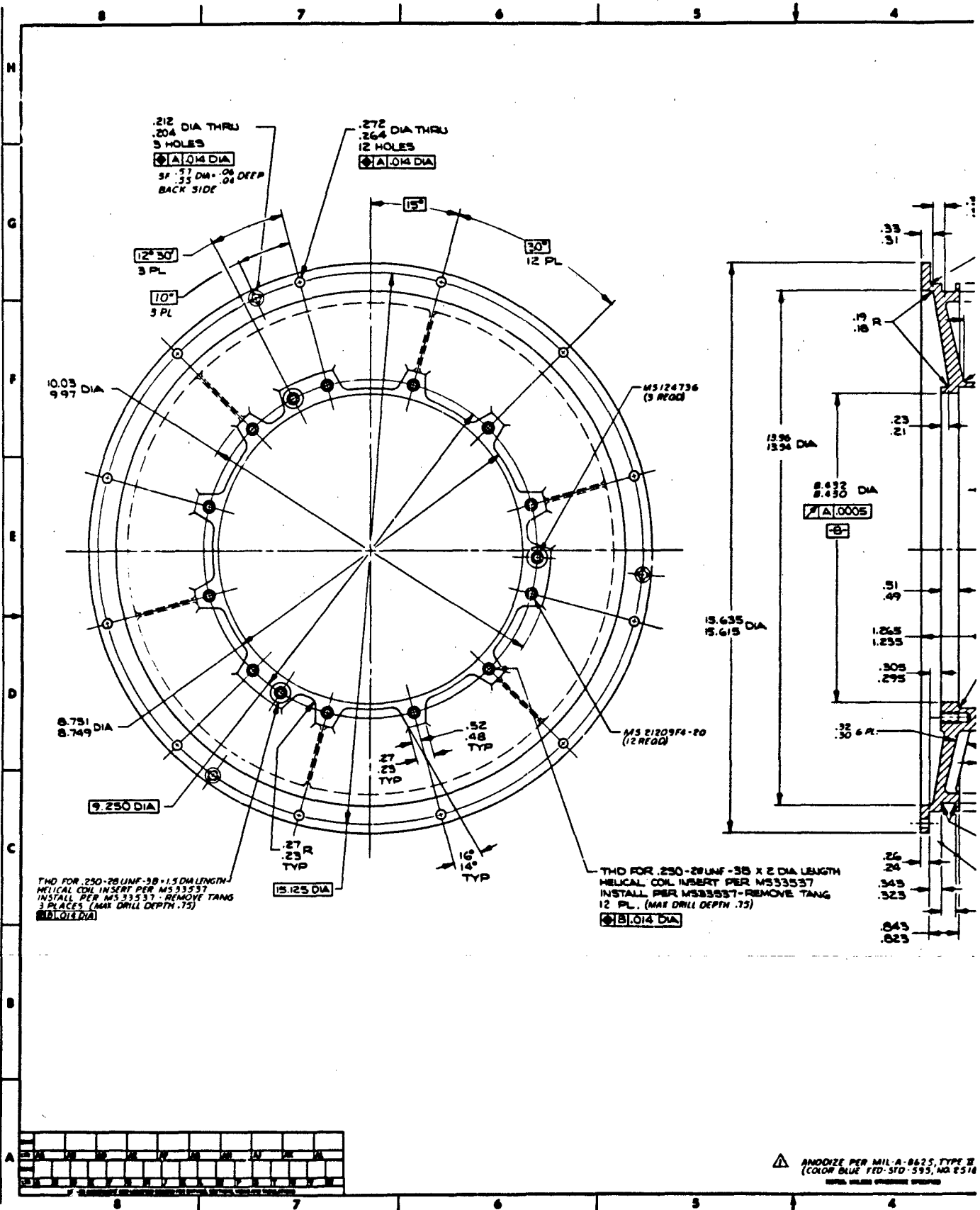
PART NO. 500411-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SCSS <i>CLB</i> STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER MC18		CONTRACT NO.		AIRESEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
DESIGNED BY <i>Handy 82014</i>		PLATE, FLANGE SUB ASSY			
CHKD					
DESIGN					
VALVE ENGR					
MATERIAL		MATERIAL		SIZE	
FINISH PROCESS		FINISH PROCESS		CODE IDENT NO	
HEAT TREATMENT		HEAT TREATMENT		DWG NO	
GOVERNMENT APPROV		GOVERNMENT APPROV		C 70210	
				500411	
				SCALE <i>NONE</i>	
				SHEET 1 OF 1	

130-1 516404-1
 ASSY USE: *M*
 LOCATION

2

3-27/3-28

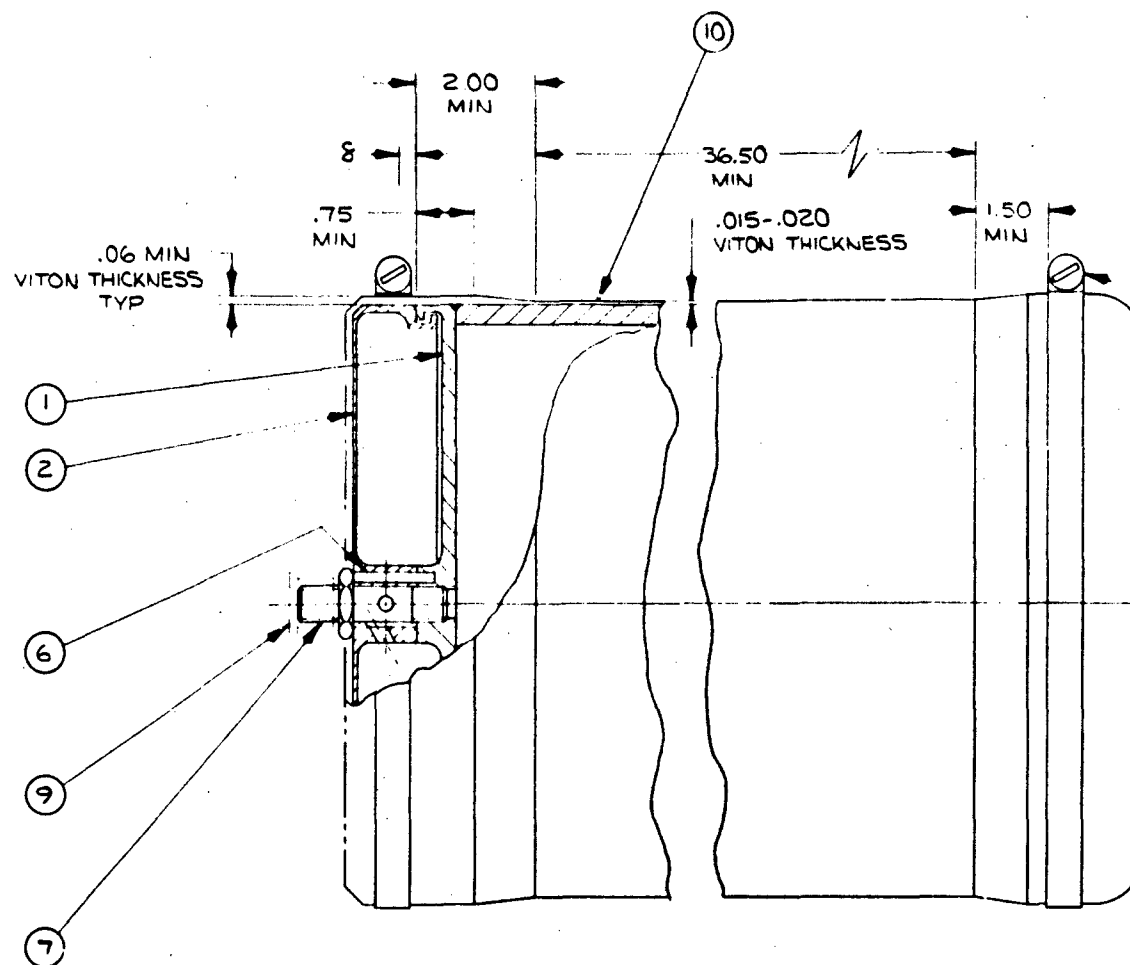


SECTIONS			
SECTION	DESCRIPTION	DATE	REMARKS



SCALE 1:100,000

2



FABRICATION

- STEP 1. ASSEMBLE MACHINED PARTS, FIND NO. 1, 2, 6, 7, 8 & 9 (OMIT CLAMPS) AS SHOWN.
- STEP 2. SPRAY ENTIRE ASSY WITH FIND NO. 11, LET DRY & BUFF LIGHTLY.
- STEP 3. DIP ASSEMBLY IN FIND NO. 10 TO OBTAIN BUILD-UP AS SHOWN.
- STEP 4. AIR DRY FOR 48 HR. THEN STEP CURE STARTING AT 150°F IN INCREMENTS OF 50°F PER HR. TO 300°F. TOTAL CURING TIME 4 HR.
- STEP 5. ASSEMBLE CLAMP FIND NO. 5 AS SHOWN.
- STEP 6. REMOVE FIND NO. 9.
- STEP 7. PRESSURIZE INTERIOR TO TBD PSI TO SEPARATE BORE SEAL AT BOND LINE. (SEE DEFLECTION PRESSURE SCHEDULE).
- STEP 8. REMOVE PRESSURE.

PRESSURE PSID	δ IN
.88	0
1.76	0
4.41	.05
8.80	.10
32.7	.10
(PROOF PRESS)	

NOTES: UNLESS OTHERWISE SPECIFIED

8

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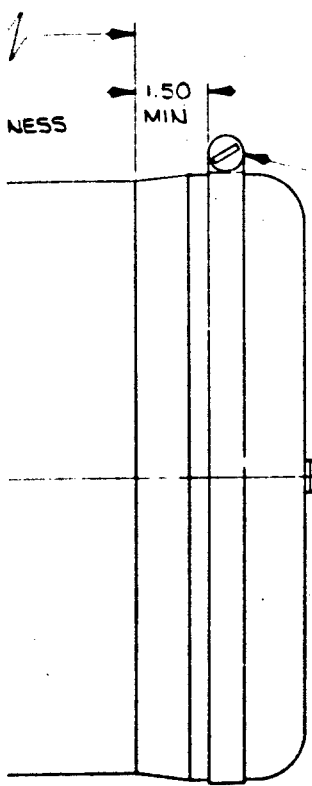
5

4

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REV STATUS									
SHEET									

ZONE		LTR	DESCRIPTION	DATE	APPROVED



(5) 2 REQD

(8)

PRESSURE	IN
PSID	
.88	0
1.76	0
1.41	.05
3.80	.10
2.7	.10

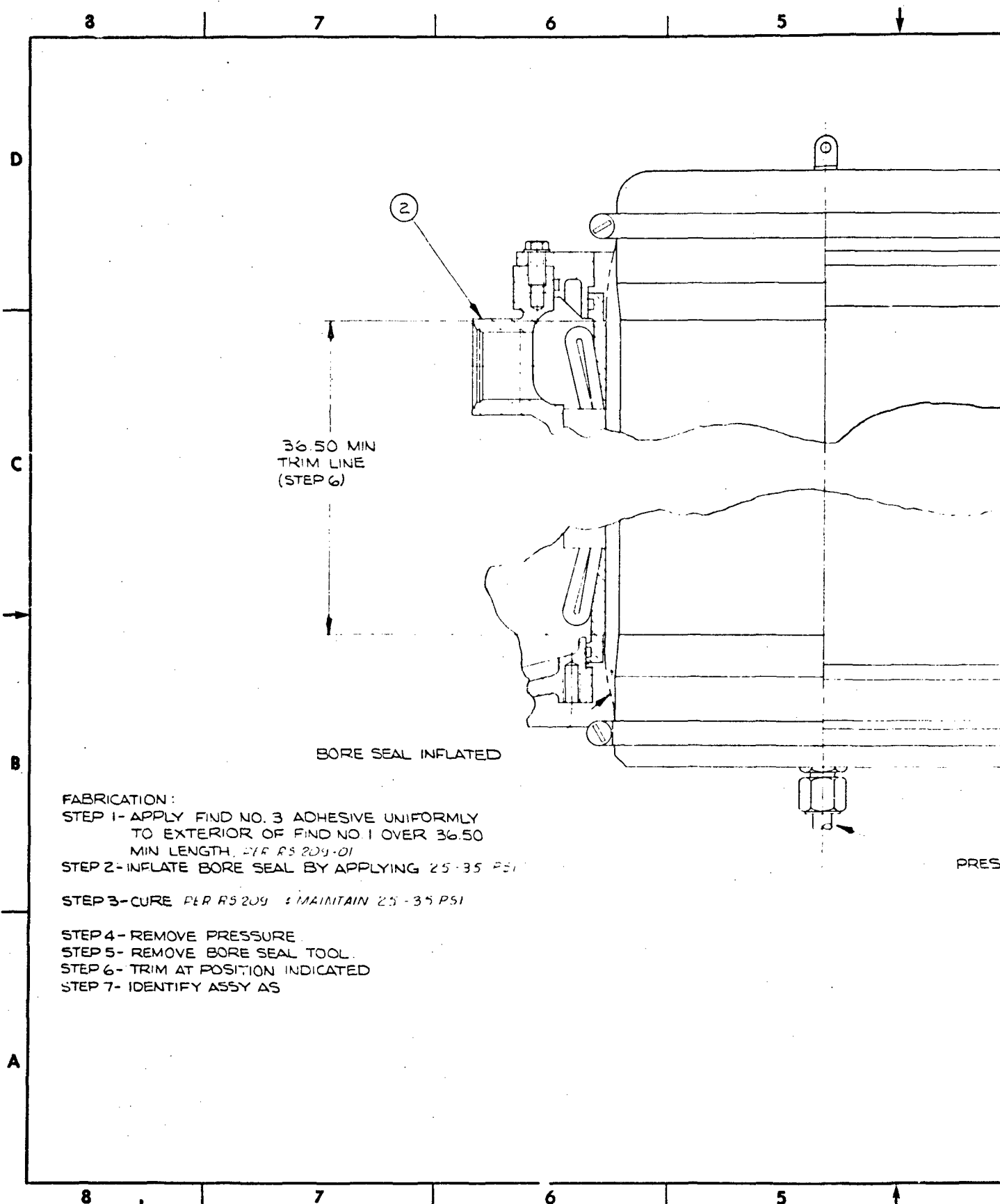
(IF PRESS)

PART NO. SEE SEPERATE PARTS LIST

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER BOES C-2 STD INTERPRETATIONS PER PMS IDENTIFICATION MARKING PER SEC10		CONTRACT NO. PROJECT NO. NAKAMURA 840728 DRAWING NO. 70210-020107 DATE BY CHECKED BY DATE		AIRSEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TERRANCE, CALIFORNIA	
MATERIAL SEE SEPERATE PARTS LIST		BORE SEAL FABRICATION		PART NO. 518404	
APPLICATION REQD NEXT ASSY USED ON		SCALE FULL		SHEET 1 OF 1	

3-31/3-32

2

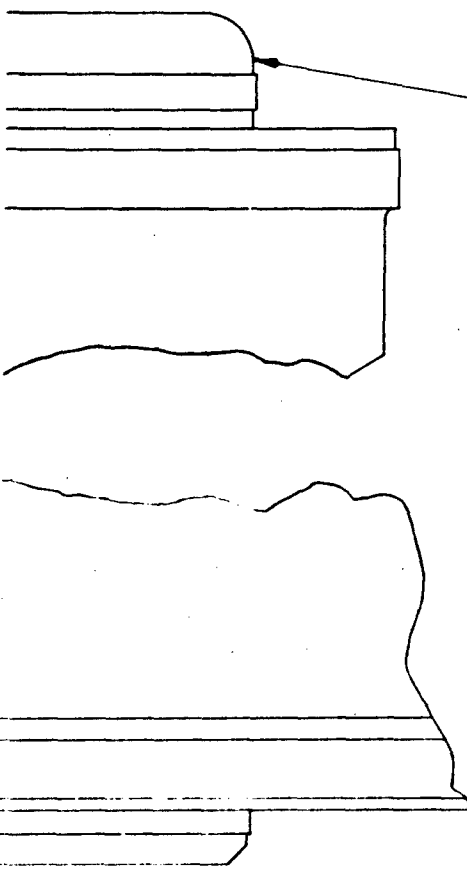


4
3
500422
1

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REV STATUS									
SHEET									

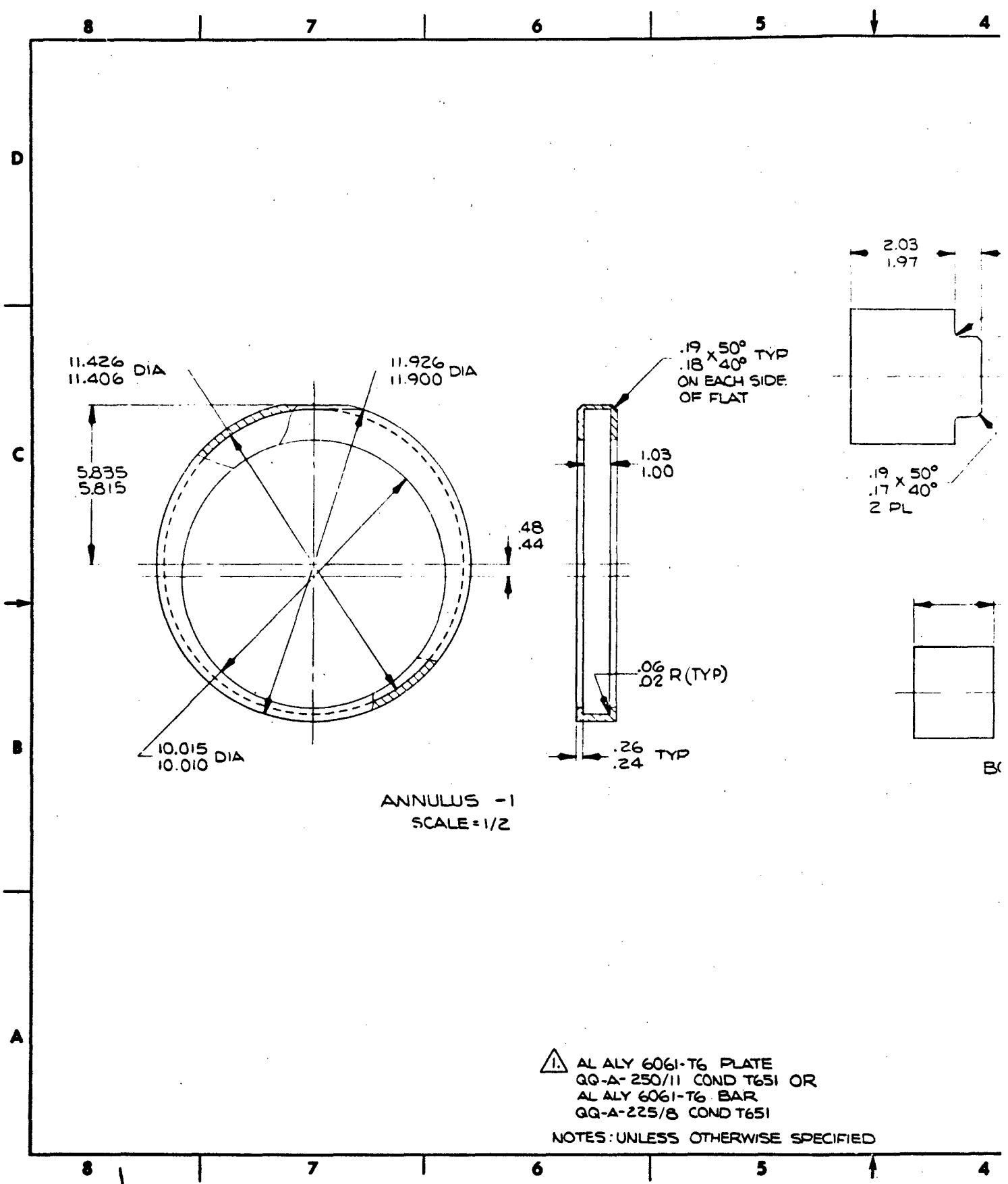
REVISE		DESCRIPTION	DATE	APPROVED
ZONE	LTP			



PART NO. SEE SEPERATE PARTS LIST

<table border="1" style="width: 100%;"> <tr> <td>READ</td> <td>NEXT ASSY</td> <td>USED ON</td> </tr> <tr> <td colspan="3">APPLICATION</td> </tr> </table>	READ	NEXT ASSY	USED ON	APPLICATION			UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SCRS - 1/2 STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER SCRS	CONTRACT NO. 510730 DESIGN 1006 2001 VALUE ENG DATE SYSTEM DESIGNED BY PROJECT NO. CONTRACT NO.	AMERICAN MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA BORE SEAL ASSY DN CONTRACT NO. 500422 D 70210 500422 SCALE FULL SHEET 1 OF 1
	READ	NEXT ASSY	USED ON						
	APPLICATION								

3-33/3-34 2



ANNULUS -1
SCALE = 1/2

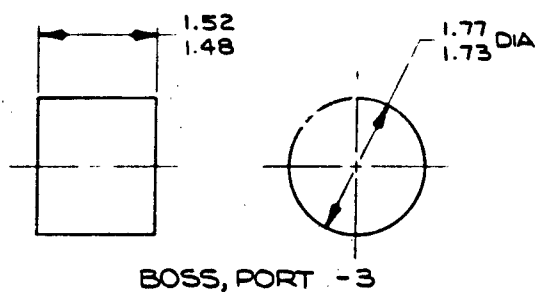
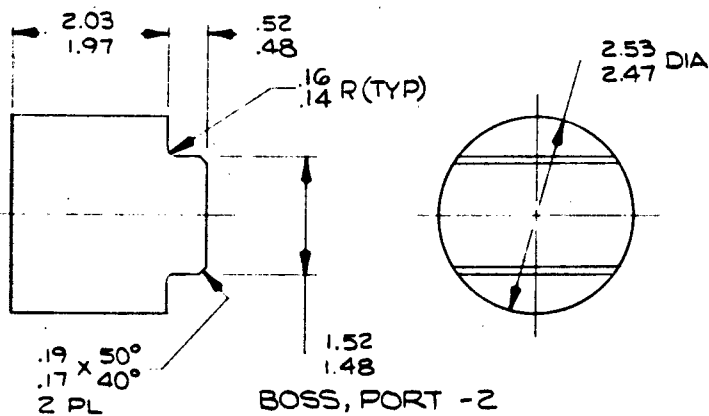
⚠ AL ALY 6061-T6 PLATE
QQ-A-250/11 COND T651 OR
AL ALY 6061-T6 BAR
QQ-A-225/8 COND T651

NOTES: UNLESS OTHERWISE SPECIFIED

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REV STATUS					
SHEET					

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



PART NO. 500425-1,-2,& -3

UNLESS OTHERWISE SPECIFIED:
SURF CONTROL PER S0863 *CL*
STD INTERPRETATIONS PER FMS
IDENTIFICATION MARKING PER
NCS14

CONTRACT NO.

NAKAMURA 811008

2000 12/14 511

VALE ENCH

DATE

NY 100

APPROVED: [Signature] DATE: 8/20/07
SPECIAL AGENT IN CHARGE

33 11-11-11

GOVERNMENT 450

Abstract

AMRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
TORRANCE, CALIFORNIA

DETAILS, ANNULUS

001	0001 0001 00	0001 00
D	70210	500425

SCALE	FIG. 1	SHEET	OF
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3-35/3-36

12

SCIFIED

4

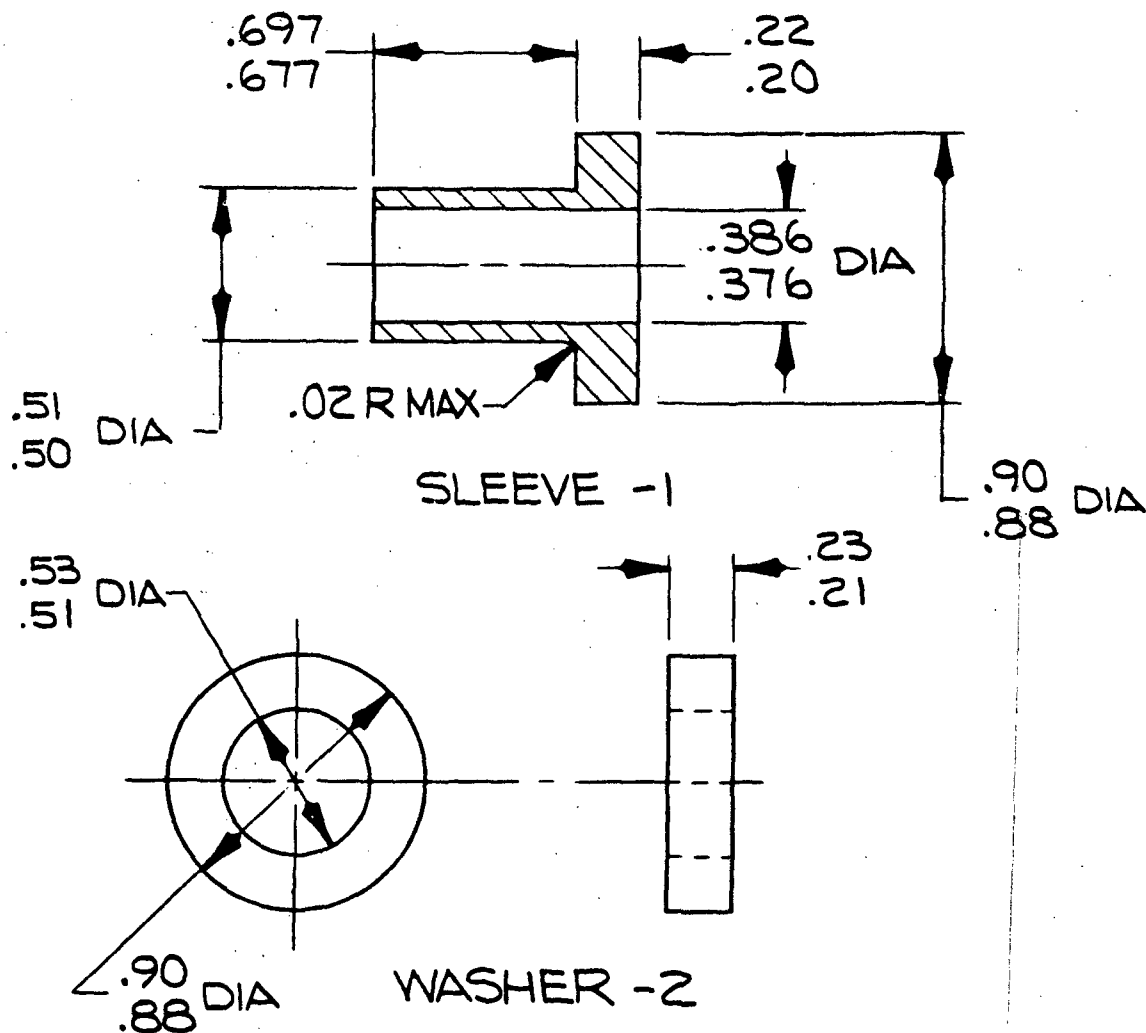
3

2

1 (-3)	500411-1	518404-
1 (-3)	500410-1	518404-
1 (-2)	500409-1	518404-
1 (-1)	500408-1	518404-
REQD	NEXT ASSY	USED ON
APPLICATION		

DWG NO 5004

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PART NO 500426-1 & 2

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 <i>CLB</i> STD INTERPRETATIONS PER P185 IDENTIFICATION MARKING PER MC16			MATERIAL NEMA GRADE G11 1.00 DIA BAR	CONTR
				PREPAP
				CHK
				VALUE
				MATL
42(-2)500430-1518404-1			HEAT TREATMENT	STRESS
42(-1)500430-1518404-1				DESIGN
REQD	NEXT ASSY	USED ON	FINISH PROCESS	PROJEC
APPLICATION				GOVER

FORM 1195



DWG NO 500426 SH A

its expressly granted by contracts to the United States Government,
t the prior written permission of THE GARRETT CORPORATION.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
A	SEE EO	820109	W. J. House

R
R

.90 DIA
.88

NOTE 5
SEALING COAT PER RS13 ALL OVER
APPLY 117-011-9001 USING 117-016-9001,
ADD ONE DROP OF 3M FC 430 WETTING
AGENT TO EACH 100 GRAMS.
AFTER DIPPING .001 MAX BUILD UP, IF TOO
MUCH BUILD UP CONSULT ENGINEERING.

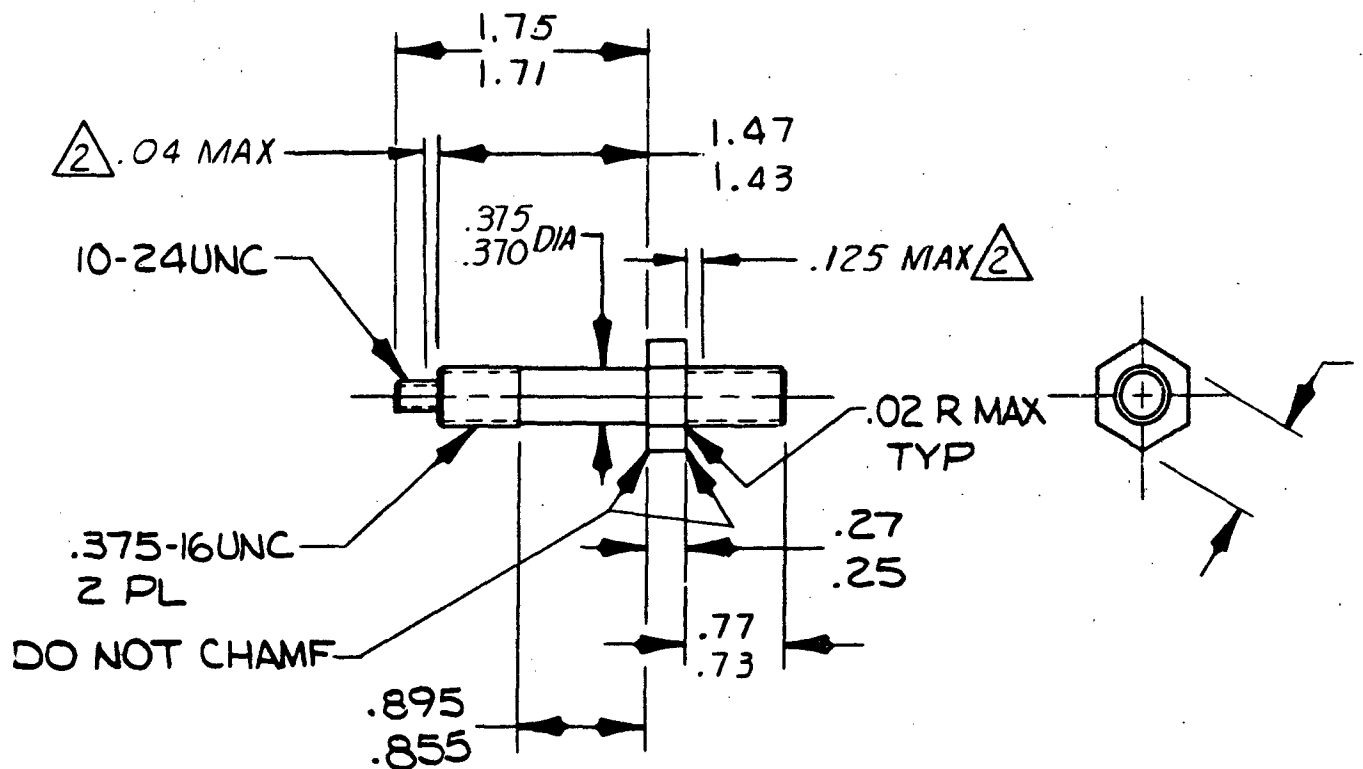
1-2

MATERIAL NEMA GRADE G11 1.00 DIA BAR	CONTR NO	 AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
HEAT TREATMENT	PREPARED BY NAKAMURA 811007 CHK <i>Handy</i> 811009 VALUE ENGR MATL <i>117-011-9001</i> 811102		INSULATOR, TERMINAL
FINISH PROCESS	DESIGN SUPERVISOR <i>[Signature]</i> PROJECT ENGINEER <i>[Signature]</i> GOVERNMENT APVD		
SIZE B		CODE IDENT NO 70210	DWG NO 500426
SCALE 2/1		SHEET 1 OF 1	

3-37/3-38

2

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- 2 INCOMPLETED THREAD
1 .625 HEX BAR
ZIRCONIUM COPPER
CDA-150 (HARD)

NOTES: UNLESS OTHERWISE SPECIFIED

PART NO 500427-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 C2B STD INTERPRETATIONS PER PIB5 IDENTIFICATION MARKING PER MC18			MATERIAL 1.	CONTR NO
			HEAT TREATMENT	PREPARED BY
				CHK <i>Wra</i>
			FINISH PROCESS	VALUE ENGR
				MATL
43(-1)	500430	518404-1	APPLICATION	STRESS
REQD	NEXT ASSY	USED ON		DESIGN SUPE 11-2-
				PROJECT ENG 81-11-1
				GOVERNMENT



DWG NO 500427 SH A

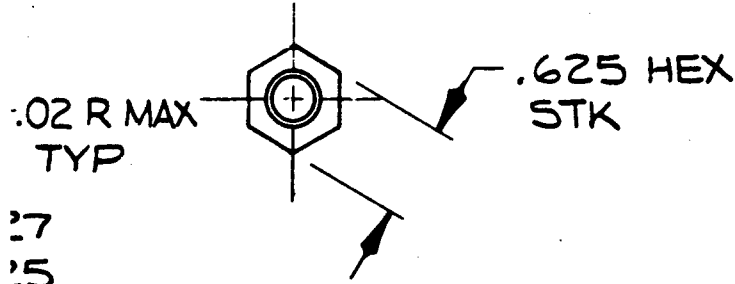
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REVISIONS

REV	DESCRIPTION	DATE	APPROVED
A	SEE E.O.	8/20/09	W.A. [Signature]

R
R

5 MAX $\triangle$



7-1

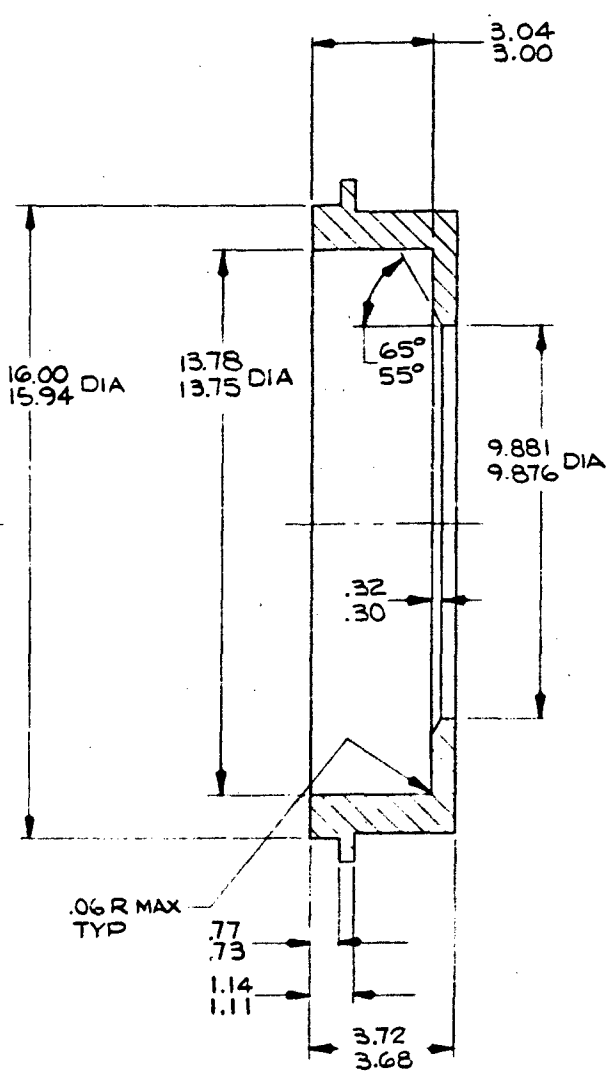
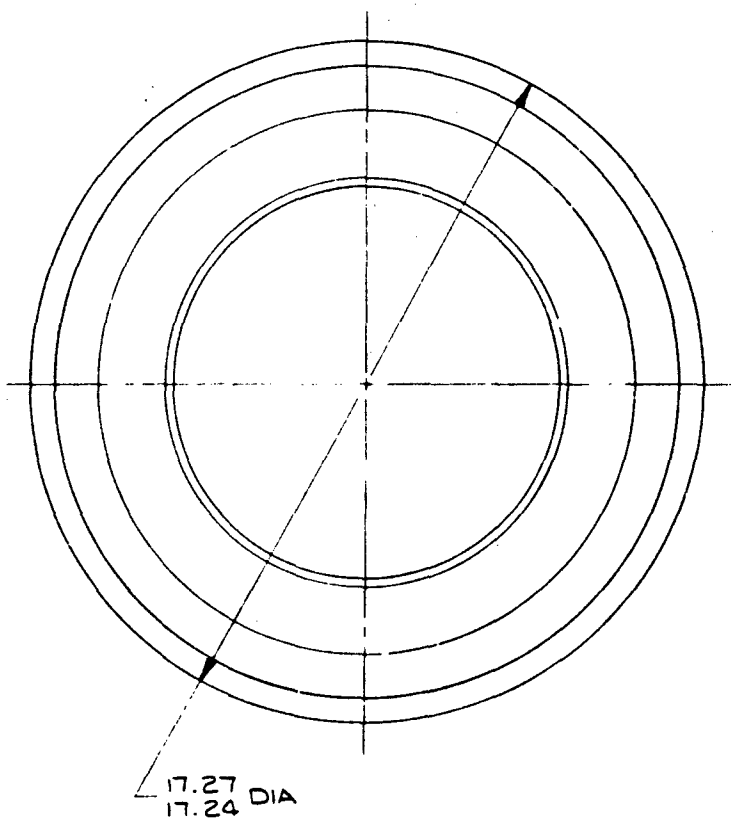
SPECIFIED: C853 <i>CLB</i> SPER P185 KING PER	MATERIAL 	CONTR NO		AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
		PREPARED BY <i>NAKAMURA</i> 811008		TERMINAL, ELECT.	
		CHK <i>Therak</i> 811009			
		VALUE ENGR			
		MATL			
	HEAT TREATMENT	STRESS			
18404-1		DESIGN SUPERVISOR 11-2-31 <i>[Signature]</i>	SIZE B	CCDL IDENT NO 70210	DWG NO 500427
USED ON	FINISH PROCESS	PROJECT ENGINEER 81-11-02 <i>[Signature]</i>			
		GOVERNMENT APVD	SCALE FULL	SHEET	OF



3-39/3-40 2

D
C
B
A

8 7 6 5 4



AL-ALY 6061-T6 PLATE
QQ-A-250/11 COND T651 OR
AL-ALY 6061-T6 BAR
QQ-A-225/8 COND T651

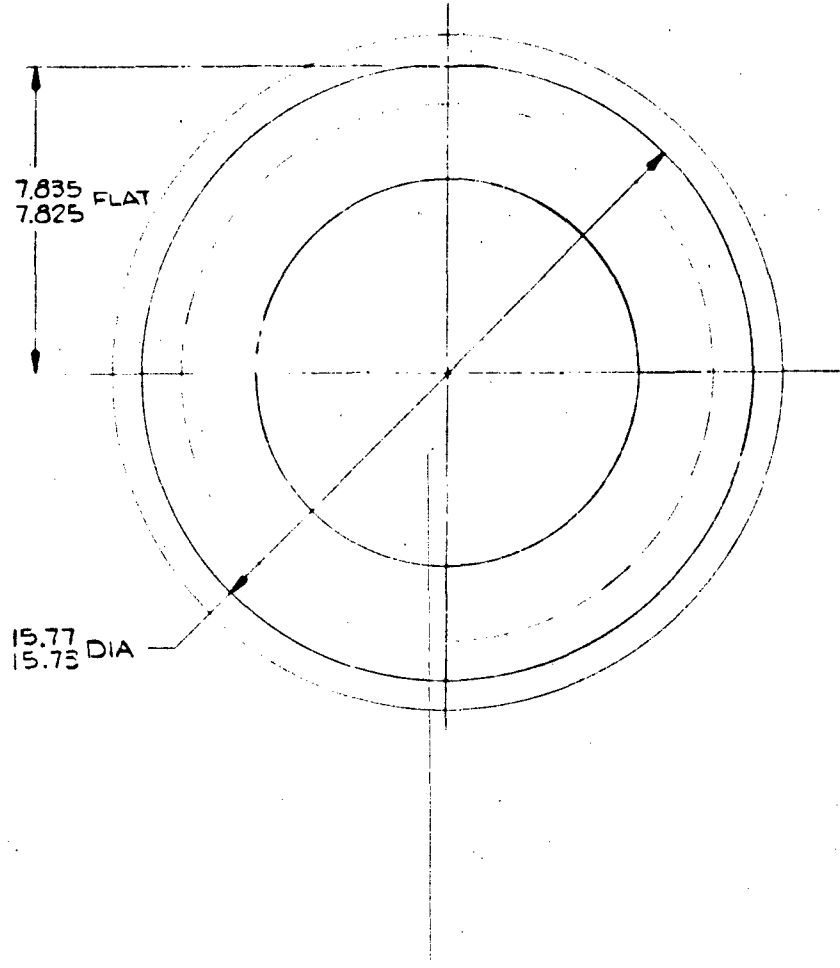
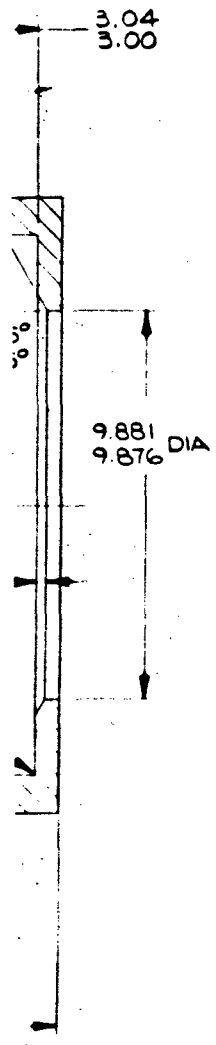
NOTES: UNLESS OTHERWISE SPECIFIED

8 7 6 5 4

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 REV. STATUS
 SHEET

A SEE ENGINEERING ORDER

DATE 1/18/52
 APPROVED E. S. Sargent



PART NO 500428-1

UNLESS OTHERWISE SPECIFIED
 BURR CONTROL PER MIL-STD-13
 STD INTERPRETATIONS PER THIS
 IDENTIFICATION MARKING PER
 MIL-STD-1308
 MATERIAL
 TREATMENT
 FINISH
 IDENTIFICATION MARKING PER
 MIL-STD-1308

CONTRACT NO.
 QUANTITY 10000
 DATE
 STATE
 CITY
 COUNTY
 ZIP CODE
 GOVERNMENT AND

ANDRESEARCH MANUFACTURING COMPANY
 A DIVISION OF THE SARGENT CORPORATION
 TORRANCE, CALIFORNIA
 PLATE, FLANGED, TERMINAL
 D 70210 500428
 SCALE 1/2 SHEET 1 OF 1

SPECIFIED

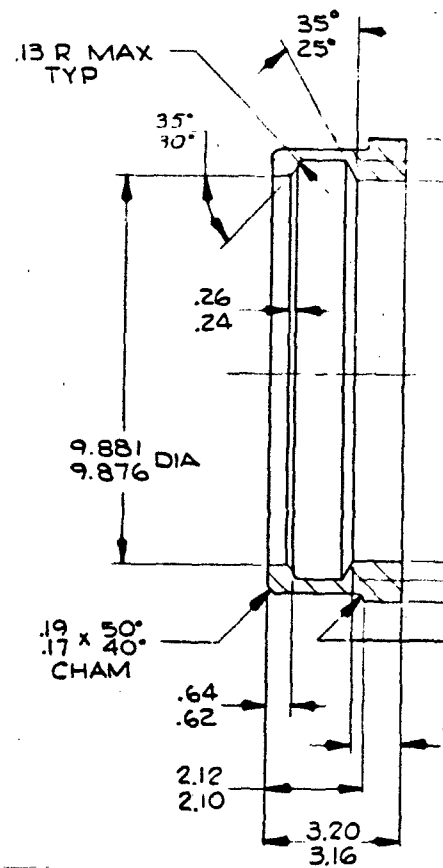
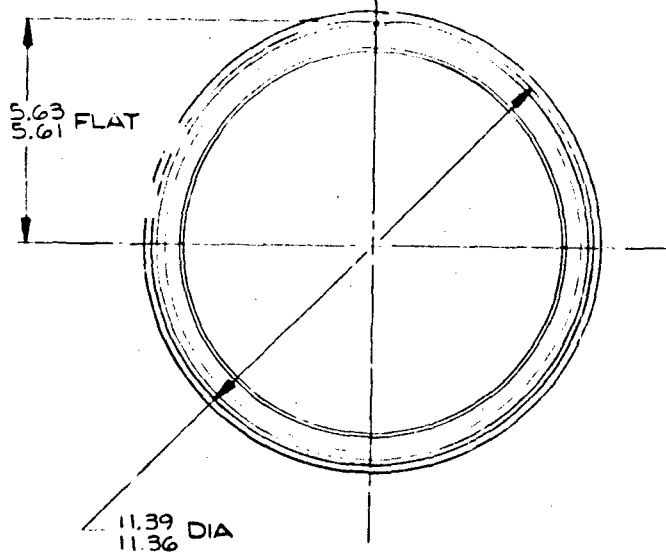
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3

2

1

2 3-41/3-42



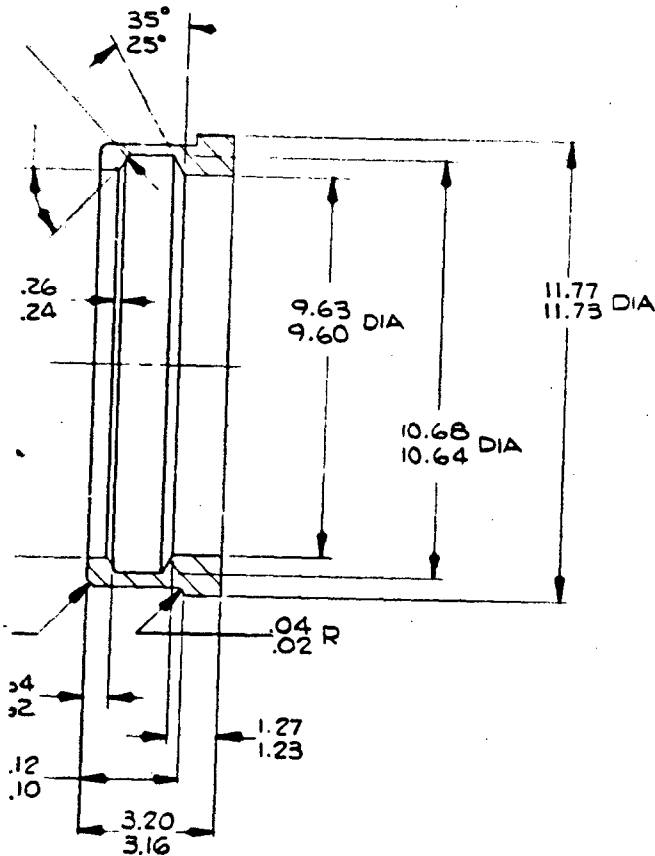
1. AL-ALY 6061-T6 PLATE
 QQ-A-250/11 COND T651 OR
 AL-ALY 6061-T6 BAR
 QQ-A-225/8 COND T651

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED:
 EXCEPT FOR RIGHTS RESERVED BY CONTRACT TO
 THE UNITED STATES GOVERNMENT, THIS DRAWING MAY NOT
 BE REPRODUCED OR TRANSMITTED IN ANY FORM OR BY ANY
 MEANS, ELECTRONIC OR MECHANICAL, INCLUDING PHOTOCOPYING,
 RECORDING, OR BY ANY INFORMATION STORAGE AND RETRIEVAL
 SYSTEM, WITHOUT THE WRITTEN PERMISSION OF THE GARRETT
 CORPORATION.

REV	STATUS								
SHEET									

ZONE	LTR	DESCRIPTION	DATE	APPROVED
A		ENGINEERING ORDER	11-21-64	Edwards



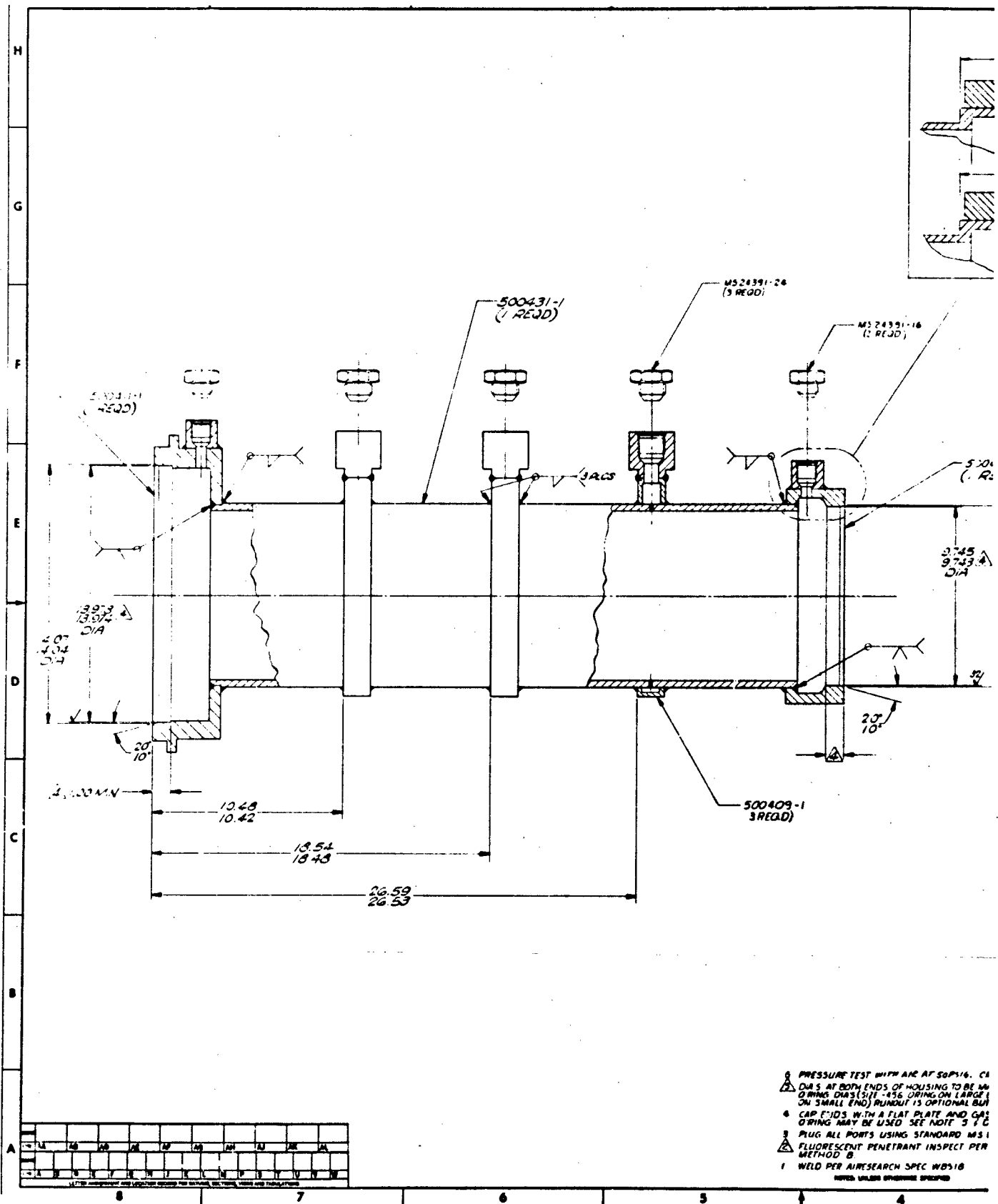
PART NO. 500429-1

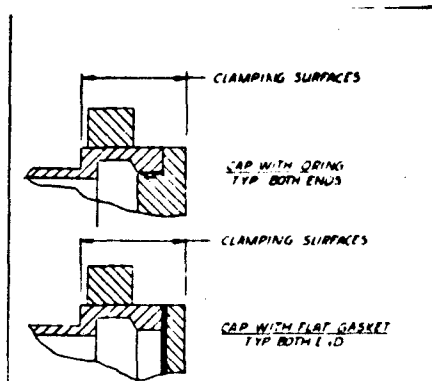
UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SCRS CC-8 STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER SCS-10		CONTRACT NO.		AIRSEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL		DESIGNED BY NAKAMURA 6/10/62		DRAWN BY	
FINISH PROCESS		CHECKED BY		DATE	
TREATMENT		APPROVED BY		DATE	
APPLICATION		OTHER APPROVALS		GOVERNMENT APPROVAL	
1-1 500410-1 518404-1		D 70210		500429	
RECD NEXT ASSY USED ON		SCALE 1/2		SHEET 1 OF 1	

SE SPECIFIED

3-43/3-44

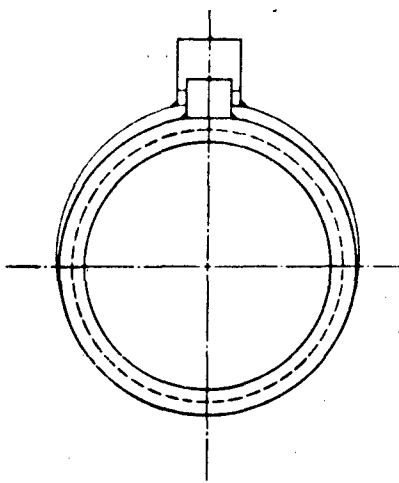
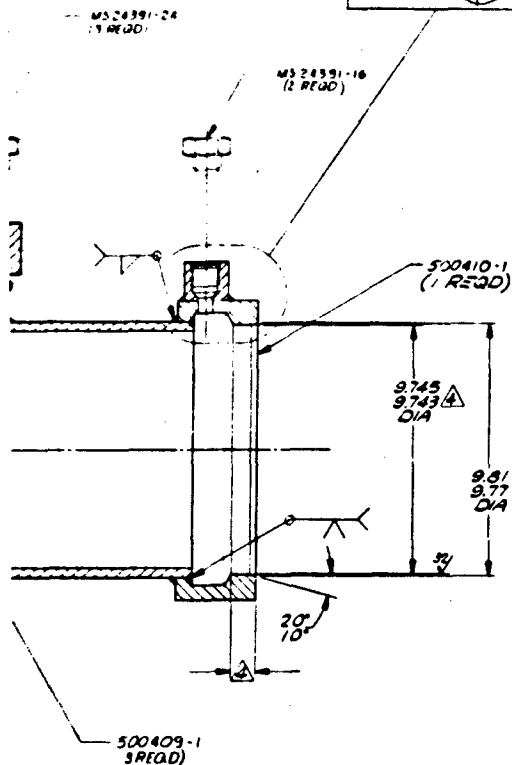
2





REV	DATE	BY	CHKD	APP'D
1				

REV	DATE	BY	CHKD	APP'D
1				



1. PRESSURE TEST WITH AIR AT 80PSIG. CHECK WITH LEAK-TEST.
2. DIA'S AT BOTH ENDS OF HOUSING TO BE MACHINED TO PROVIDE O-RING DIA'S (SIZE .456 O-RING ON LARGE END & SIZE .272 O-RING ON SMALL END) ROUNDOFF IS OPTIONAL BUT CLEANUP MUST BE GOOD.
3. CAP ENDS WITH A FLAT PLATE AND GASKET OR PLUGS WITH O-RING MAY BE USED SEE NOTE 5 & 1 DETAIL SHOWN.
4. PLUG ALL PORTS USING STANDARD MS PLUGS AS SHOWN.
5. FLUORESCENT PENETRANT INSPECT PER MIL-T-6860, TYPE I, METHOD B.
6. WELD PER AIRRESEARCH SPEC WBS18.

NOTES: UNLESS OTHERWISE SPECIFIED

PART NO. 500430-1		HOUSING, STATOR, FABRICATED	
MIL-H 6008 COND. T6		E 70210 500430	
APPLICATION		SCALE 7/8	

3-45/3-46

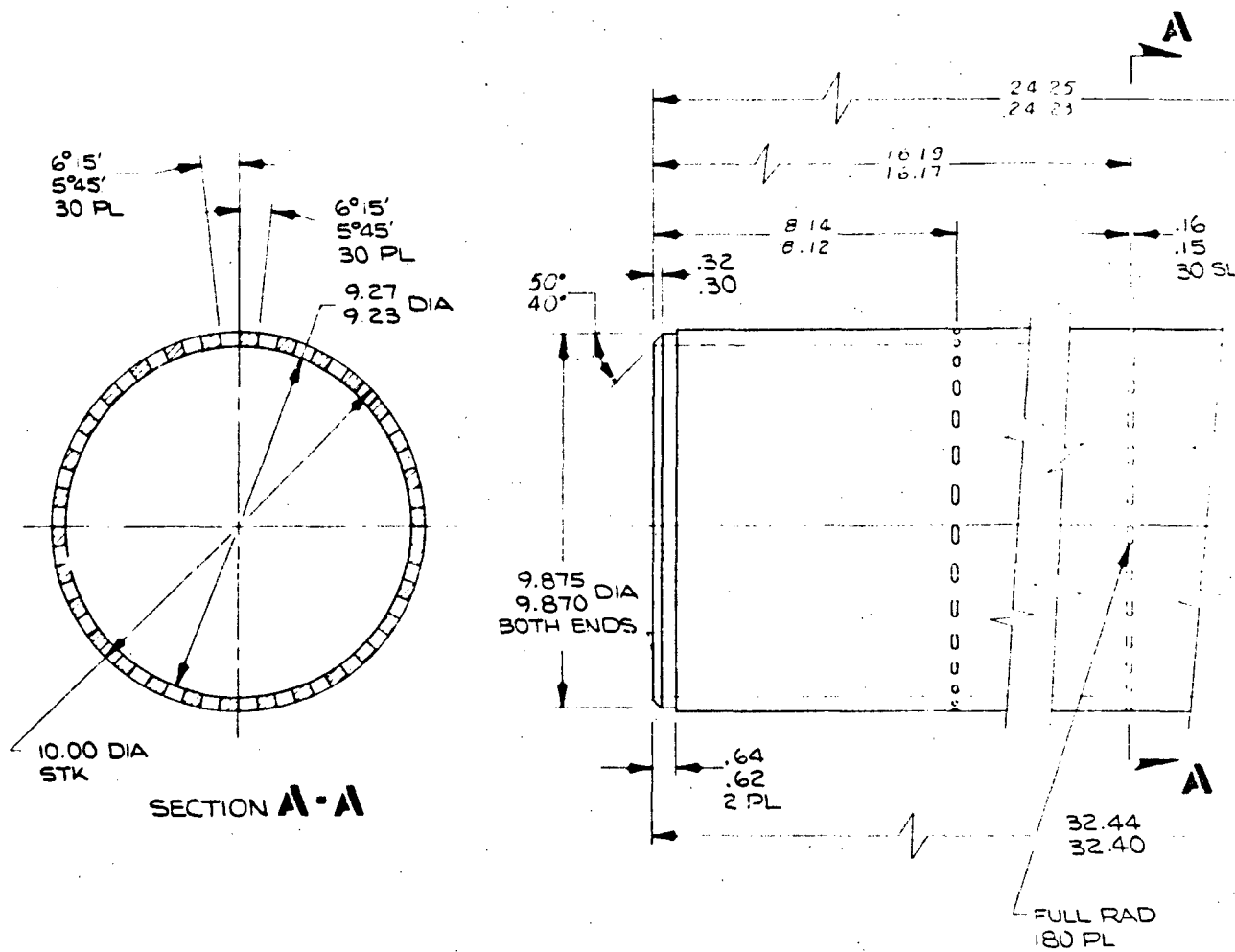
2

D

C

B

A



8

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5

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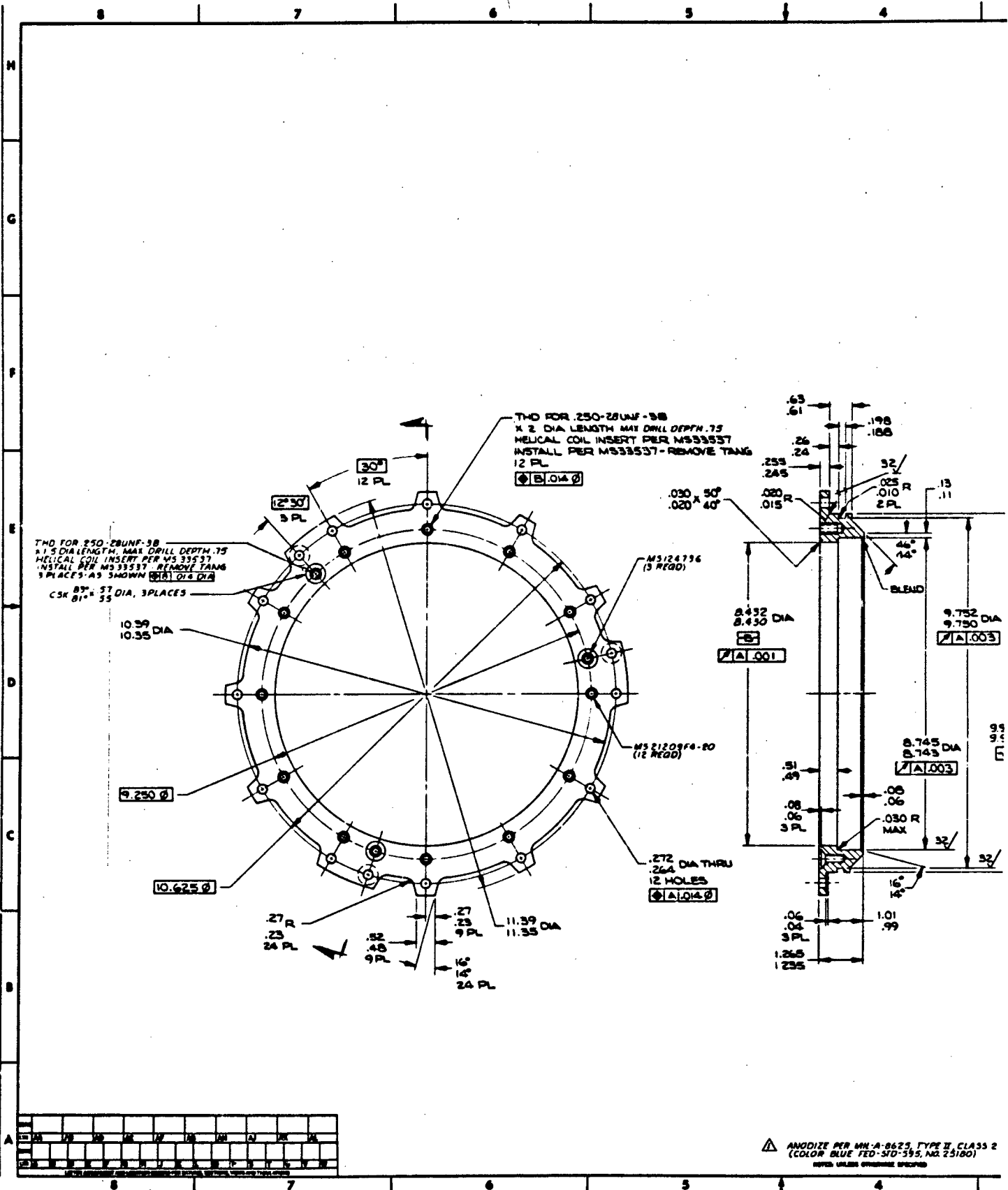
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

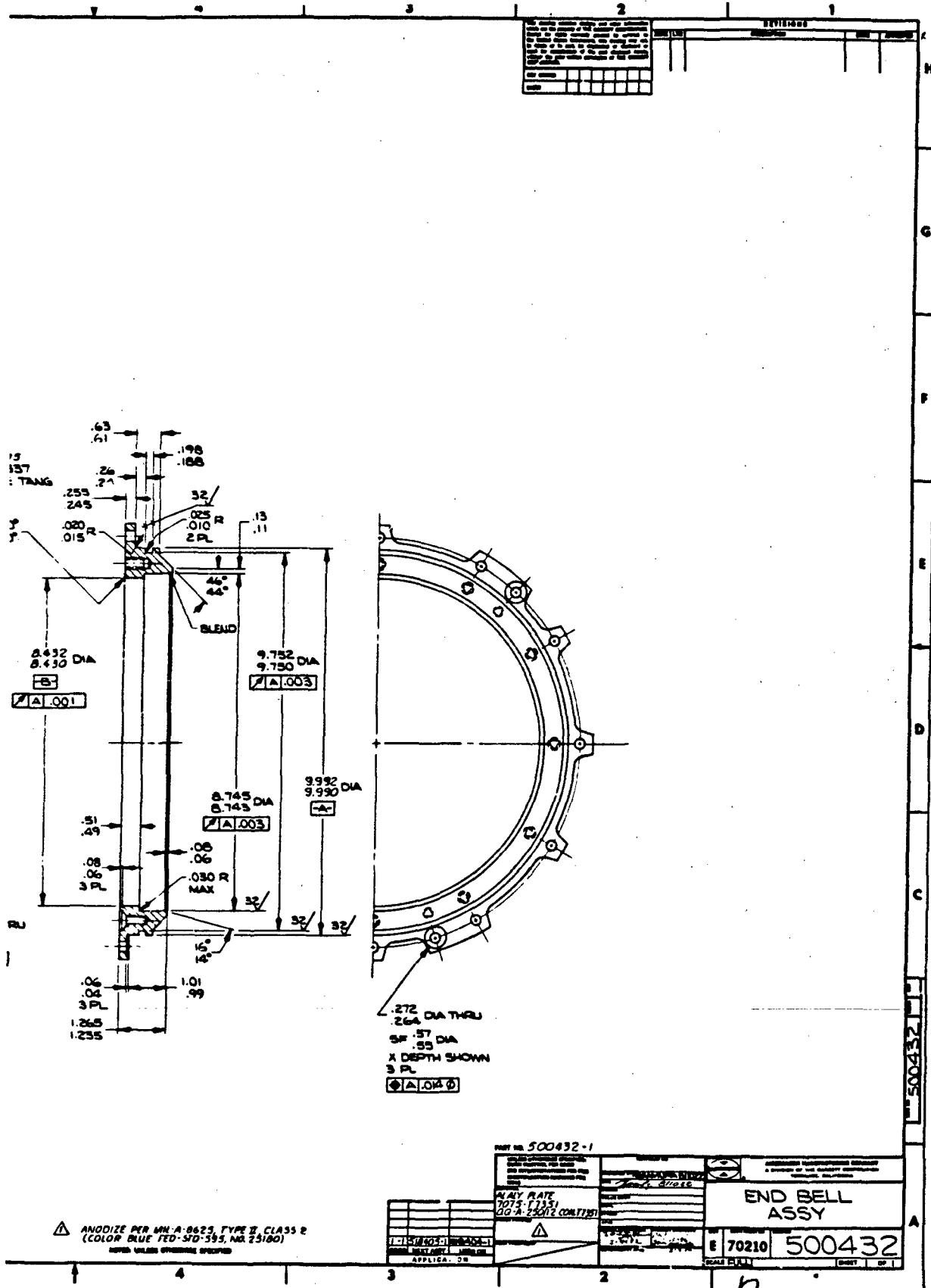


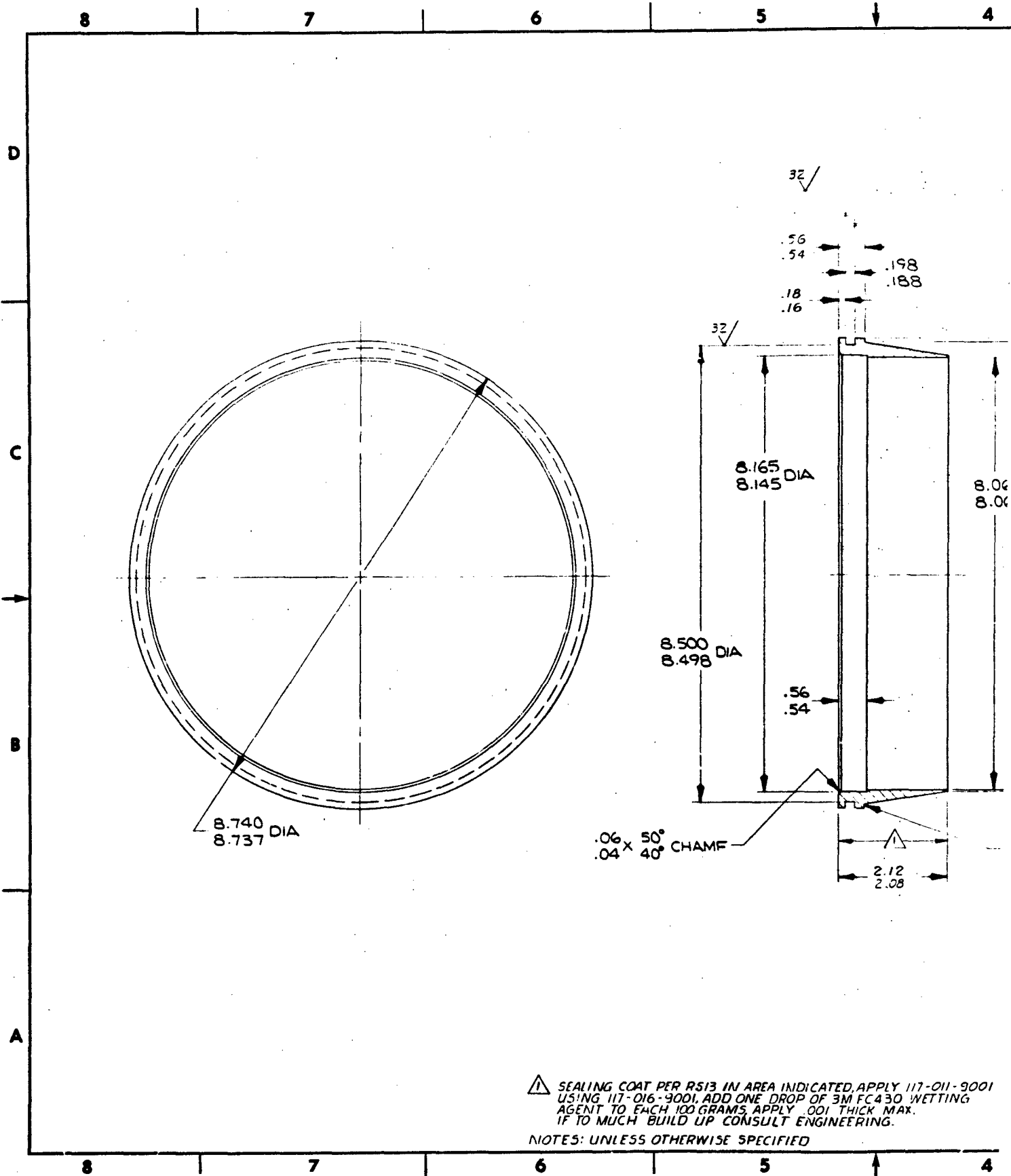
PART NO. 500431-1		CONTRACT NO.		 ARBREATHEN MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SCRS 1.1 STD INTERPRETATIONS PER AWS IDENTIFICATION MARKING PER AWS		DESIGNED BY NAKAMURA R 105 DATE 7-1-61 211012 DESIGN VALVE END MATEL STRESS AND 20 1/2" Tube FRANK DESIGN SUPERVISOR PROJECT ENGINEER W. J. JAMES		TUBE HOUSING SIZE CODE IDENT NO QWID NO D 70210 500431	
MATERIAL AL-ALY TUBING 10.00 O.D. X .375 WALL 6061 T6511 FINISH PROCESS		GOVERNMENT AND			
IDENTIFICATION (1-500430-1) 516404-1 READ NEXT ASSY USON APPLICATION				SCALE 1/2 SHEET 1 OF	

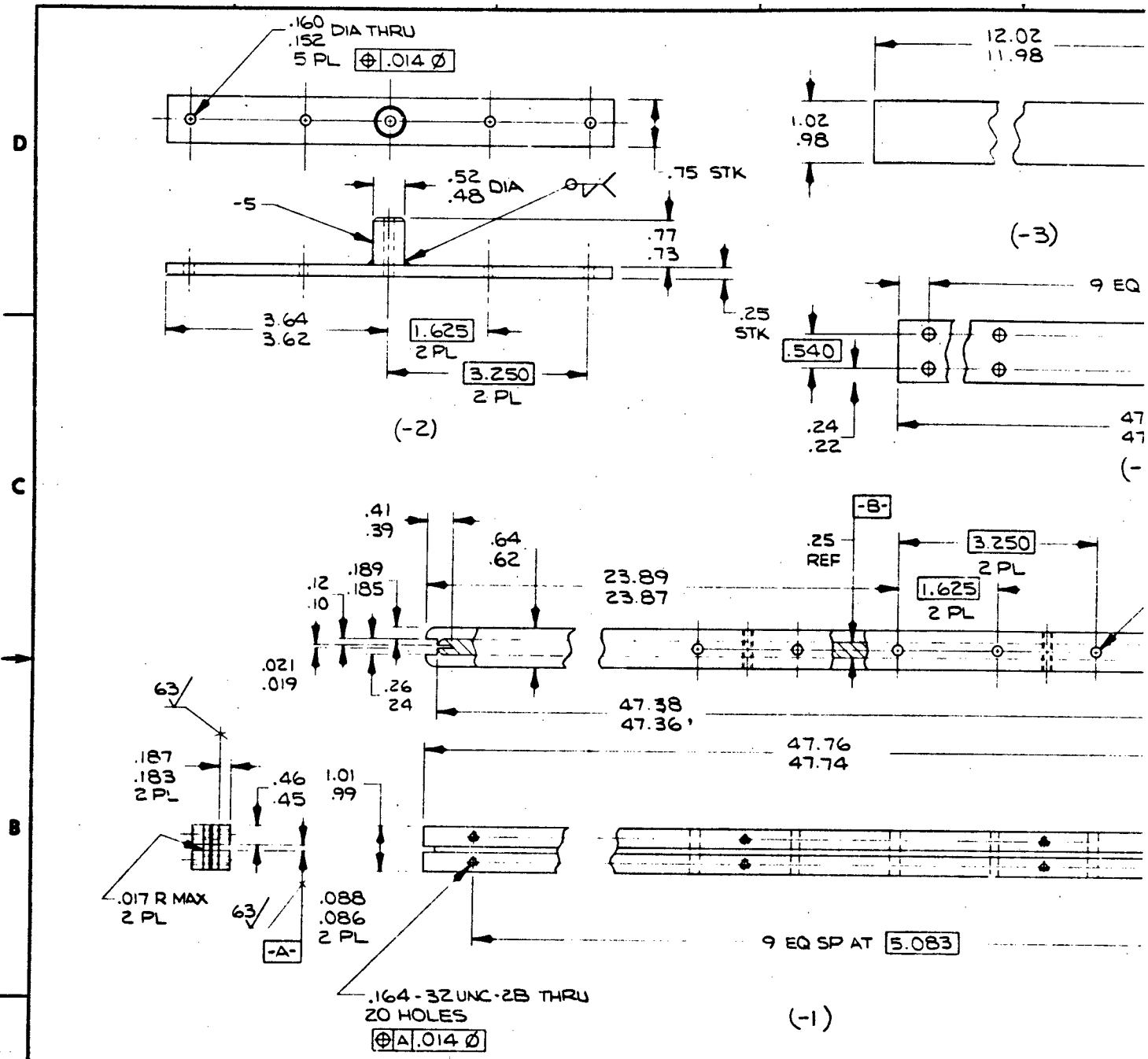
3-47/3-48

21

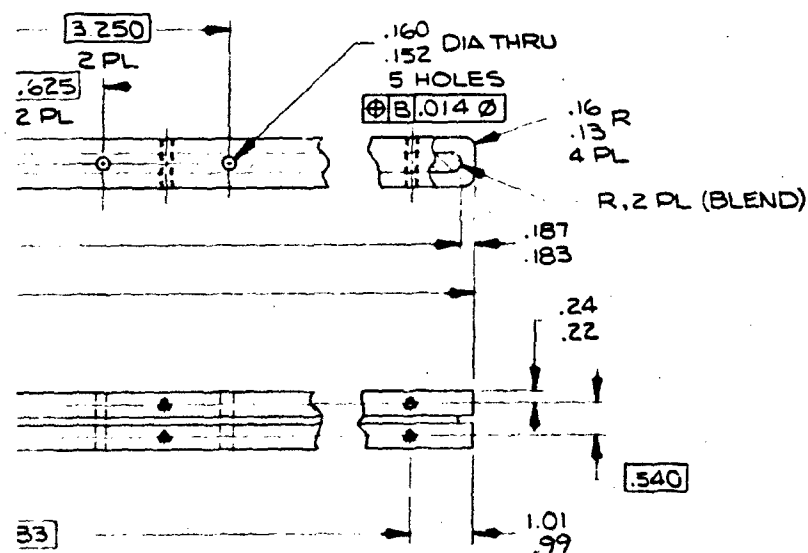








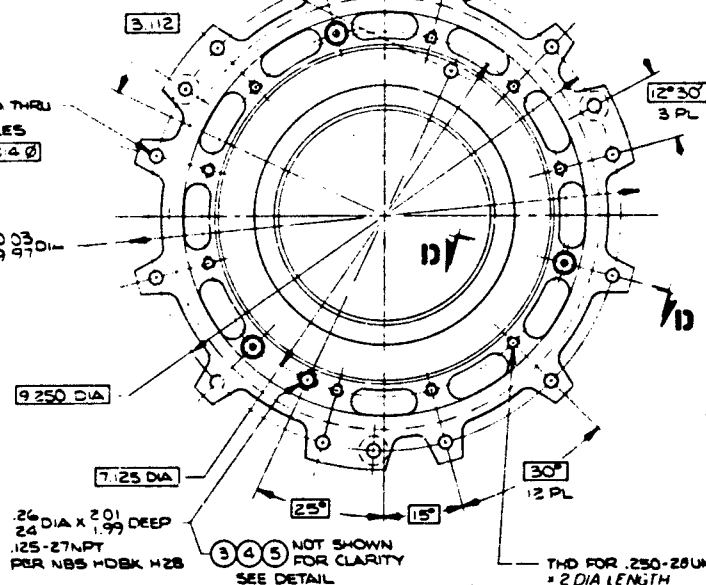
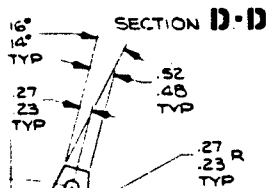
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE E.O.	12-22-11	[Signature]



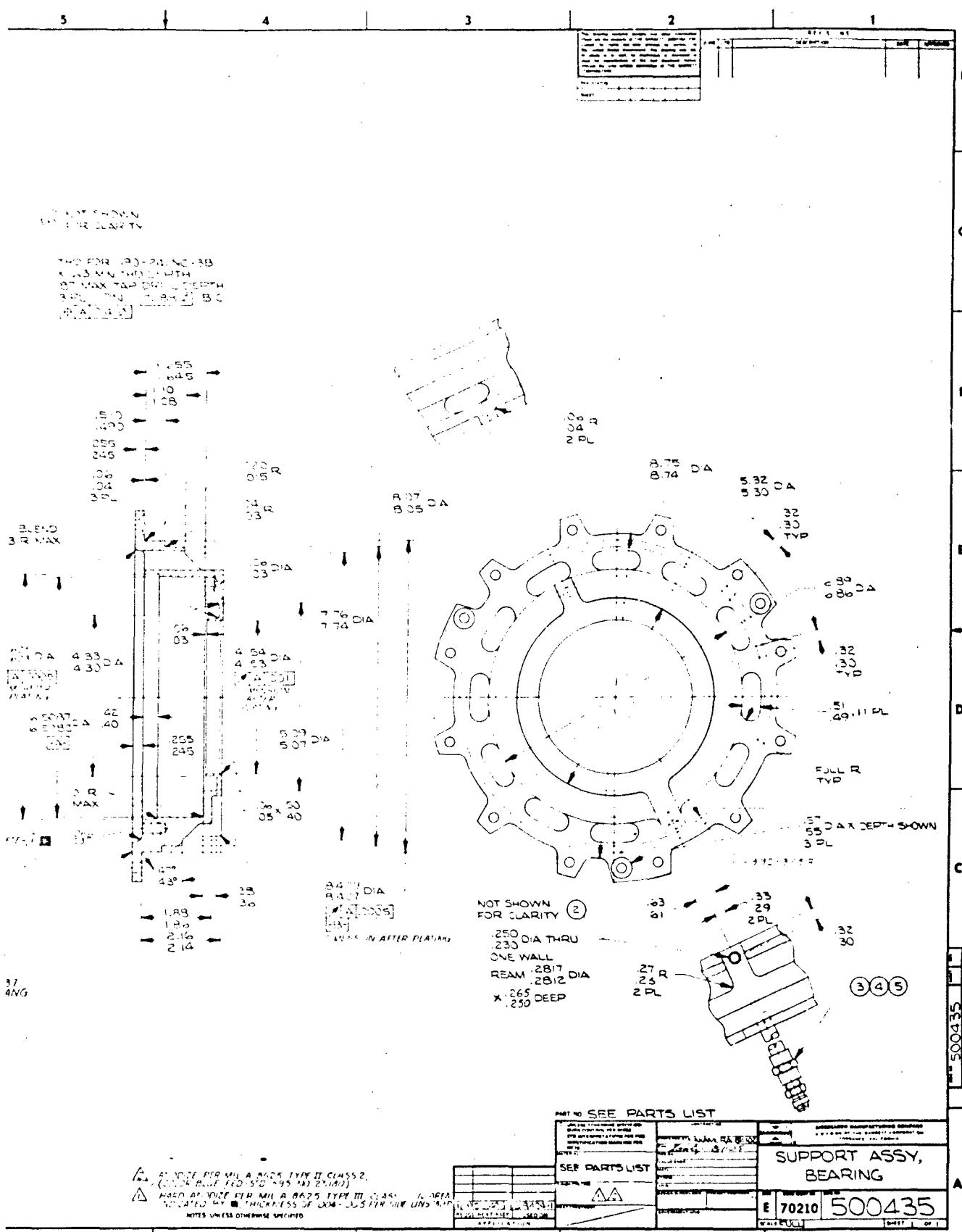
UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SCSS STD INTERPRETATIONS PER PMS IDENTIFICATION MARKING PER MIL-STD-1312	CONTRACT NO.		ANDREASSEN MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
	DRAWING BY <u>NAXAMURA BIKOIS</u> C-14 DET. 4 VALVE SHGR SEAL STAIN APD <u>10/11/61</u> DESIGN SUPERVISOR PROJECT ENGINEER <u>J. J. [Signature]</u> GOVERNMENT ACCT.		FORM, WINDING ASSY	D 70210
MATERIAL FINISH PROCESS TREATMENT	SCALE <u>FULL</u>		SHEET <u>1</u> OF <u>1</u>	

3-53/3-54

2

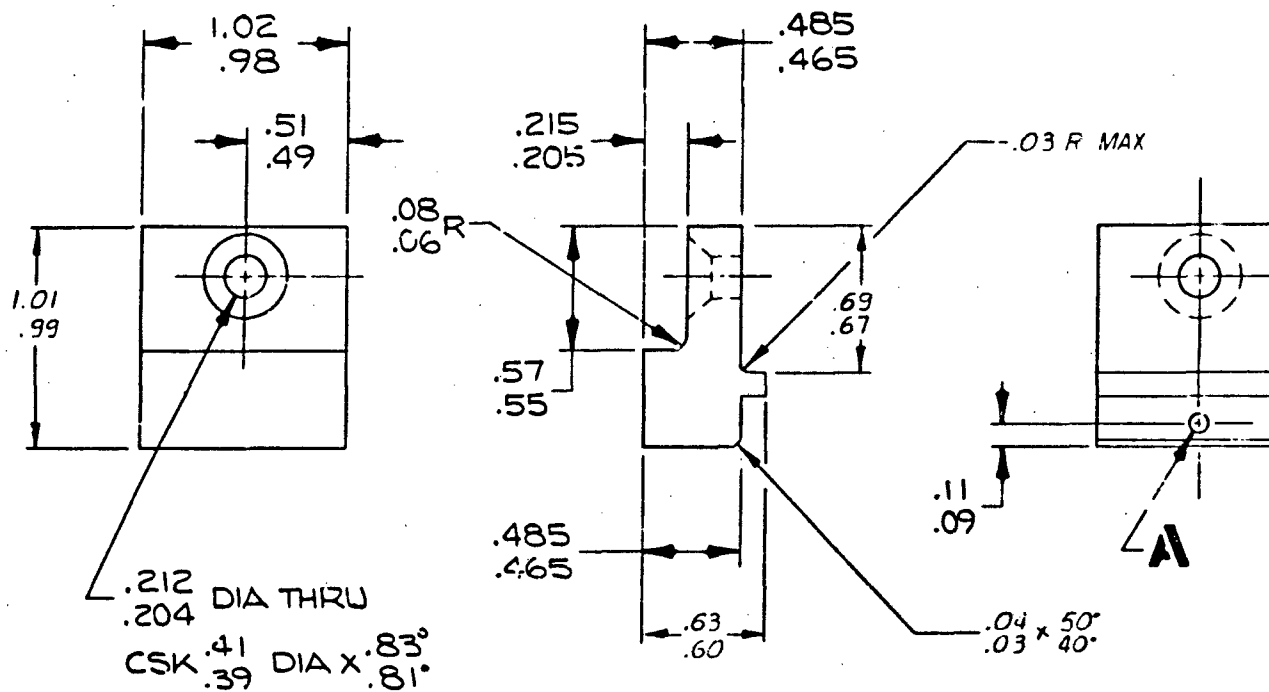
[illegible]

ANODIZE PER MIL-A-8625, TYPE II CLASS 2,
(COLOR BLUE FED-STD-595 NA 25180)
HARD ANODIZE PER MIL-A-8625, TYPE III CLASS
INDICATED BY ■, THICKNESS OF .004-.005 PER S
PLATE UNLESS OTHERWISE SPECIFIED



DASH NO	
-1	
-2	.12 DIA X .31 DEEP .10 .29

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PART NO. SEE TABULATION

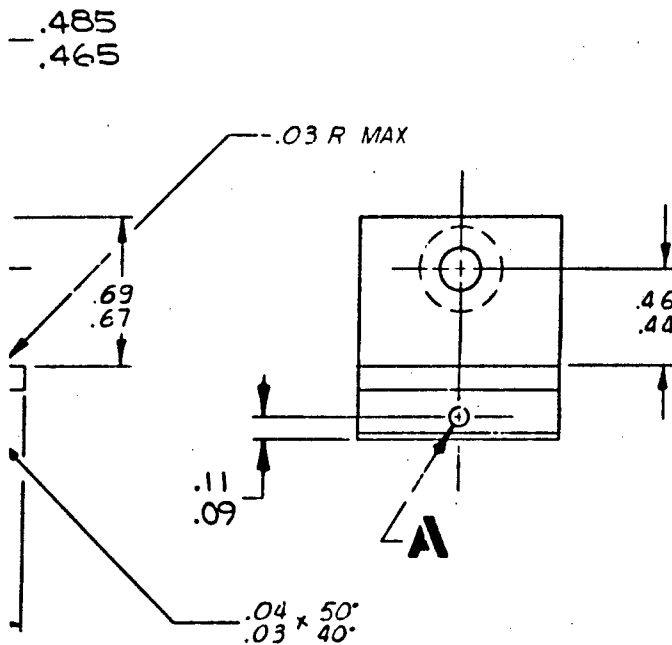
UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC63 CC 0 STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER MC16		PREP. BY LHR
MATERIAL NEMA GRADE G11 EPOXY GLASS LAMINATED		DESIGN VALUE ENGR
FINISH PROCESS		MATL
HEAT TREATMENT		APPROV DESIGN 3.3.54 1.2.54
APPLICATION		GOVERNMENT

2(2)	500400-1	518404-1
10(1)	500400-1	518404-1
REQD	NEXT ASSY	USED ON

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REVISIONS

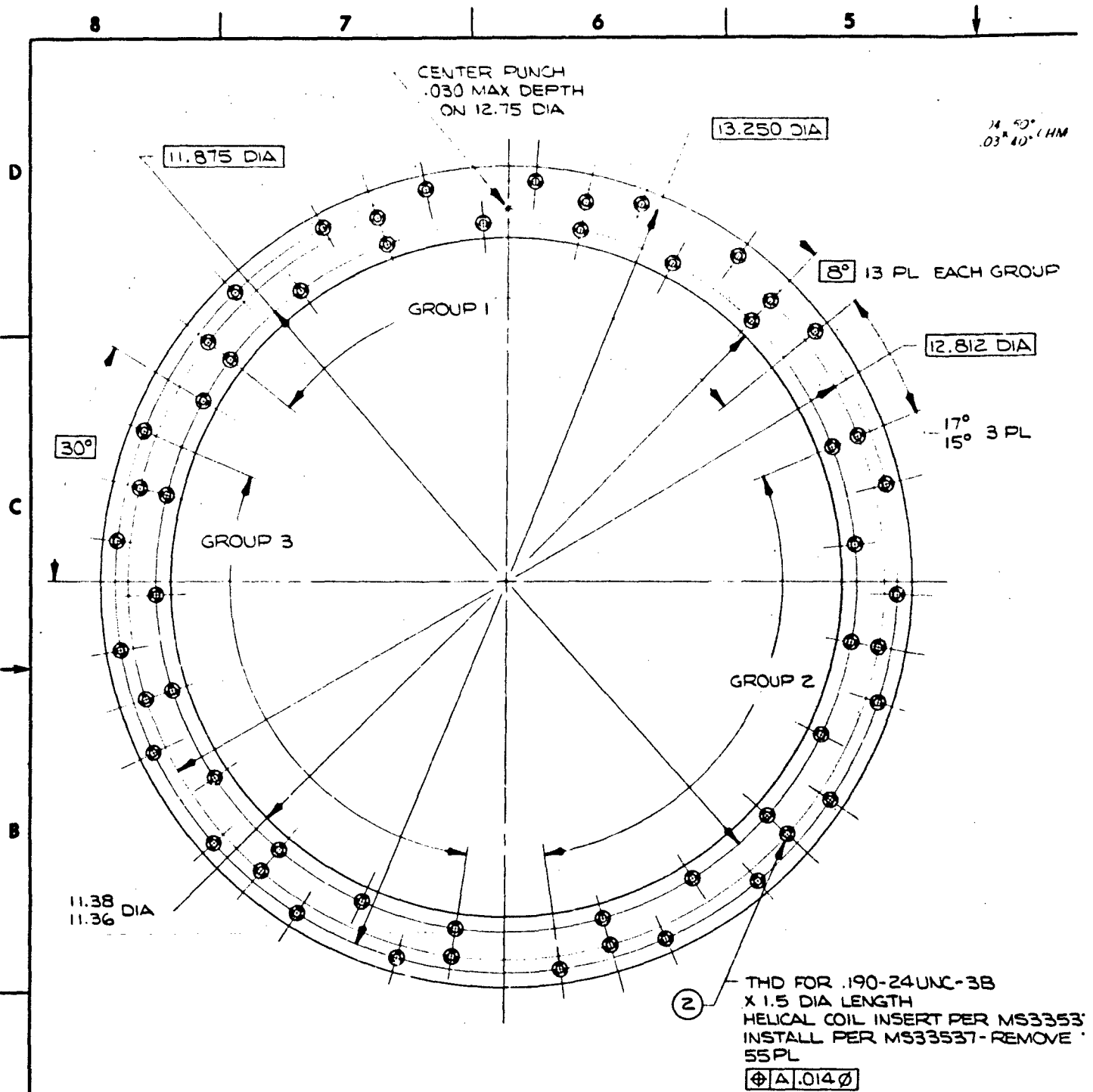
ZONE	LTR	DESCRIPTION	DATE	APPROVED



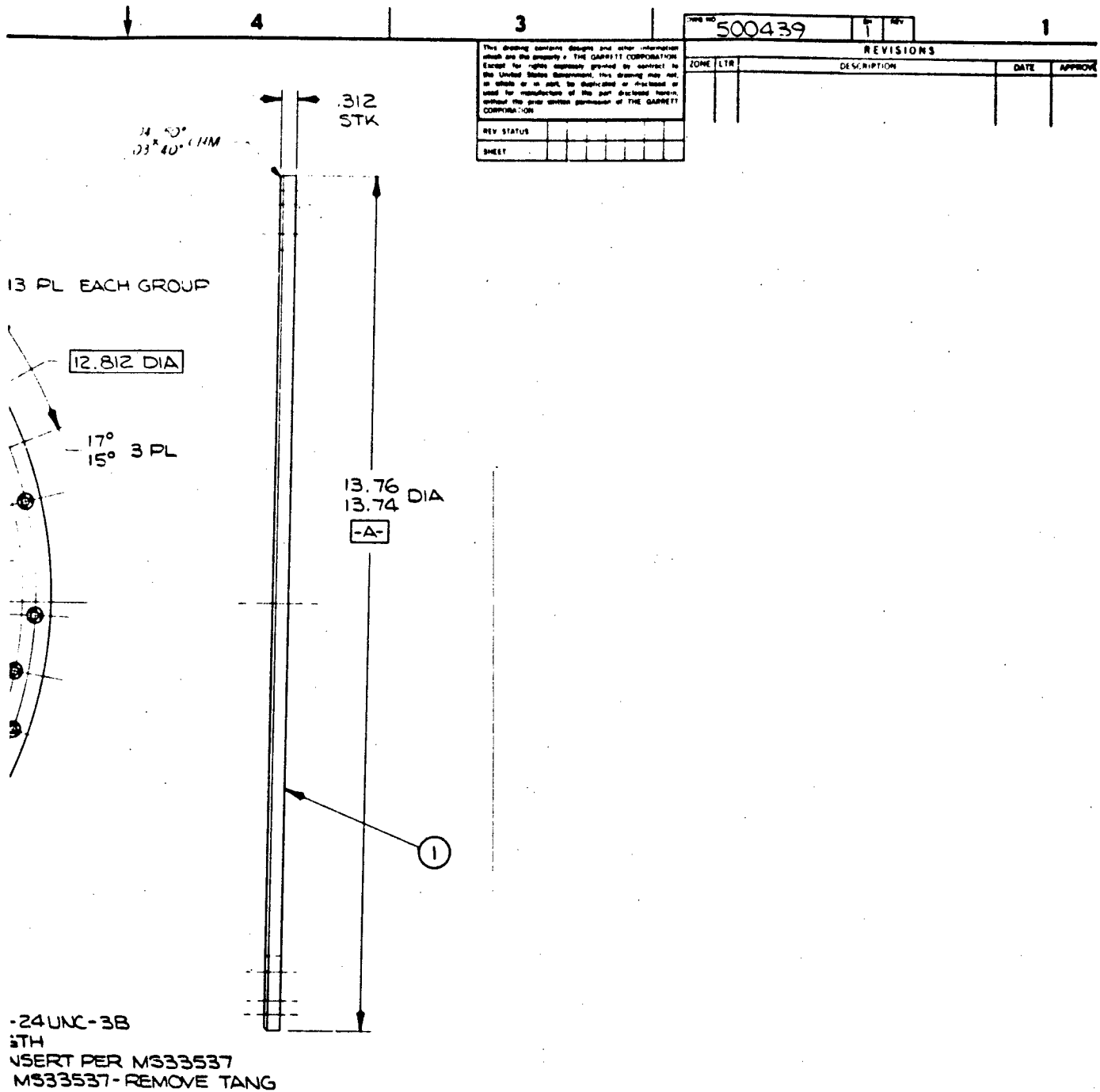
RESEARCH
REDUCED SIZE

PART NO. SEE. TABULATION

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 CCB STD INTERPRETATIONS PER PIDS IDENTIFICATION MARKING PER MC16		CONTRACT NO.		AIRRESEARCH MANUFACTURING COMPANY A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL NEMA GRADE G11 EPOXY GLASS LAMINATED		PREPARED BY NAKAMURA 8/11/12		INSULATOR, NEUTRAL RING	
FINISH PROCESS		CHK 7-1-6 8/11/12			
DESIGN		VALUE ENGR		SIZE C CODE IDENT NO 70210 DWS NO 500438	
MATERIAL		MATERIAL			
DESIGN SUPERVISOR		PROJECT ENGINEER		SHEET 1 OF 1	
GOVERNMENT APPROV		GOVERNMENT APPROV			



MS21209-CI-15	INSERT SCR THD	2	55
500439-1	13.75 O.D. X 11.37 I.D. AL-ALY PLATE 6061-T6 QQ-A-250/11 COND T651	1	1
PART NO	MATERIAL/DESCRIPTION	ITEM NO	QTY



PART NO. 500439-1

UNLESS OTHERWISE SPECIFIED
BURR CONTROL PER SCS3 C8
STD INTERPRETATIONS PER PHS
IDENTIFICATION MARKING PER
SCS18

MATERIAL
SEE TABULATION

FINISH PER SCS3

PROPERTY

APPLICATION

REGD NEXT / SSY USED ON

14-1 500400-1 518404-1

CONTRACT NO.

PREPARED BY NAKAMURA SHIOTI

DATE 7/21/61

VALUE ENG

DATE

BY

AND 7/21/61

CONTRACT NO.

PREPARED BY NAKAMURA SHIOTI

DATE 7/21/61

VALUE ENG

DATE

BY

AND 7/21/61

DESIGN & CHECKED

DATE 7/21/61

BY

GOVERNMENT AND

CONTRACT NO.

PREPARED BY NAKAMURA SHIOTI

DATE 7/21/61

VALUE ENG

DATE

BY

AND 7/21/61

DESIGN & CHECKED

DATE 7/21/61

BY

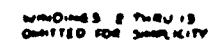
GOVERNMENT AND

SCALE FULL

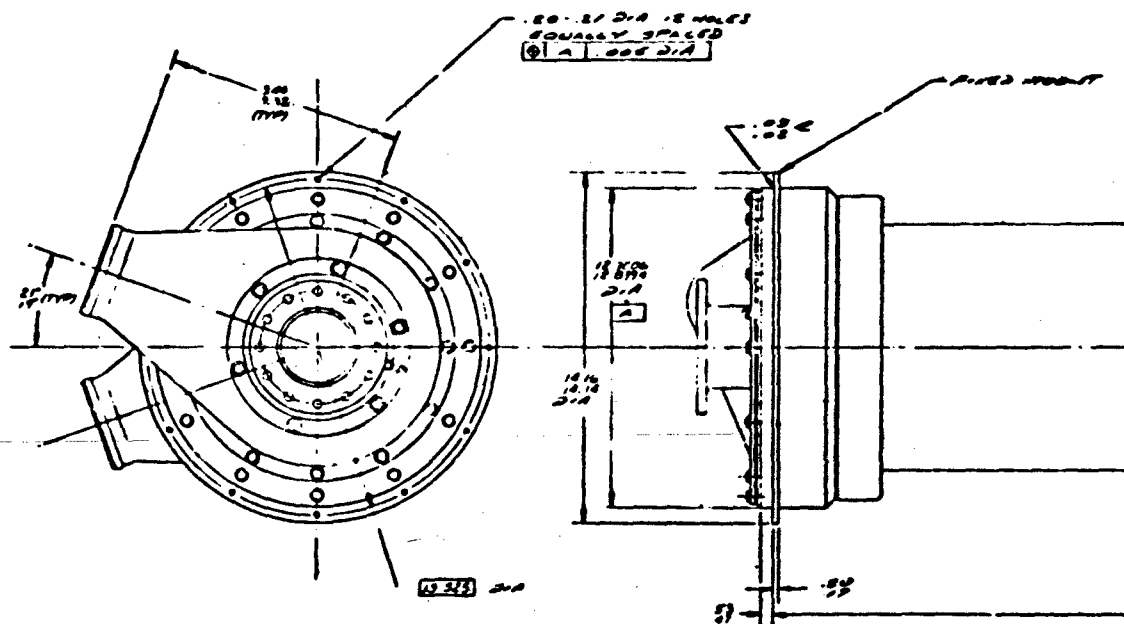
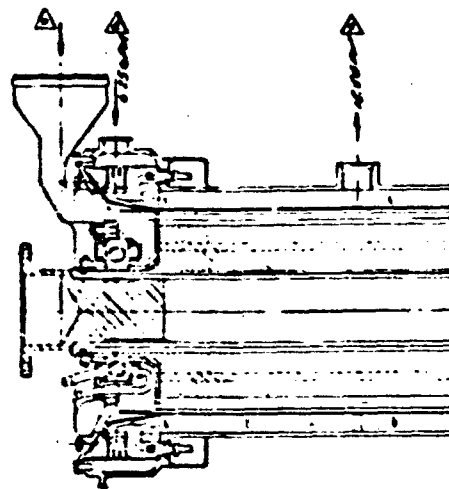
SHEET 1 OF 1

3-59/3-60

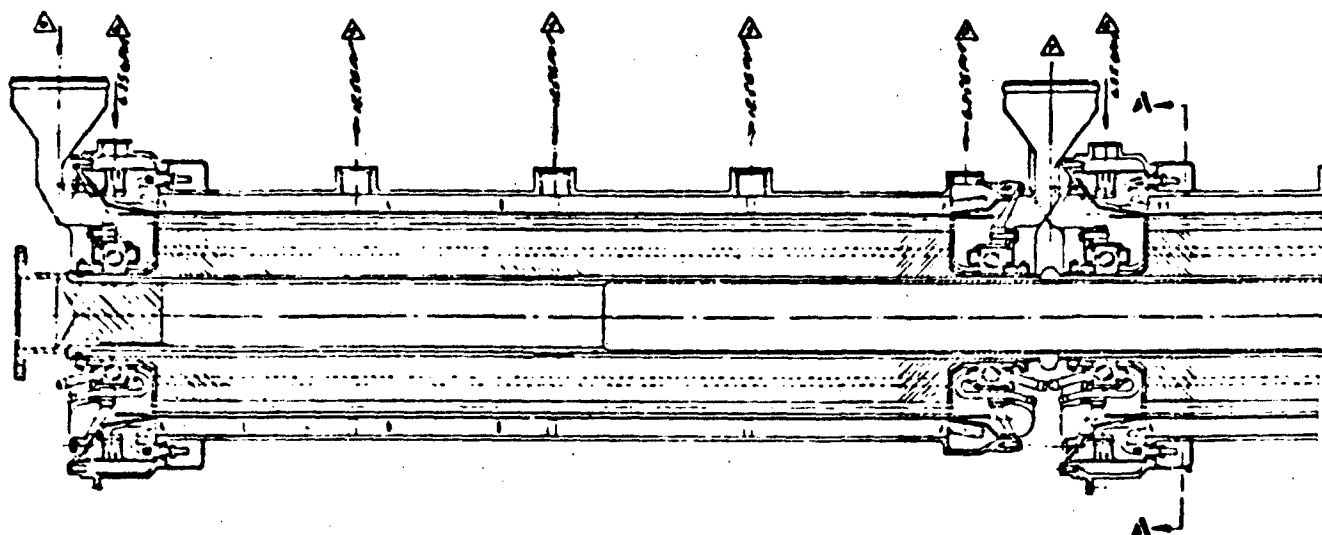
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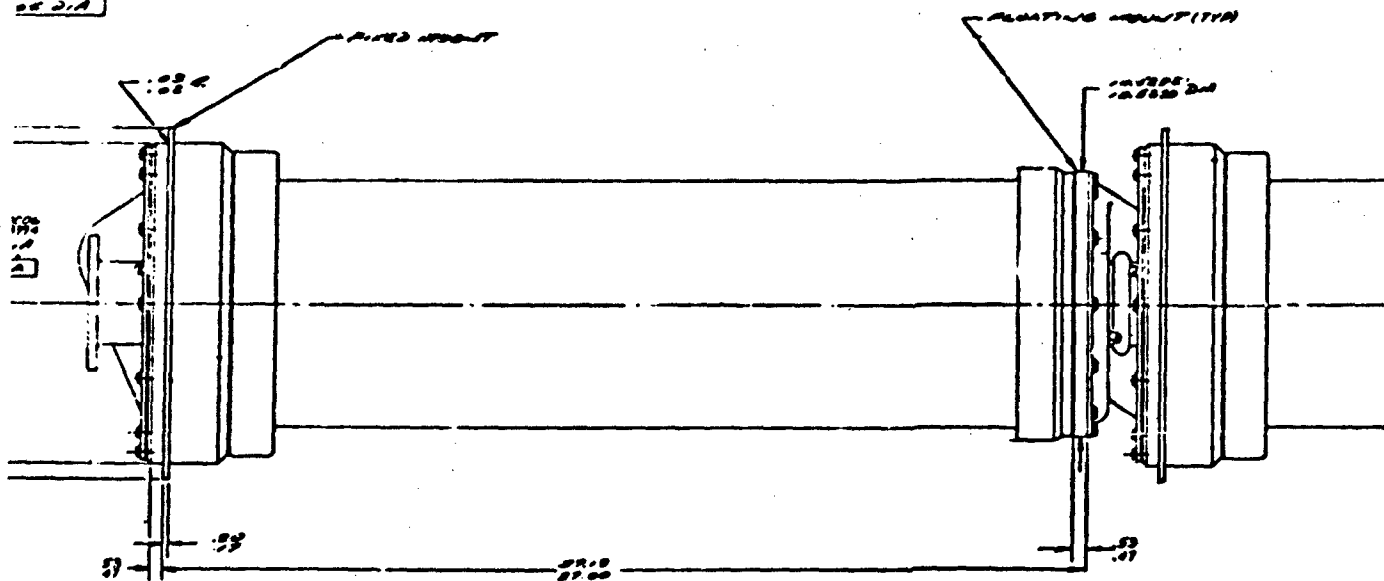
WIRING DIAGRAM -
WIRE CONNECTIONS SHOWN AS
DASH LINES WILL BE SUPPLIED
BY CUSTOMER



13 12 11 10 9



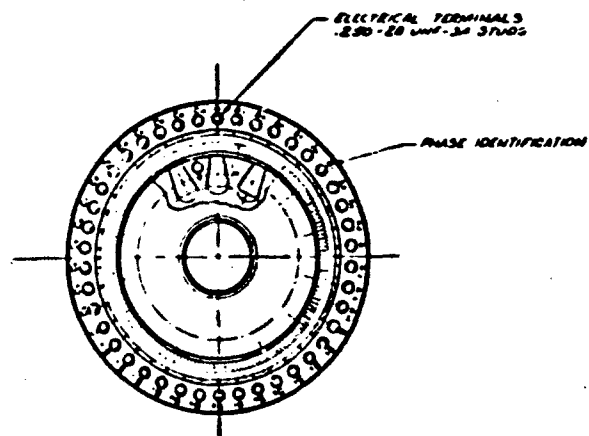
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100



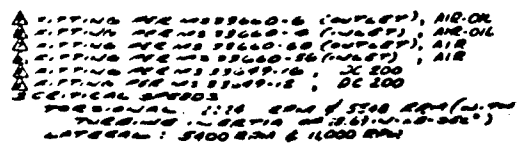
13 12 11 10 9

2

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SECTION A-A



P00041486 -

	DATE	TIME	LOCATION
1. 1000	10:00	10:00	10:00 (MIL-23679)
2. 1000	10:00	10:00	10:00
3. 1000	10:00	10:00	10:00
4. 1000	10:00	10:00	10:00
5. 1000	10:00	10:00	10:00
6. 1000	10:00	10:00	10:00
7. 1000	10:00	10:00	10:00
8. 1000	10:00	10:00	10:00
9. 1000	10:00	10:00	10:00
10. 1000	10:00	10:00	10:00

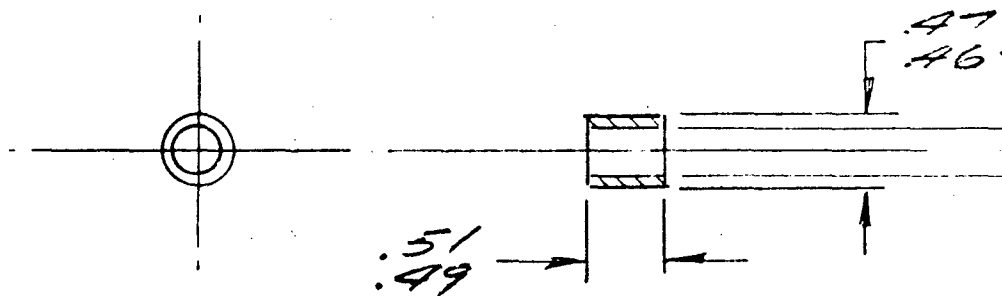
1. ASSASSINATIONS -

[illegible]

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DWG NO. 2046

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PART NO 2046855-1

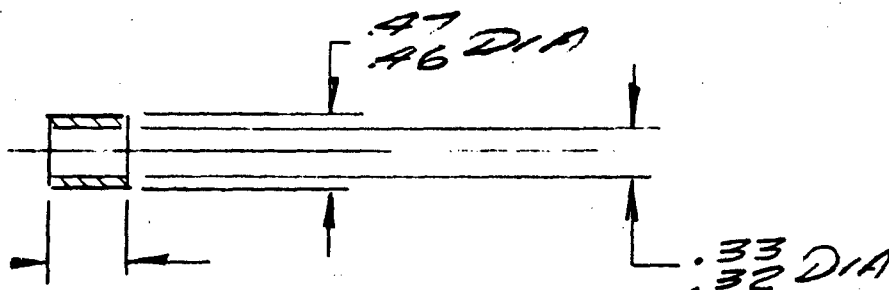
1. MATL: .50 DIA BAR
ASTM A 582 TYPE 303

NOTES

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 CLB STD INTERPRETATIONS PER PIB5 IDENTIFICATION MARKING PER MC16			MATERIAL	CONTR
			NOTE 1	CHKD
				VALUE
				MATL
			HEAT TREATMENT	STRES:
REQD NEXT ASSY USED ON			FINISH PROCESS	DESIGN
APPLICATION				PROJECT
				GOVER

FORM 1195 (1-77)

DWG NO 2046855 SH		REVISIONS			
Except for rights expressly granted by contracts to the United States Government, herein, without the prior written permission of THE GARRETT CORPORATION.		REV	DESCRIPTION	DATE	APPROVED

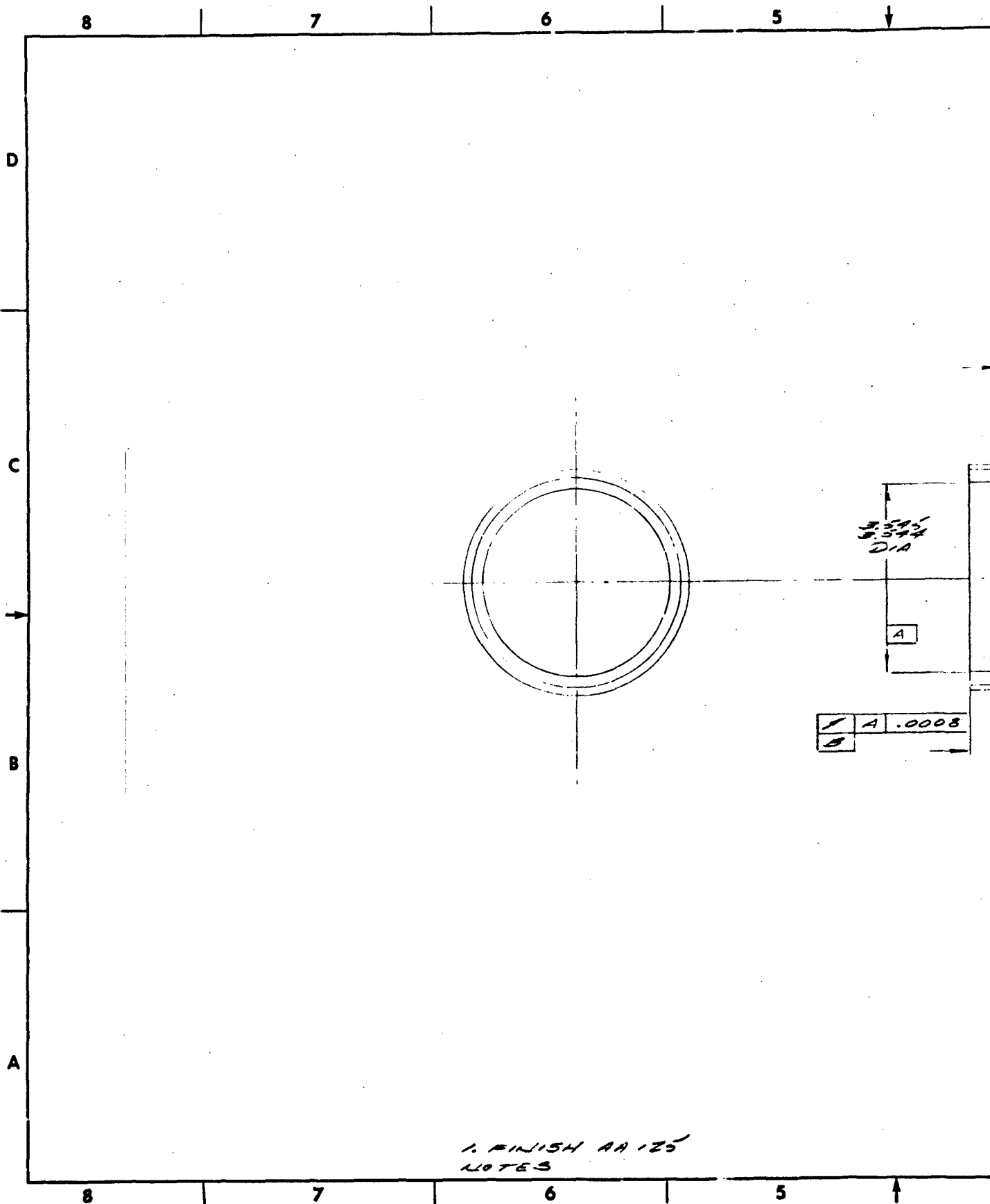


855-1

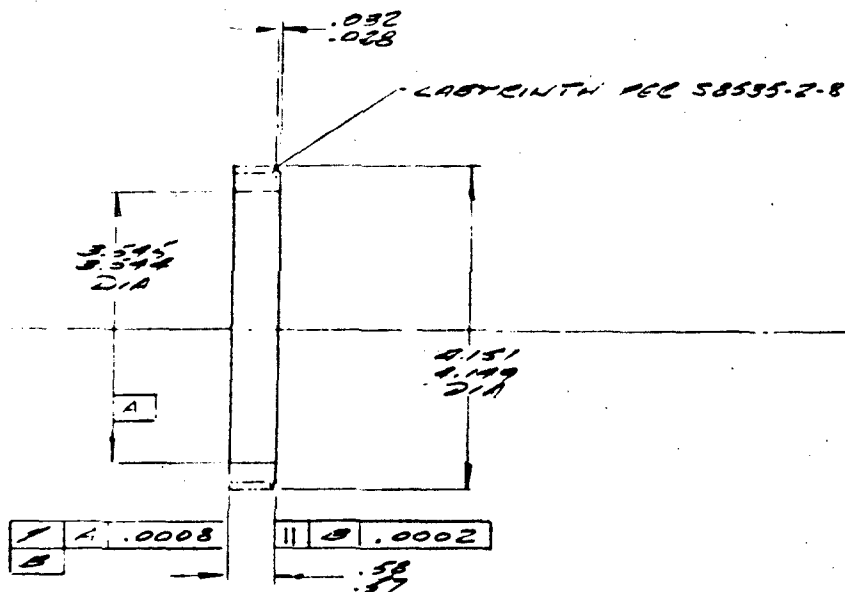
ECIFIED: 3653 CLB PER PIBS ING PER	MATERIAL NOTE 1	CONTR NO 4-13-78 5-9-78 CHE VALUE ENGR MATL	AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA
			WEIGHT BALANCE
46870 USED ON	HEAT TREATMENT FINISH PROCESS	STRESS DESIGN SUPERVISOR 830109 PROJECT ENGINEER 10A King 1-2-52 GOVERNMENT APVD	SIZE B CODE IDENT NO 70210 DWG NO 2046855
		SCALE 1-1	SHEET 1 OF 1

2

3-63/3-64



5	4	3	2	1
Dwg No. 2046874			REVISIONS	
This drawing contains design and other information which is the property of THE GARRETT CORPORATION. It shall be kept secret and not be disclosed or used for manufacture of the part described herein without the prior written permission of THE GARRETT CORPORATION.			ZONE LTR DESCRIPTION DATE APP	
REV STATUS			DATE	
SHEET			APP	



PART NO 2046874-1		UNLESS OTHERWISE SPECIFIED: SURF CONTROL PER SPEC CL3 DIMS UNLESS OTHERWISE SPECIFIED PER CL3		CONTRACT NO. 715-10 715-10		APPROXIMATE MANUFACTURING COMPANY OF SEAL A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
42-025375-111 1115		00-T-430 50-T-416 TYPE CL3		VALUE SIZE REV TYPE		SPACER	
40-025370-1046870		40-025370-1046870		40-025370-1046870		D 70210 2046874	
REQ. NEXT ASSY. USED ON		APPLICATION		SCALE FULL		SHEET 1	

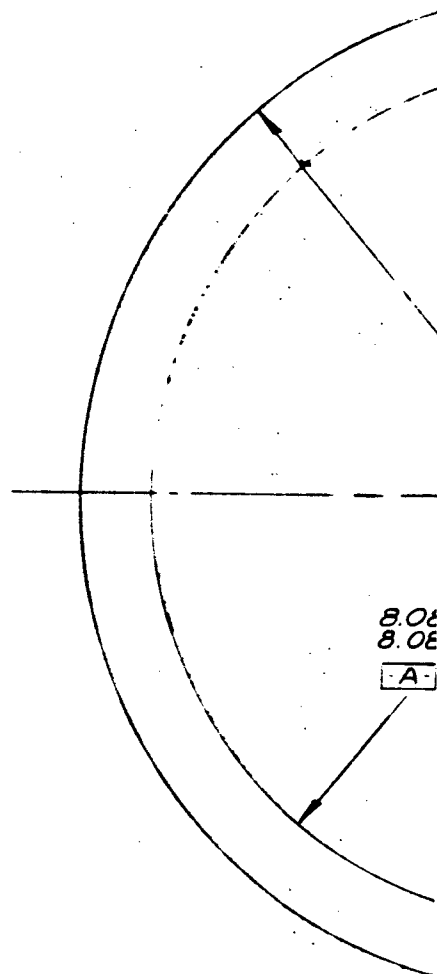
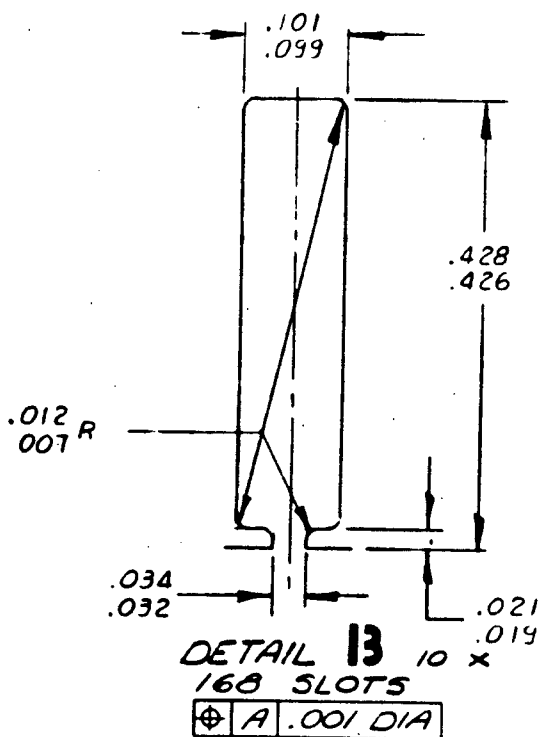
3-65/3-66

2

PART NO.	MATERIAL
2096875-1	
2096875-2	SYNTHETIC FIBER PAPER (NOMEX) MIL-1-24204 TYPE I .020 THICK

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 .001 N.



 .007 THICK MAGNESIL N 

... FULLY PROCESSED

... UNCOATED

 MAGNETICS, BUTLER, PA. FSC 90799

 ANNEAL AFTER PUNCHING PER HT 59, TYPE I.
INERT GAS ONLY. NO PAC ANNEAL.

2. LAMINATIONS SHALL BE

PLAT WITHIN .005 UNDER SLIDING

7. SURFACE SHALL NOT EXCEED

.0007 AS PUNCHED

NOTES

PART NO. TABULA

UNLESS OTHERWISE SPECIFIED:
SAW CONTROL PER SCSS 508
STD INTERPRETATIONS PER PHS
IDENTIFICATION MARKING PER
SCSS

MATERIAL

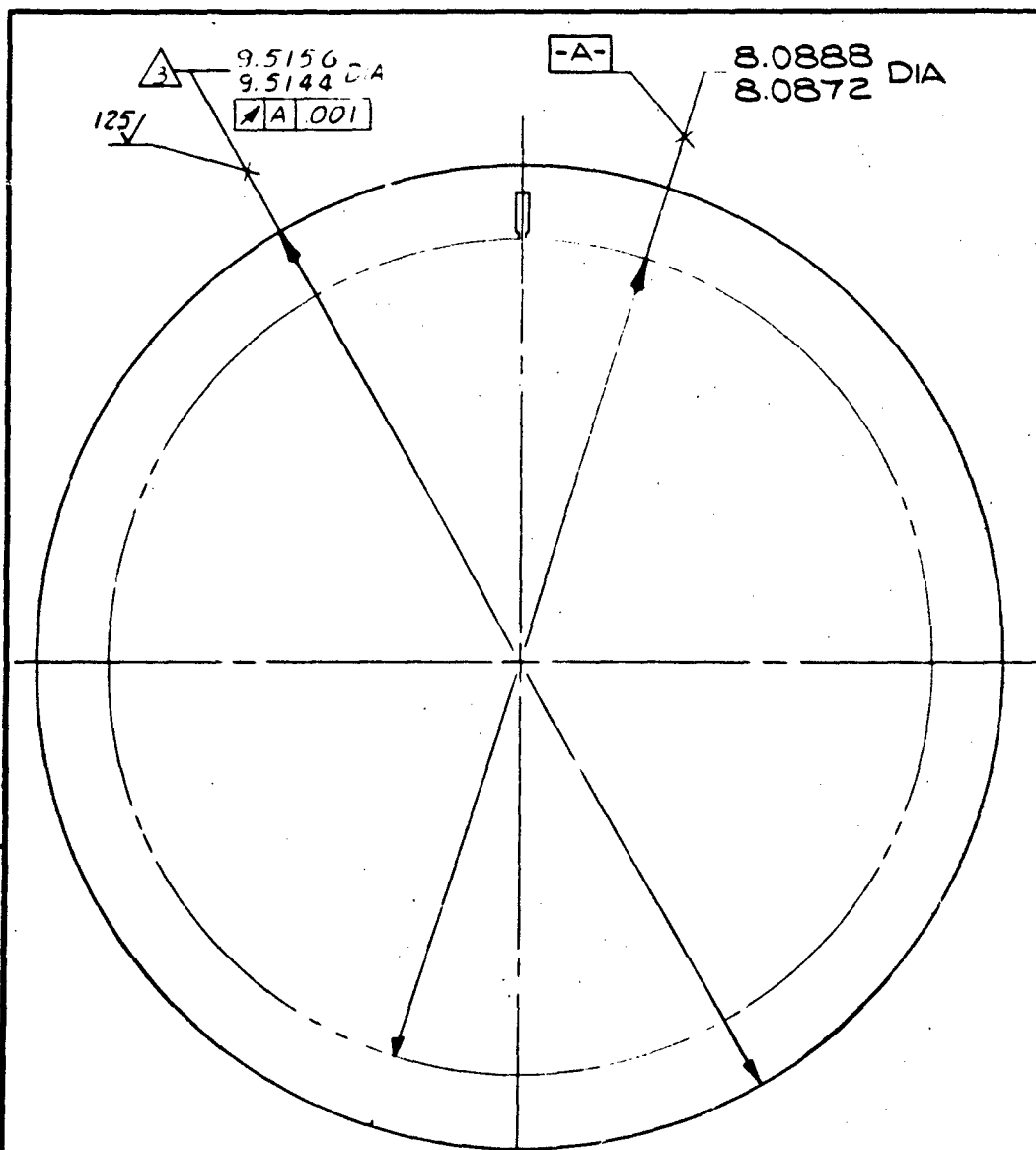
TABULATED

FINISH PROCESS

PLAT TREATMENT



PROD. NEXT ASSY. USED ON
APPLICATION



THIS DRAWING CONTAINS DESIGNS AND WHICH ARE THE PROPERTY OF THE GARR. EXCEPT FOR RIGHTS EXPRESSLY GRANTED BY THE UNITED STATES GOVERNMENT, THIS IN WHOLE OR IN PART, BE DUPLICATED FOR MANUFACTURE OF THE PART WITHOUT THE PRIOR WRITTEN PERMISSION OF THE CORPORATION.

1
2
5
6
2

5. ANY EXCESS ADHESIVE AFTER BONDING MUST BE REMOVED FROM OD, ID & SLOTS BEFORE CURING.
4. FOR SLOT ALIGNMENT A MIN. OF 3 DRILL RODS OR CENTERLESS GROUND RODS MUST BE USED, APPROX. 120° APART.
3. PROCESS PER FPI3AC3B EXCEPT COLD BRUSH PHOSPHATE ONLY PER FPI5 FOR APPLICATION OF DRY FILM LUBE TO ID.
2. FIND NO. 516 TO HAVE 24.00 LB OF ACTUAL STEEL WEIGHT TO INSURE SUFFICIENT IRON CONTENT BEFORE MACHINING.
1. APPLY INSULATING COAT OF FIND 2 .0003-.0005 THICK TO FIND 1, & THOROUGHLY CURE. APPLY BONDING COAT OF FIND 2 TO FIND 1 & STACK FIND 5 & 6 WITH SLOTS ALIGNED WITHIN .001. PER RS 25

NOTES: UNLESS OTHERWISE SPECIFIED.

A .005

PART NO. SEE SEP

UNLESS OTHERWISE SPECIFIED:
JURA CONTROL PER SC863 CLP
STD INTERPRETATIONS PER PHS
IDENTIFICATION MARKING PER
MCS

MATERIAL

FINISH PROCESS

HEAT TREATMENT

2(2)500400-1518404-1	REQD	NEXT ASSY	USED ON	APPLICATION
2(1)500400-1518404-1				

3

28 DIA

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MATERIAL FINISH PROCESS HEAT TREATMENT		STACK ASSY STATOR		SIZE CODE IDENT NO C 70210 2046960	
PART NO. 00400-1518404-1 NEXT ASSY USED ON APPLICATION		SCALE FULL		SHEET 1 OF 1	

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BURN CONTROL PER SC883 *CLB*
STD INTERPRETATIONS PER PMS
IDENTIFICATION MARKING PER
MC16

6061-76

FINISH PROCESS

HEAT TREATMENT

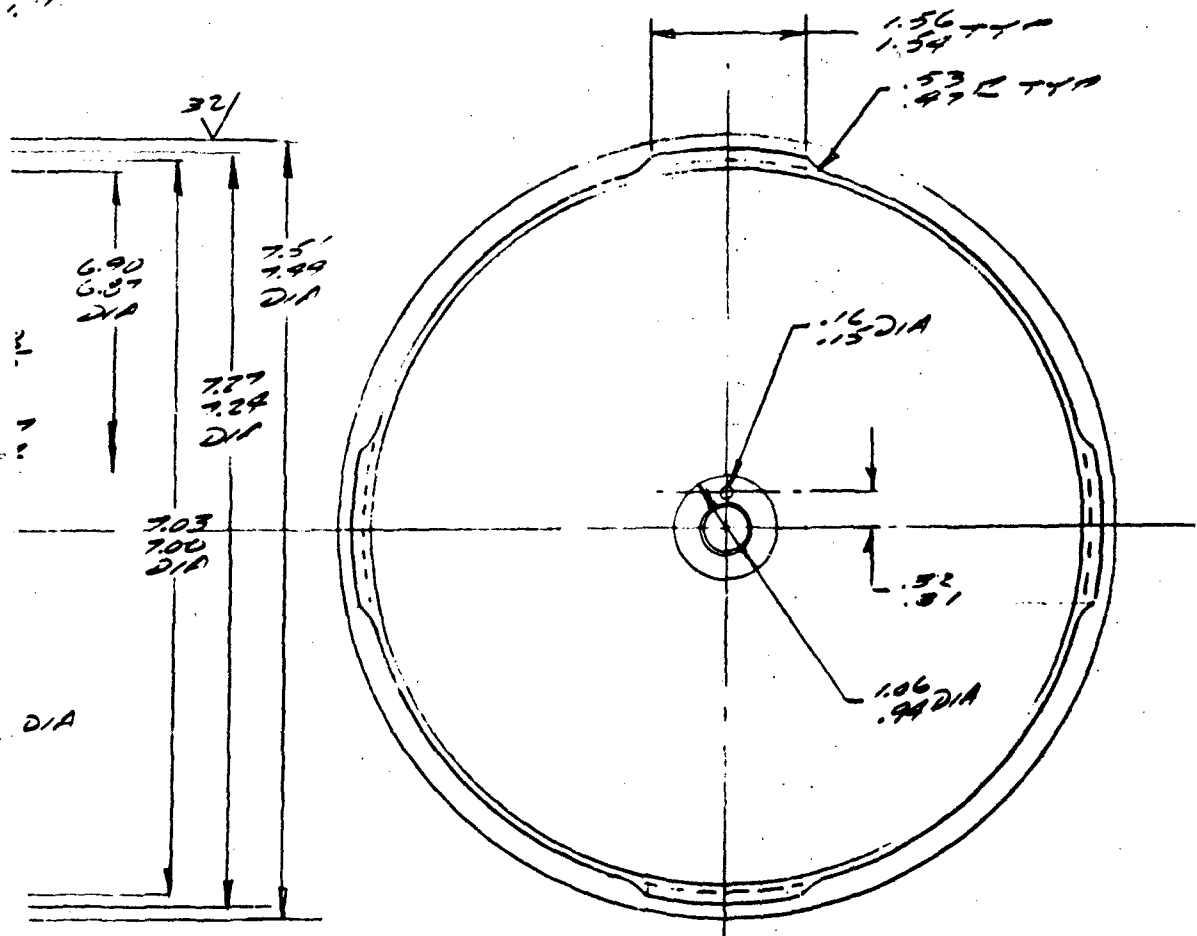
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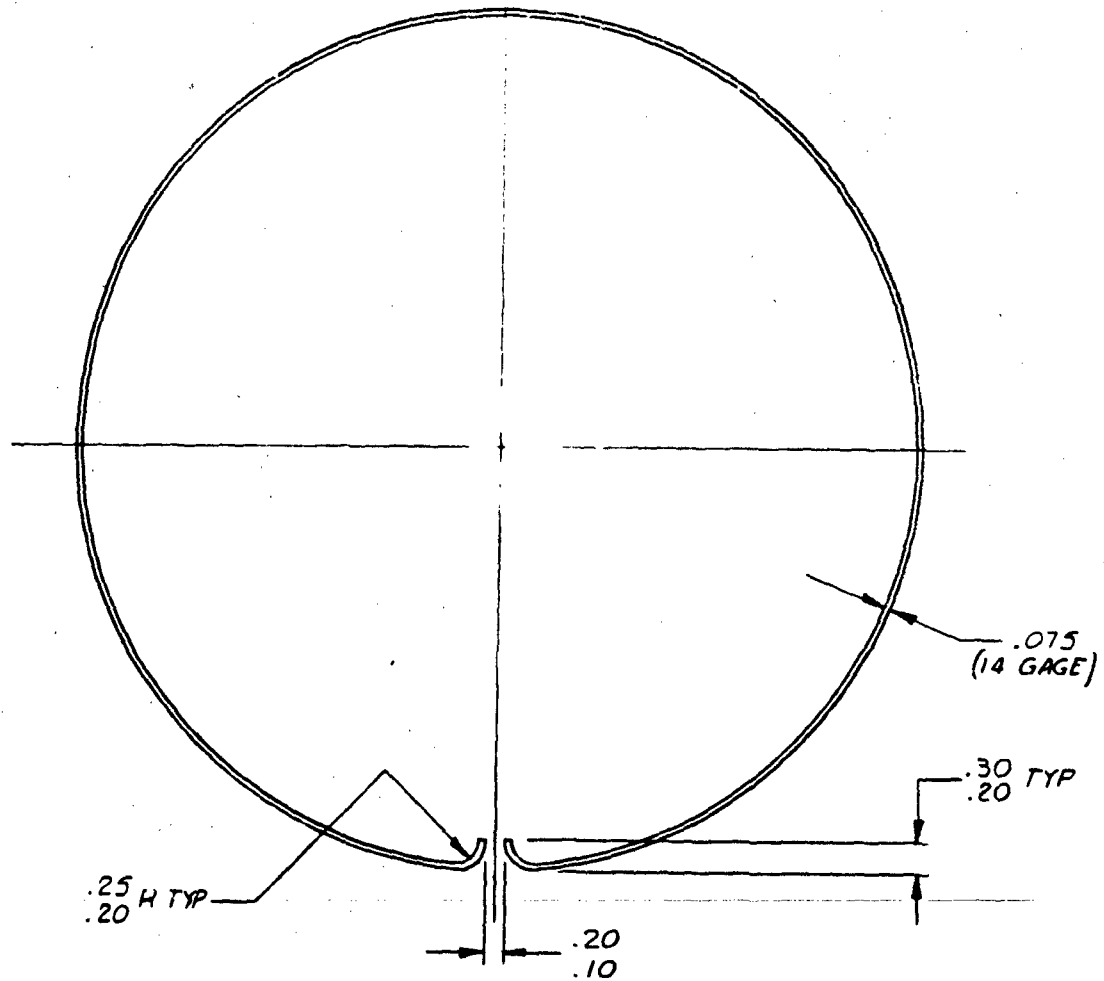
PART NO. 2047040-1

UNLESS OTHERWISE SPECIFIED: BURN CONTROL PER SC883 CLB STD INTERPRETATIONS PER PMS IDENTIFICATION MARKING PER MCSB		CONTRACT NO. 8-68-78		AIRRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL 7.50 DIA ALALY BAC 6061-T6		DESIGN VALUE ENGR		TOOL END CAP, BORE SEAL	
FINISH PROCESS		MATERIAL			
HEAT TREATMENT		DESIGN SUPERVISOR		SIZE C	CODE IDENT NO 70210
USED ON ON		GOVERNMENT APPO		SHEET 1 OF 1	

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3-71/3-72

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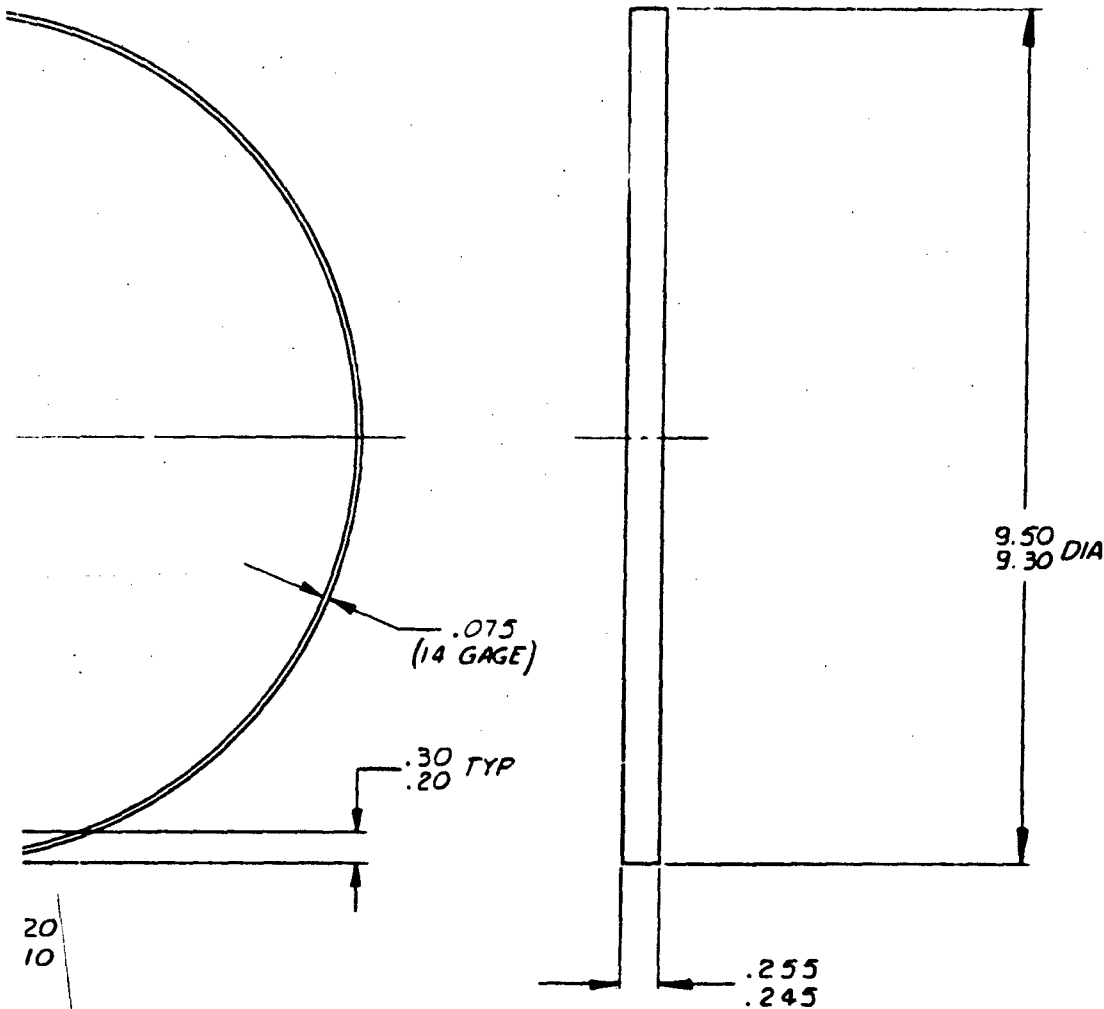
UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC863 C.B. STD INTERPRETATIONS PER PMS IDENTIFICATION MARKING PER MC18	
MATERIAL AL ALY 6061-T6 QQ-A-250/II COND T6	
FINISH PROCESS	
HEAT TREATMENT	
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 NOTES: UNLESS OTHERWISE SPECIFIED

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MATERIAL AL ALY 6061-T6 QQ-A-250/II COND T6		DESIGNED BY C. DUNNIRE 7/20/72		SPACER	
FINISH PROCESS		CHECKED 7/20/72			
HEAT TREATMENT		DESIGN SUPERVISOR 7/20/72		SIZE C 70210	DWG NO 2047043
APPLICATION		GOVERNMENT APO		SCALE: 1/1	SHEET 1 OF 1

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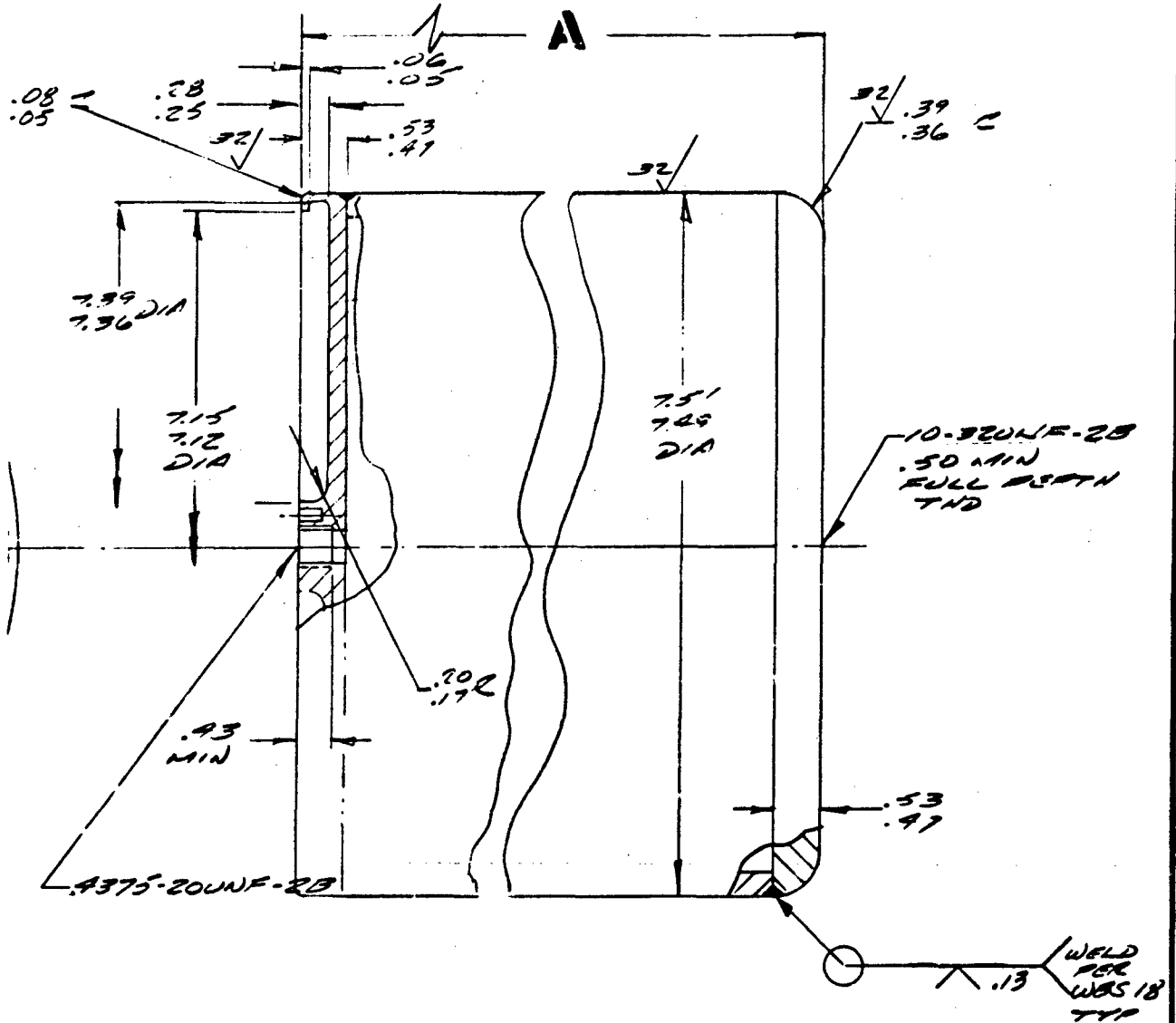
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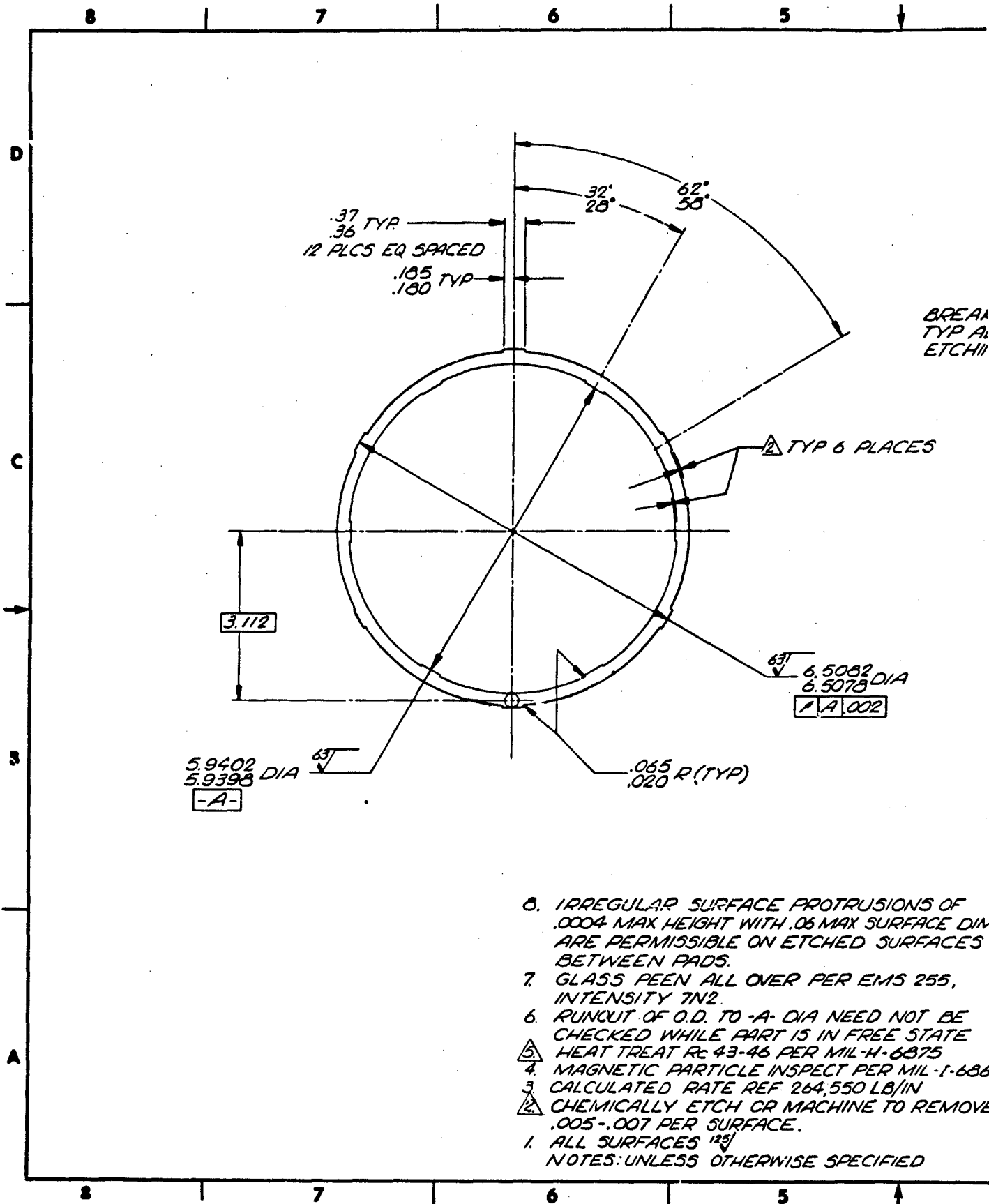
PART NO. 2047176-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC63 C10 STD INTERPRETATIONS PER FIBS IDENTIFICATION MARKING PER INC18		CONTRACT NO. 8-28-78 CHR 81011		AIRSEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION FERRANCE, CALIFORNIA	
MATERIAL NOTE 1		DESIGN VALVE ENGR MAYL SYRES		TOOL BODY BORE SEAL	
FINISH PROCESS		APPROVED BY DESIGN SUPERVISOR PROJECT ENGINEER MAY 1-12-82		SIZE C	CODE IDENT NO 70210
HEAT TREATMENT		GOVERNMENT APPROV		OWN NO 2047176	
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REVIEWS				
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PART NO 2047324-1		USE/LES OTHER/ELSE SPECIFIED: DRAWING CONTROL PER BOSS C.B. REV. INFORMATION PER FMS IDENTIFICATION MARKING PER REV. C.B.A.		DATE 1-1-79 BY 218 CHECKED 2-14-79 TITLE:		AMERICAN MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE BARRETT CORPORATION TORRANCE, CA., U.S.A.	
MATERIAL 6.50 O.D. TUBING 1.50 WALL 4340 STL. AMS 6415 FINISH:		FINISH:		MOUNT, RESILIENT, BEARING		D 70210 2047324	
RECD NEXT ASBY APPLICATION		MAY 1980 218		SCALE 1/1		SHEET 1 OF 1	

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STD INTERPRETATIONS PER PDS
IDENTIFICATION MARKING PER
MC16

MATERIAL
6.00 DIA BAR
4340 STL.
MIL-S-5000

FINISH PROCESS

HEAT TREATMENT

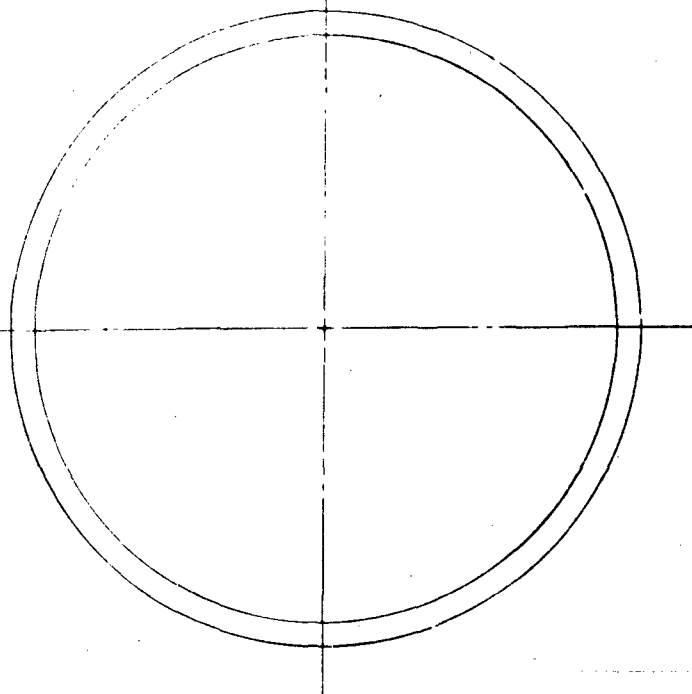


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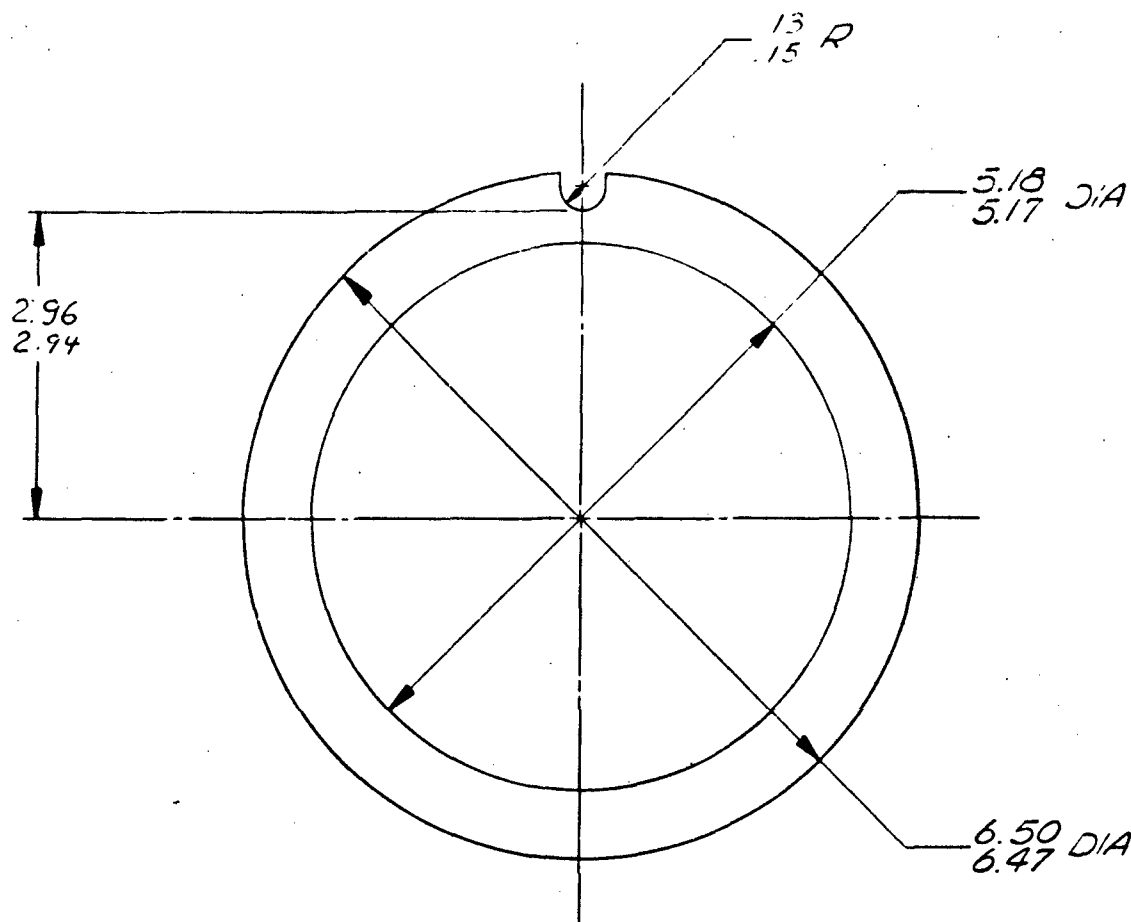
PART NO. 2047325-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SC653 STD INTERPRETATIONS PER PHS IDENTIFICATION MARKING PER MIL-18		CONTRACT NO. PREPARED BY <i>Wick</i> 8-1-79 CHKD BY <i>Wick</i> 8-16-79 VALUED IN <i>Wick</i> 8-16-79 MATL STRESS APVD BY <i>Wick</i> 8-16-79 DESIGN SUPERVISOR <i>Wick</i> PROJECT ENGINEER <i>Wick</i> GOVERNMENT APVD		AIRSEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL: 6.00 DIA BAR .2340 STL MIL-5-5000		SPACER			
HEAT TREATMENT 2		SIZE C	CODE IDENT NO 70210	DWG NO 2047325	
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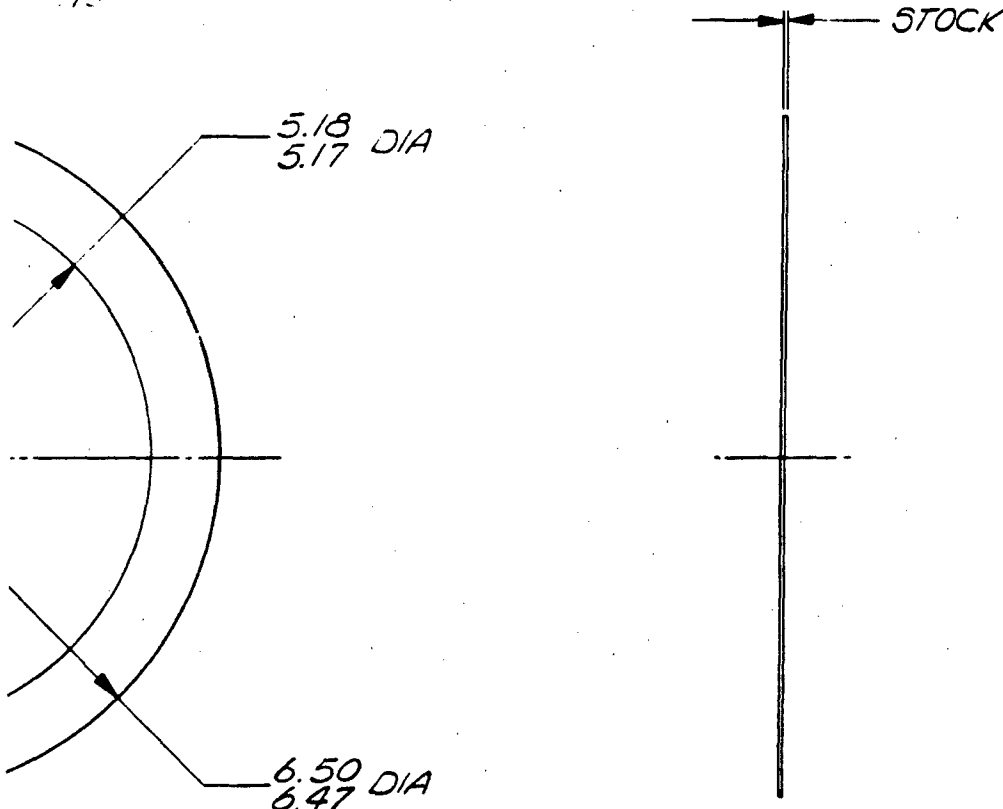
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MATERIAL .010 STL STRIP QQ-5-698 (1010 OR 1020)			CHE. <i>7</i>
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APPLICATION			STRESS
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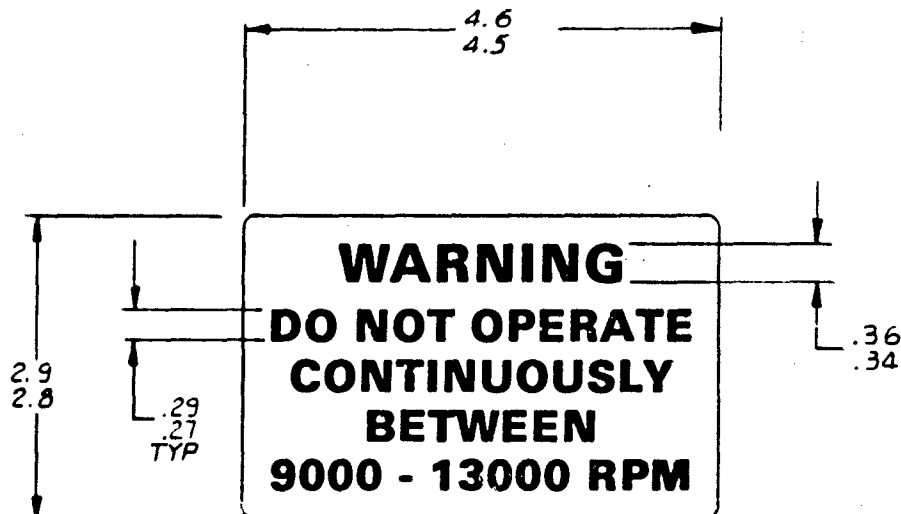
UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER SCMS CLA STD INTERPRETATIONS PER PIDS IDENTIFICATION MARKING PER BC18		CONTRACT NO.		 AIRESEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL .010 STL STRIP QQ-S-698 (1010 OR 1020)		PREPARED BY <i>W. J. [Signature]</i> 8-14-79 CHK. <i>W. J. [Signature]</i> 8-14-79 DESIGNED BY <i>W. J. [Signature]</i> 8-14-79 VALUE ENG. MATL. STRESS		WASHER, SHIM	
FINISH PROCESS		APPROV. <i>W. J. [Signature]</i> 8-20-84 DESIGN SUPERVISOR PROJECT ENGINEER MR. LAM: 1-12-82			
HEAT TREATMENT		GOVERNMENT APPO		SIZE C 70210	DWS NO 2047328
APPLICATION				SCALE // 1	SHEET / OF /

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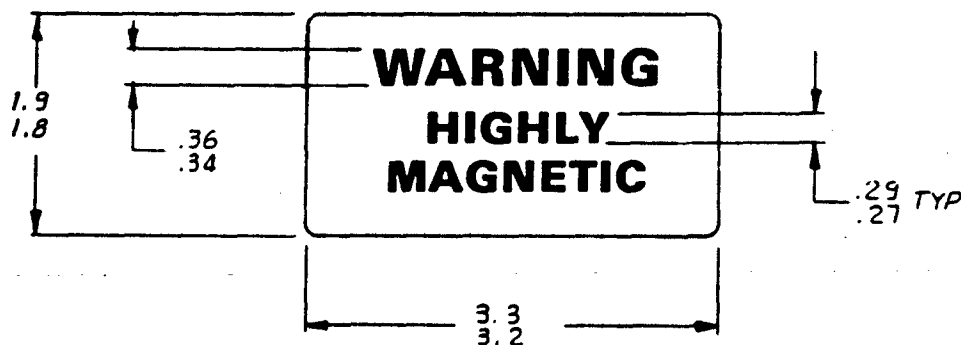
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PART NO. 2047329.

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SURF CONTROL PER SC883 C.B.
STD INTERPRETATIONS PER PHS
IDENTIFICATION MARKING PER
MCTB

MATERIAL



FINISH PROCESS

HEAT TREATMENT



MATERIAL: ADHESIVE BACKED METAL FOIL
PER EMS 729 TYPE III-A
FINISH: DATA LETTERS TO BE RED
ANODIZE ON NATURAL COLOR
BACK GROUND.

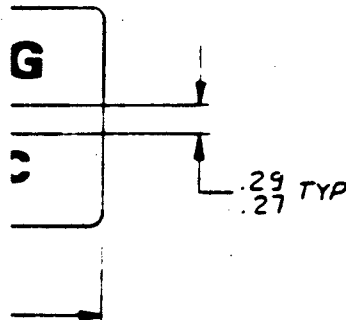
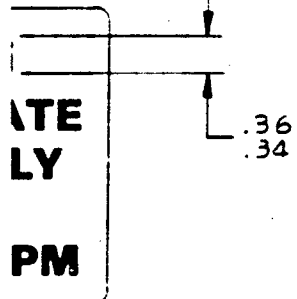
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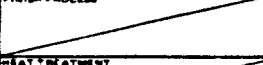
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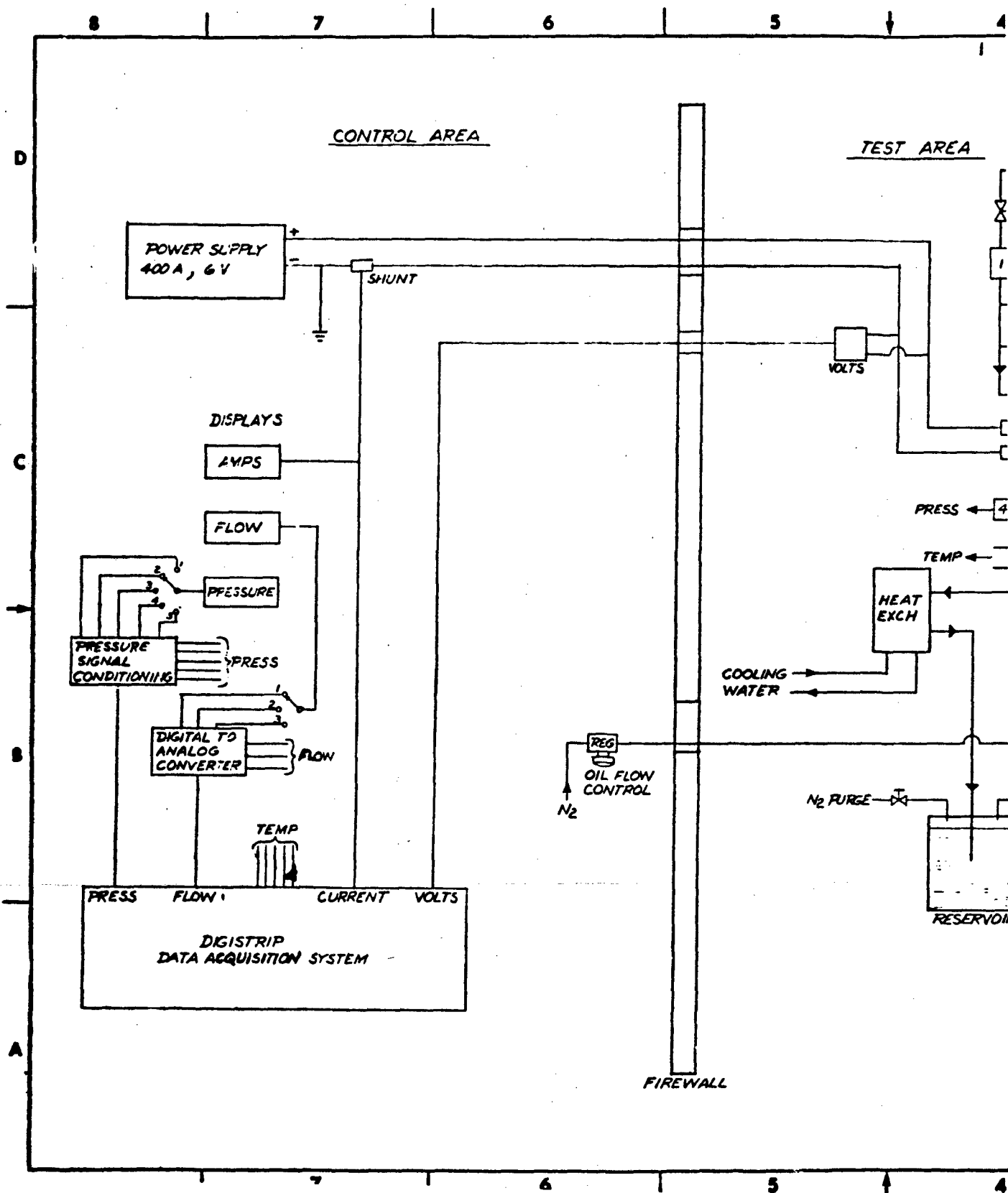
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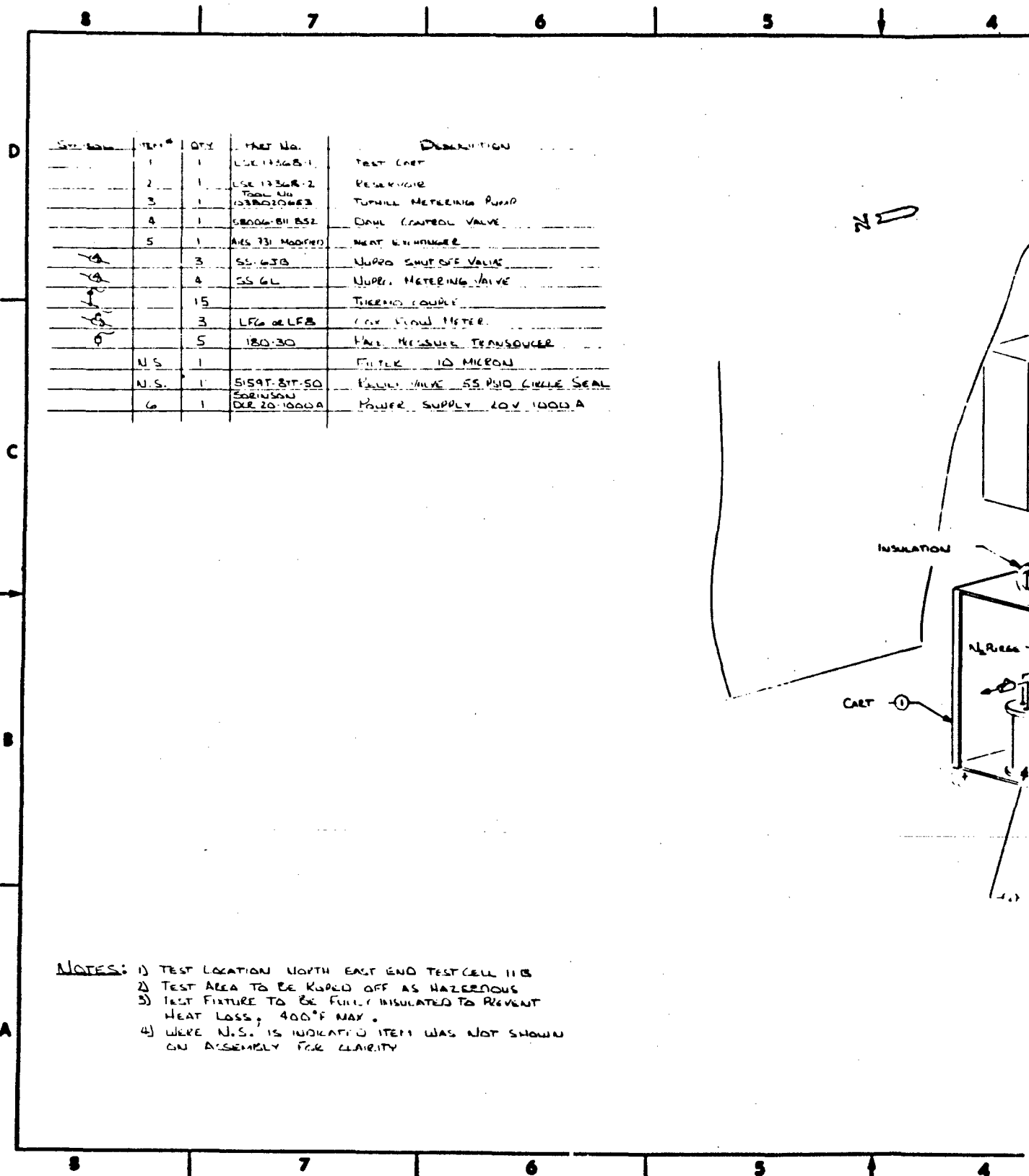
PART NO. 2047329-1

UNLESS OTHERWISE SPECIFIED: BURR CONTROL PER BOM3 CL8 STD INTERPRETATIONS PER PUB IDENTIFICATION MARKING PER BC16		CONTRACT NO.		 AIRSEARCH MANUFACTURING COMPANY OF CALIFORNIA A DIVISION OF THE GARRETT CORPORATION TORRANCE, CALIFORNIA	
MATERIAL 		PREPARED BY <i>John Hwang 8-14-79</i> CHK. <i>W. J. ... 8-14-79</i> DESIGNED <i>John Hwang 8-14-79</i> VALUE ENG. MATL. STRESS		LABEL, WARNING	
FINISH PROCESS 		APPROVED BY <i>John Hwang 8-14-79</i> DESIGN SUPERVISOR PROJECT ENGINEER GOVERNMENT APPROV.			
HEAT TREATMENT NEXT ASSY. USED ON APPLICATION		SIZE CODE IDENT NO. SHEET NO. C 70210 2047329		SCALE <i>1/1</i> SHEET / OF /	

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4. NO LOAD TEST PLAN

The no load test plan for the 5 MW generator (AiResearch Report 80-18822) is presented as Exhibit 4A. This report is submitted for approval.

EXHIBIT 4A

**AIRESEARCH REPORT 82-18822
NO-LOAD TEST PLAN**

CONTENTS

<u>Section</u>	<u>Page</u>
1. INTRODUCTION	4-7
1.1 Scope	4-7
1.2 Test Facility	4-7
2. GENERAL REQUIREMENTS	4-9
2.1 Test Setup	4-9
2.2 Cooling Requirements	4-10
2.3 Mechanical Drive System Requirements	4-16
3. TEST INSTRUMENTATION	4-23
4. NO-LOAD TEST PROCEDURE	4-25
5. SYSTEM SAFETY/HAZARD ANALYSIS	4-30
5.1 Analysis	4-30
5.2 Conclusions and Recommendations	4-30

1. INTRODUCTION

1.1 SCOPE

No-load testing of the 5-Mw permanent magnet generator as described in this report will be an intermediate step in the development of an advanced nonsuperconducting synchronous generator for airborne applications. The rotor and stator/housing are presently being developed under two separate contracts with the Air Force Aeronautical Systems Division, Wright Patterson AFB, Ohio, for delivery in early 1982 and mid-1983, respectively.

This test plan is being prepared well in advance of hardware availability in order to effectively schedule the fabrication of special test equipment and to ensure ready utilization of the test facility.

A cutaway drawing of the generator to be tested is shown in Figure 1-1.

1.2 TEST FACILITY

The generator will undergo its no-load checkout at the AiResearch Torrance facility, Building 9A, Test Cell 31. After setup, approximately one week of testing will be required to perform the tests outlined in this plan.

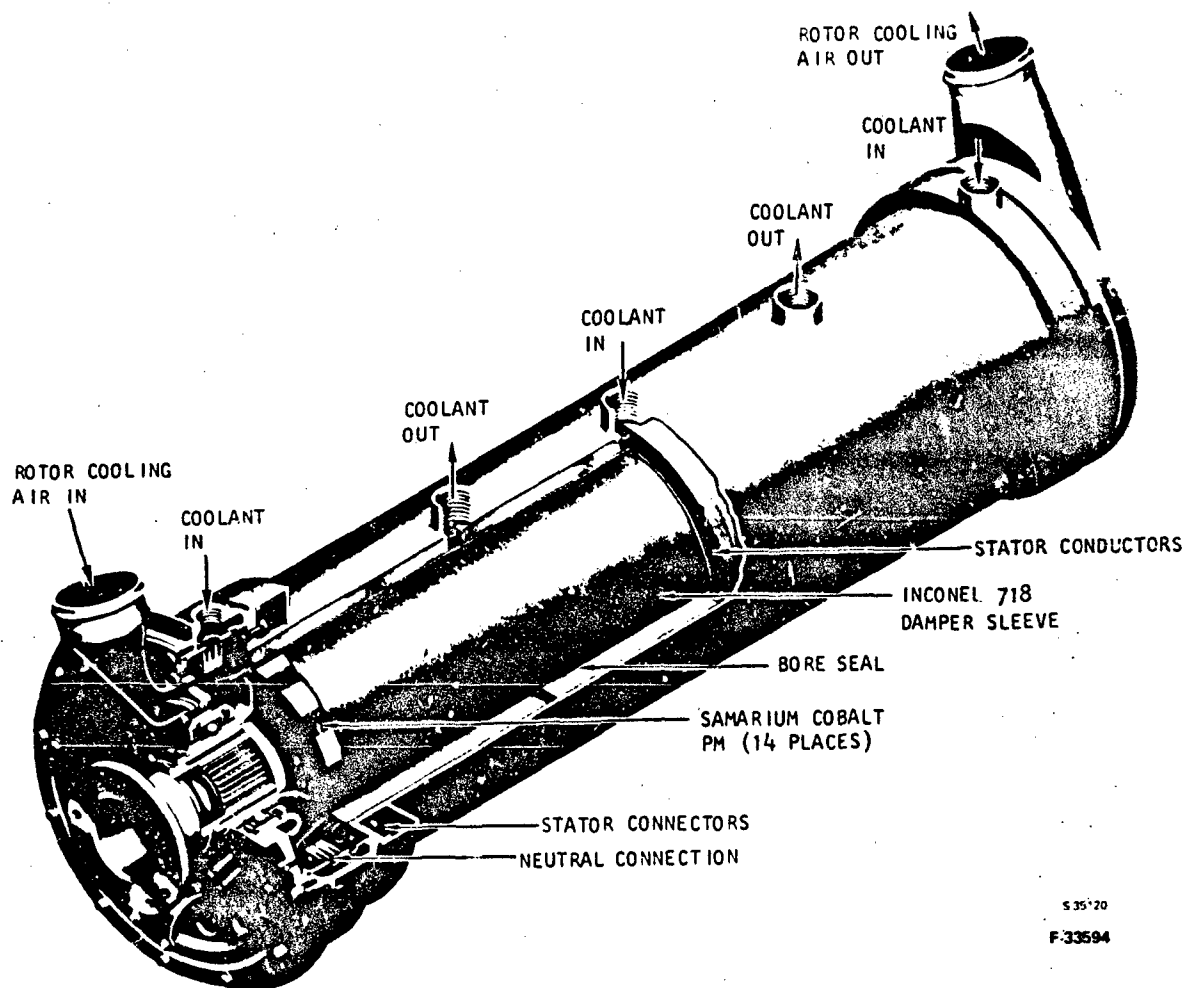


Figure 1-1. Complete 5-Mw Generator Design

2. GENERAL REQUIREMENTS

2.1 TEST SETUP

AiResearch Dwg. SK74954 details the 5-Mw generator as it will be configured for testing.

The overall test setup schematic is shown in AiResearch Dwg. S4-3B-0532.

Major design parameters for the generator are listed in Table 2-1.

TABLE 2-1
5-MW GENERATOR DESIGN PARAMETERS

Parameter	Value
Rating into 3-phase, full-wave bridge	1,046 vdc, 4,780 adc @ 18,000 rpm 648.3 v/phase (air gap), 3638 amp/phase
Current density, amp/in. ²	36,270
Stator temperature, °F	450
Rotor temperature, °F	200
Overall length, in.	43
Overall diameter, in.	16.25
Total weight, lb	500

2.2 COOLING REQUIREMENTS

2.2.1 Rotor

The permanent magnet rotor will be cooled by forced air generated by a test cell centrifugal blower and measured with an orifice or venturi section. Cooling air will be discharged into the test cell (see Figure 2-1).

Operating parameters are the following:

<u>Parameter</u>	<u>Requirement</u>
Airflow	100 to 300 cfm
Air pressure	
Inlet	Ambient plus 0.5 psig
Outlet	Ambient
Air temperature	
Inlet	Ambient
Outlet	To 210°F

2.2.1.1 Blower Power Requirements

Power requirements for the blower are 230-460 vac, 3-phase, 60 Hz, 2 hp.

2.2.1.2 Instrumentation

Instrumentation requirements are as follows:

<u>Parameter</u>	<u>Requirement</u>
Flow	Measuring section inlet static pressure gage (1) and delta pressure gage (1)
Pressure	Unit inlet pressure transducer (1)
Temperature	
Inlet	Thermocouples (2)
Outlet	Thermocouples (2)

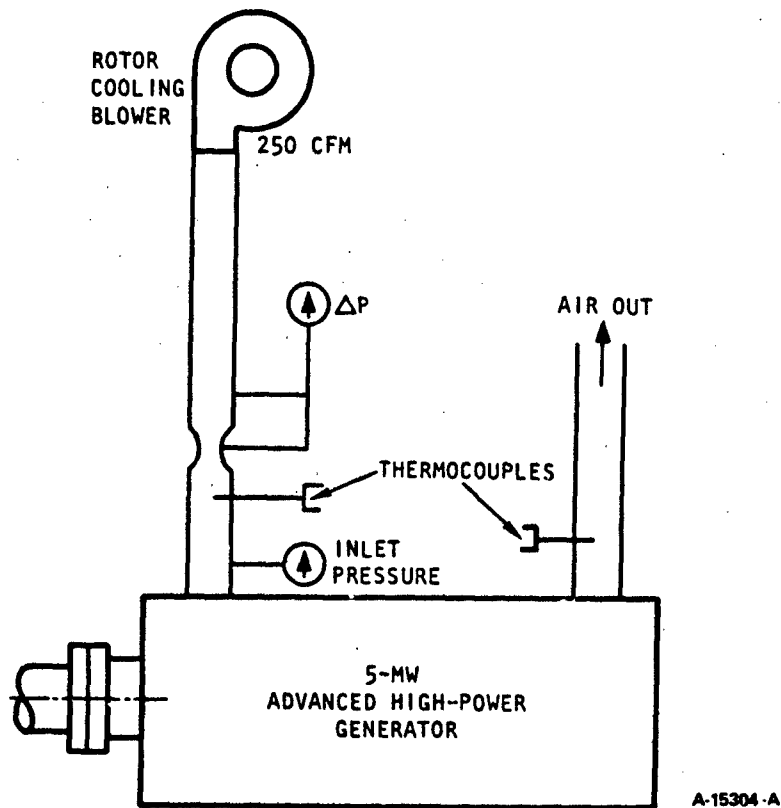


Figure 2-1. Rotor Cooling System

2.2.2 Stator

Stator conductors will be cooled by oil pumped through passages around the conductors. The cooling system (see Figure 2-2) will utilize a two-pump approach because of the requirement for a subatmospheric discharge pressure (7 psia) and a vented sump.

Operating parameters are shown in Table 2-2.

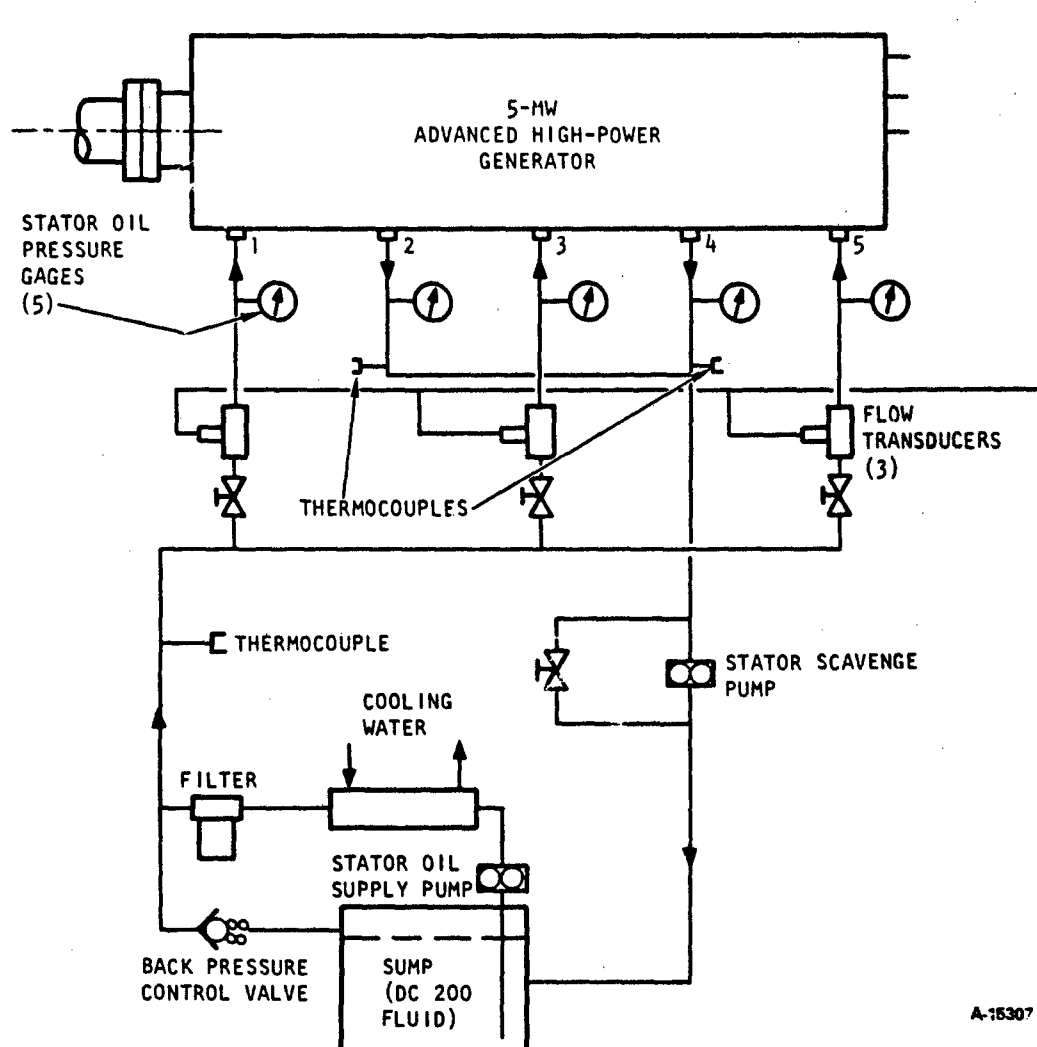


Figure 2-2. Stator Cooling System

2.2.2.1 Pump Power Requirements:

Power requirements for the pumps are as follows:

<u>Parameter</u>	<u>Requirement</u>
Supply	230 to 460 vac, 3-phase, 60 Hz, 1 hp
Scavenge	230 to 460 vac, 3-phase, 60 Hz, 3 hp

TABLE 2-2
STATOR OPERATING PARAMETERS

Parameter	Requirement
Oil	Dow Corning 200
Oil Flow	
Inlet No. 1, gpm	6.25
Inlet No. 3, gpm	12.5
Inlet No. 5, gpm	6.25
Total, gpm	25.0
Outlet No. 2, gpm	12.5
Outlet No. 4, gpm	12.5
Pressure	
Inlet, psia	19
Outlet, psia	7
Temperature	
Inlet, °F	120
Outlet, °F	To 250
Filtration, μ	25
Sump capacity, gal	50
Ultimate heat sink	Cooling tower water at TBD Btu/hr rate

2.2.2.2 Accessories

One level sight gage and five mechanical pressure gages are required.

2.2.2.3 Instrumentation

Instrumentation is required as follows:

<u>Parameter</u>	<u>Requirement</u>
Flow	Inlet transducers 0 to 6.25 gpm (2)
	0 to 12.5 gpm (1)
Pressure	Inlet gages (psia) (3)
	Outlet gages (psia) (2)
Temperature	Inlet thermocouple (1)
	Outlet thermocouples (2)

2.2.3 Bearings

The rotor bearings will be cooled and lubricated by a system providing air-oil mist under pressure (see Figure 2-3).

Operating parameters are shown in Table 2-3.

2.2.3.1 Instrumentation

Instrumentation requirements are the following:

<u>Parameter</u>	<u>Requirement</u>
Pressure	Inlet gage (psia) (1)
Temperature	Inlet thermocouple (1)
	Outlet thermocouples (2)

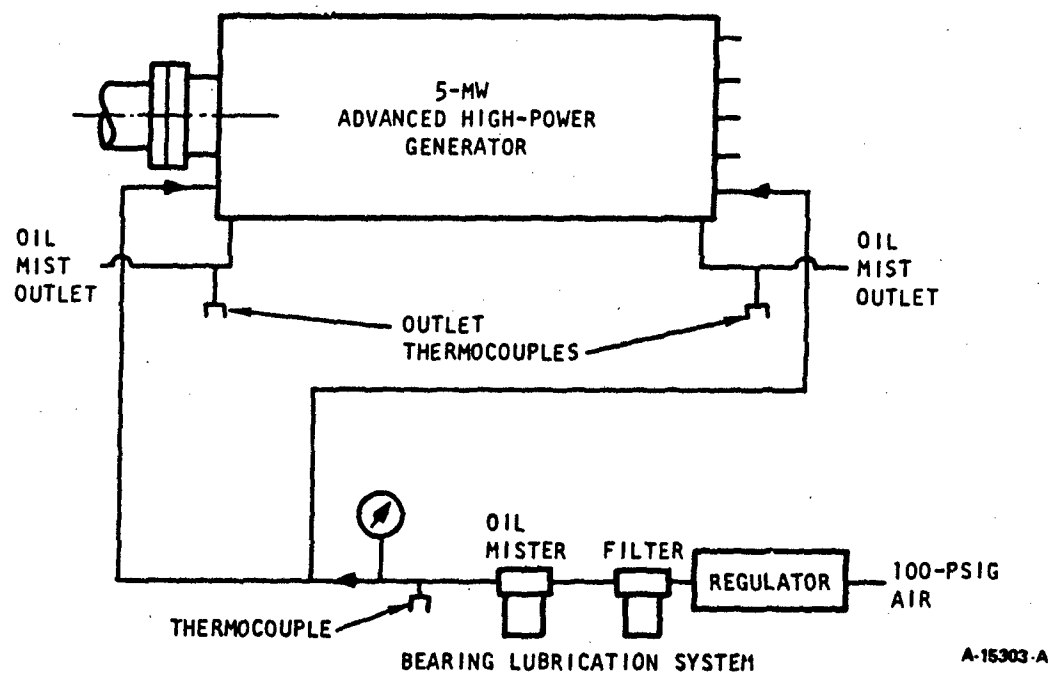


Figure 2-3. Bearing Cooling and Lubrication System

TABLE 2-3
BEARING OPERATING PARAMETERS

Parameter	Requirement
Oil	Mobile Jet II (MIL-L-23699)
Flow	
Air, lb/min	0.045
Oil	TBD
Pressure	
Inlet, psia	15.3
Outlet	Ambient
Temperature	
Inlet	Ambient
Outlet	TBD
Filtration, μ	10
Sump capacity, oz	10

2.3 MECHANICAL DRIVE SYSTEM REQUIREMENTS

The 5-mw advanced high-power generator will be supported by a heavy weldment stand. The stand in turn will be bolted to the test cell floor bed plate. In addition, the drive motor and gear box will also be bolted to the bed plate (see Figure 2-4).

The generator will be driven by an AiResearch manufactured standard light rail vehicle traction motor through a Vistar 7.7 to 1 step up gear box.

Drive system torque will be measured by a Lebow rotary transformer torque sensor with a maximum rating of 500 inch-pounds. The final drive system will consist of a specific pillow block assembly and flexibox two element disk/diaphragm coupling adapted to the generator shaft (see Figure 2-5).

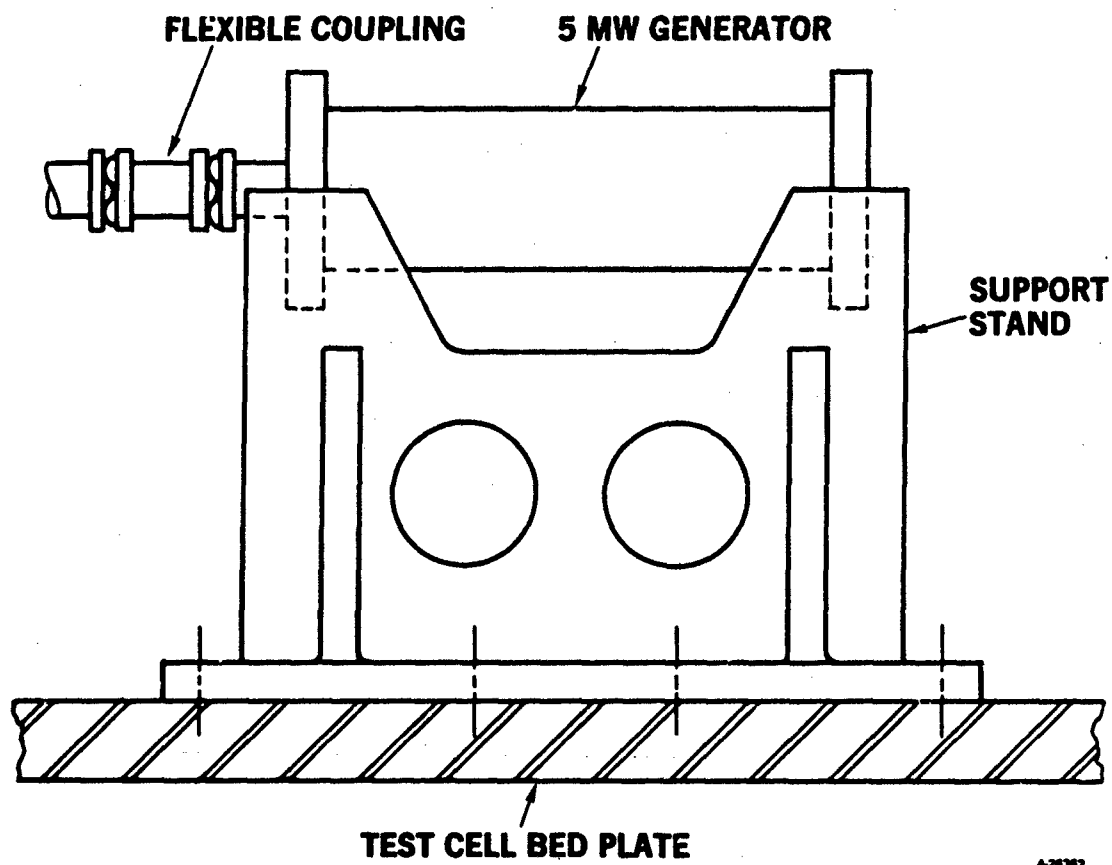
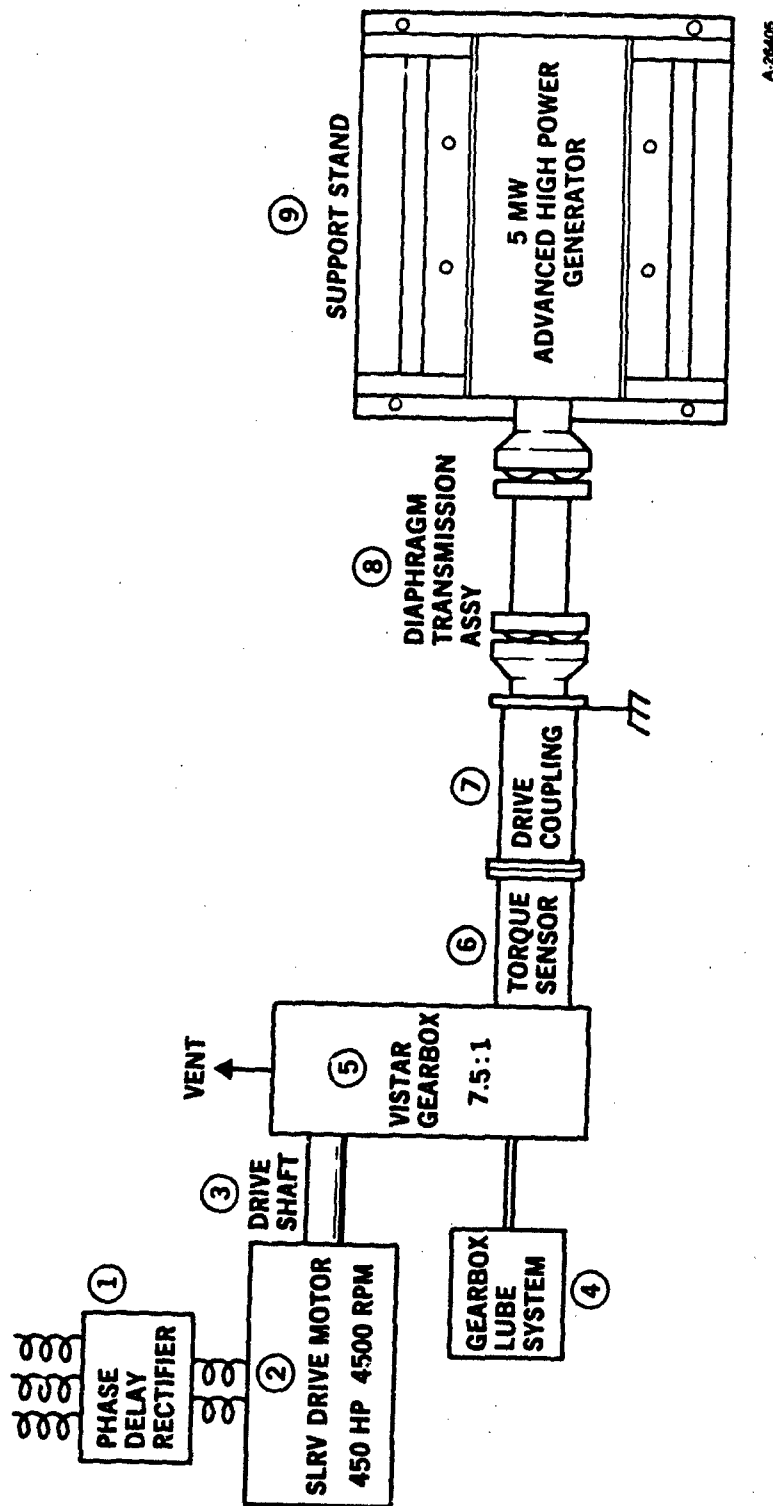


Figure 2-4. Generator Mounting



A-28405

Figure 2-5. Mechanical Drive System (Top View)

2.3.1 Power Requirements

Drive horsepower and torque requirements are based on a no-load loss estimate of 71.2 kw at 18,000 rpm.

Generator input horsepower

$$\frac{7.12 \times 10^4 \text{ w}}{746 \text{ w/hp}} = 95.4 \text{ hp}$$

Generator input torque

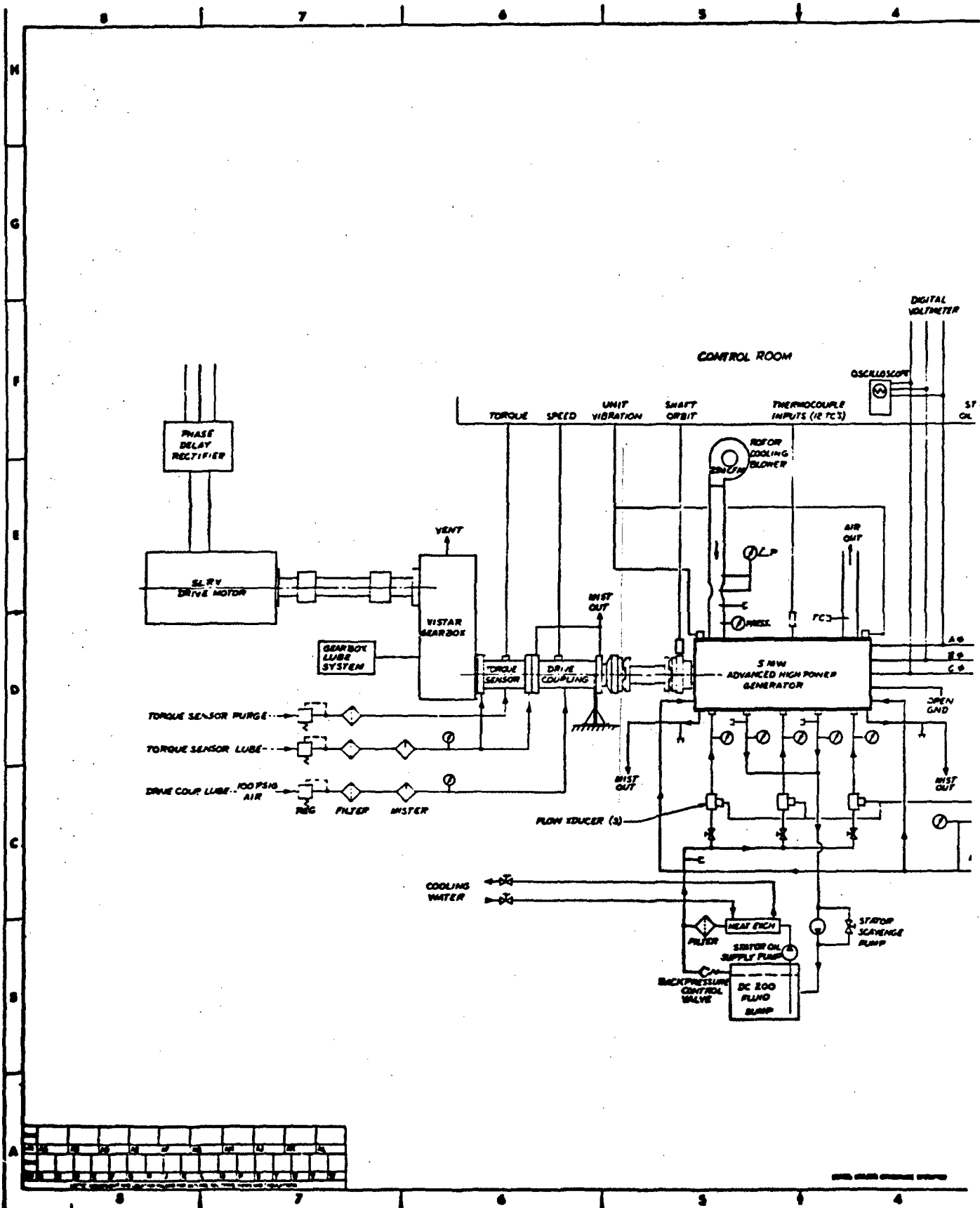
$$\frac{95.4 \text{ hp} \times 33,000 \text{ lb-ft/min./hp}}{2 \times 18,000 \text{ rpm}} = 27.8 \text{ ft-lb}$$

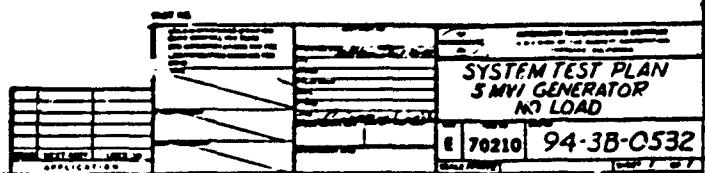
2.3.2 Drive System Components Required for Testing

Item No. from
Figure 2-5

Requirement

- | | |
|---|---|
| 1 | Phase delay rectifier, supplies power and control for drive motor. Standard laboratory equipment |
| 2 | Drive motor, SLRV traction motor, 450 hp, 4500 rpm. Standard laboratory equipment. |
| 3 | Drive shaft assembly, floating shaft with two single flex gear couplings (Zurn). Standard laboratory equipment. |
| 4 | Lube system, gear box, MIL 23699 oil, 35 psig. Standard laboratory equipment. |
| 5 | Gear box, Vistar 7.75 to 1 step-up, 150 hp, Model 6513-3, S/N 664-16. Standard laboratory equipment. |
| 6 | Torque sensor, Lebow Model 1615K-500, 500 inch-pounds, 20,000 rpm, rotary transformer type, air/oil mist lubricated. Standard laboratory equipment. |
| 7 | Drive coupling assembly, dual angular contact bearings, air/oil mist lubricated. Provides speed signal and shear section protection, set point 900 in-lb. Special test equipment. |
| 8 | Transmission assembly, diaphragm. Manufacturer Flexibox, type Metastream, Model 3.5 T, spacer 5 inch. Rating 3.5 hp/100 rpm, maximum speed 25,500 rpm. Provides connection from drive coupling to generator and necessary flexibility to cope with residual misalignment. |



[illegible]

2.

3. TEST INSTRUMENTATION

The instrumentation to be used for generator testing is listed in Table 3-1.

TABLE 3-1
TEST INSTRUMENTATION

System	Measurement	Sensor Type	Quantity
Drive Motor	Temperature, field	Thermocouple	1
	Voltage, arm. field	Meter	1
		Meter	1
	Current, arm. field	Meter	1
		Meter	1
Drive coupling	Speed	Monopole	1
	Temp. bearings	Thermocouple	2
	Oil mist pressure	Gage (psi)	1
	Vibration	Accelerometer	1
Gearbox	Temp. high speed shaft bearings	Thermocouple	2
	Oil pressure	Gage (psi)	1
	Vibration	Accelerometer	1
Torque Sensor	Torque, inch-lb.	AiResearch special test equipment, optical phase shift type, or Lebow 1615K-500.	1
	Temp, bearings	Thermocouple	2
	Oil mist pressure	Gage (psi)	1
	Purge pressure	Gage (psi)	1
Rotor	Vibration, vertical horizontal	Accelerometer	2
		Accelerometer	2
	Temperature	Temperature sensitive paint	

Rotor Cooling	Temp., air inlet	Thermocouple	1
	air outlet	Thermocouple	1
	Pressure, air inlet	Gage	1
	Air Flow, lb/min.	Orifice	1
Stator	Conductor Temp.	Thermocouple	44
Stator Cooling	Temp., oil inlet	Thermocouple	1
	oil outlet	Thermocouple	2
	Pressures:		
	oil inlet 0-25 psia	Gage	3
	oil outlet 0-25 psia	Gage	2
	Oil flow 0-15 gpm	Turbine	3
Bearings, Generator	Temperature:		
	oil mist inlet	Thermocouple	1
	oil mist outlet	Thermocouple	2
	Press., oil mist inlet	Gage	1
Electrical	Voltage	Digital voltmeter	1
	Wave form	Oscilloscope	1

4. NO LOAD TEST PROCEDURE

The following must be verified before testing begins:

- SLRV drive motor cooling air on
- Gearbox oil system on, 30-35 psig
- Torque sensor purge on, 3 psig
- Torque sensor bearing mist on, 10 psig
- Drive coupling bearing mist on, 10 psig
- Unit rotor air flow on, 250 scfm
- Unit rotor bearing mist on, 10 psig
- Cooling water on
- Stator scavenge pump on
- Stator supply pump on, set required flows in 3 circuits

After all the lubrication and cooling systems have been thoroughly checked and the required coolant and air flows have been demonstrated, the alternator may be tested at speed according to the procedures outlined below.

This series of tests will determine the no load voltage versus speed characteristics of the alternator and the stator cooling capabilities with iron losses only.

The losses under no load and rated load were predicted by mathematical model Bigmag to be as follows:

WATTS x 1000 at 18,000 rpm

<u>Loss Type</u>	<u>No-Load</u>	<u>Rated Load</u>
Iron	58.6	41.0
Copper	0	136.0
Stray	0	45.3
Windage	12.0	12.0
Pole Head	0.5	1.0
Rotor Damper	0	7.7
Total Losses	71.1	243.0

A considerable amount of power (71.0kw) must be dissipated by the stator cooling system during no-load operation even though no output power is being used.

The test is begun by running the alternator at 1000 rpm and then increasing the speed to 18,000 rpm in 1000 rpm increments. Discrepancies in any of the test variables must be resolved before moving to the next higher speed. The test variables that must be recorded are shown in the sample lab data sheets in Figures 4-1 and 4-2. The actual gathering of data will be done with a data logger such as the Kaye Digistrip II or III. The acceptable range of the variables during the testing is shown in Table 4.1. The data logger will be programmed to register an alarm if any of the minimum or maximum values are sensed. Input power is a variable that is calculated according to the following equation.

$$\text{Input Power(kw)} = \frac{\text{Shaft Torque (lb.-ft.)} \times 2 \times \pi \times \text{rpm} \times 0.7456}{33,000} \frac{\text{kw}}{\text{hp}}$$

This calculation can be performed internally by the data logger and printed out along with the other variables.

EWO _____ DATE _____ TEST PURPOSE _____

P/N _____ BAROM _____

S/N _____ TEMP _____ TEST PERS. _____

	Time	Speed rpm x 1000	V _{L-N}			Coolant Inlet Pressure (psil)			Coolant Flow (gpm)			Coolant Inlet Temp. °F			Coolant Outlet T. °F		REMARKS
			A-B	B-C	A-C	P ₁	P ₂	P ₃	F ₁	F ₂	F ₃	T _{Cl₁}	T _{Cl₂}	T _{Cl₃}	T _{CO₁}	T _{CO₂}	
NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	1																
	2																
	3																
	4																
	5																
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Figure 4-1. Lab Data Sheet (Page 1 of 2)

FORM 4185A
 PRELIMINARY

LAB DATA SHEET

Page 2 of 2

ENO _____ DATE _____ TEST PURPOSE _____

P/N _____ BAROM _____

S/N _____ TEMP _____ TEST PERS. _____

NO.	Bearing Temp. °F		Bearing lube Press. psi		Stator Back Iron Temperature °F				Rotor Inlet Air Press. psi	Shaft Torque lb	Input Pwr. (kw) Calc	REMARKS
	FT	REAR	FT	REAR	T _{S1}	T _{S2}	T _{S3}	T _{Sn}				
1												
2												
3												
4												
5												
6												
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Figure 4-2. Lab Data Sheet (Page 2 of 2)

TABLE 4-1
OUTPUT VARIABLE RANGES

Variable	Range		
	Min	Max	Units
Speed	0	18,000	rpm
Volts, line to neutral	0	588	volts
Coolant inlet pressure	5	20	psi
Coolant flow	.1	.2	gpm
Coolant inlet temperature	75	250	°F
Coolant outlet temperature	75	400	°F
Bearing temperature	75	300	°F
Bearing lube system pressure	10	20	°F
Stator back iron temperature	75	400	°F
Roto. inlet air pressure	20	30	psi
Shaft torque	0	30	ft.-lbs.
Input power	0	71	kw

5. SYSTEM SAFETY/HAZARD ANALYSIS

A preliminary hazard analysis has been completed for the advanced high-power generator test. All hazards found appeared to be adequately controlled except that of dropping the generator during installation. Extreme care should be exercised in lifting the generator since no dedicated attachment points have been provided. This document supplements AiResearch Report 80-17402.

5.1 ANALYSIS

The preliminary hazard analysis for the advanced high-power generator test is contained in Table 5-1. Column 1 of the table lists the hazardous conditions that are or may be present during testing or installation of the generator. The possible causes of these conditions are listed in Column 2. The third column lists the possible effects of the hazardous condition. Hazard levels were assigned to the hazardous condition effects per MIL-STD-882A categorized as follows:

<u>Hazard Category Classification</u>	<u>Description</u>
I (Catastrophic)	May cause death of personnel or loss of generator or test facility (unrepairable).
II (Critical)	May cause severe injury to personnel or major damage to generator or to test facility (repairable).
III (Marginal)	May cause minor injury to personnel or minor generator or test facility damage.
IV (Negligible)	Will not result in injury to personnel or damage to the generator or to the test facility.

These hazard levels are applied in the fourth column of Table 5-1. The last column lists recommended corrective action and describes the protective features of the generator and test facility.

5.2 CONCLUSIONS AND RECOMMENDATIONS

There are four Category II hazards, four Category III hazards, and one Category IV hazard associated with the installation and testing of the advanced high-power generator. Adequate protection has been provided against all hazards except those associated with lifting the generator. Special care must be taken to prevent damage to the generator or injury to personnel when the unit is moved.

TABLE 5-1
PRELIMINARY HAZARD ANALYSIS

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Bearing Seizure	- Contamination of bearing. - Foreign material between rotor and housing. - Loss of bearing lubrication.	Large inertia loads leading to possible fracture of fixture mounts and freed rotor/housing assembly.	II	- Bearings are ABEC 7 quality with oil spray lubrication. - Personnel will not be permitted in the test chamber during testing. - Test fixture will be designed to hold the generator in the event of rotor lock up at maximum speed.
Large Mass of Generator	Absence of lifting provisions allows generator to be dropped during transportation or installation.	- Possible fracture of generator parts. - Possible injury to personnel moving the generator.	III	Appropriate provisions should be made to enable safe movement of the generator, e.g., lifting eyelets.
Rotor Overspeed	Test equipment malfunction	Possible rotor burst, releasing fragments of steel into the test chamber.	II	- Shaft speed is instrumented. Test fixture contains provisions for emergency shutdown in case of overspeed. - Shields are provided to contain fragments to the test facility. - No personnel will be permitted in facility during testing.
Fire	- Bearing overheat from contamination or too much oil during operation. - DC 200 cooling oil igniter (flash point 175°F, Autoignition Temp. 806°F). - From overheat. - From electrical spark.	Possible injury to personnel or equipment damage.	III	- Oil/air mister should filter oil. - Facility is equipped with fire detection and 4 tons of 300 psig CO₂ for total flooding extinguishment. - Inlet and outlet oil/air mixture pressure and temperature will be monitored and alarm will sound if temperature is excessive or pressure is too low. - Outlet cooling oil temperature will be monitored and alarm will sound if temperature becomes excessive.

TABLE 5-1 (Continued)

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
High Voltage	1. Exposed terminals may come into contact with personnel or equipment.	1. Possible injury to personnel or equipment damage.	IV	1. Personnel will not be in vicinity when test is in progress. 2. An insulating cover will be provided.
Static Electricity	1. Buildup during test due to improper grounding.	1. May cause personnel injury, equipment damage or initiate a fire.	III	1. Generator will be grounded during test by bolting to the test fixture.
Excessive Vibration	1. Bearing failure. 2. Bearing support failure. 3. Rotor imbalance due to internal fracture.	1. Damage to generator and test equipment; may lead to fatigue failure of generator parts.	II	1. Test fixture contains provisions for quick shutdown in case of excessive vibration. 2. Bearings are resilient-mounted. 3. Structural integrity has been verified by rotor test and stress analysis.
Excessive Torque at Shaft	1. Malfunction of test equipment. 2. Bearing failure. 3. Rotor becomes locked with stator.	1. Possible overstress of generator parts; e.g., windings, shaft or bearing.	II	1. Torque sensor is provided on the input shaft; alarm will sound if torque is excessive.
Short Circuit	1. Damaged winding. 2. Misconnection of windings.	1. Loss of load. 2. Overheated windings. 3. Fire.	III	1. Phase balance is sensed and there will be quick shutdown if unbalance is excessive.

5. LOAD TEST PLAN

The test plan for the 5 MW generator (AiResearch Report 81-17964) is presented as Exhibit 5A. This report was approved in a previous submittal.

EXHIBIT 5A
AIRESEARCH REPORT 81-17964
TEST PLAN

5-3/5-4

FOREWORD

This test plan describes the procedure for testing a 5-Mw permanent magnet generator currently being built under the Advanced High Power Generator program, Contract F33615-76-C-2168, sponsored by the Power Systems Branch, Aerospace Power Division, of the Aeropropulsion Laboratory at Wright-Patterson Air Force Base.

At Wright-Patterson, the program is under the technical direction of Paul R. Bertheaud. At AiResearch, Fred B. McCarty is principal investigator, Frank E. Echolds is project engineer, and Andrew R. Druzsba is program manager. Special acknowledgement is given to Paul Gassen, AiResearch test engineer.

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1. INTRODUCTION

1.1 SCOPE

Full-load testing of the 5-Mw permanent magnet generator as described in this report will be the final step in the development of an advanced nonsuperconducting synchronous generator for airborne applications. The rotor and stator/housing are presently being developed under two separate contracts with the Air Force Aeronautical Systems Division, Wright Patterson AFB, Ohio, for delivery in late 1981 and mid-1983, respectively.

This test plan is being prepared well in advance of hardware availability in order to effectively schedule the fabrication of special test equipment and to ensure ready utilization of the test facility.

A cutaway drawing of the generator to be tested is shown in Figure 1-1.

1.2 TEST FACILITY

The generator will be delivered to the Compressor Research Facility (CRF), Wright Patterson AFB, for testing after a no-load checkout at AiResearch. Generator test support requirements have already been coordinated with CRF personnel. After setup, approximately three weeks of testing will be required to perform the tests outlined in this plan.

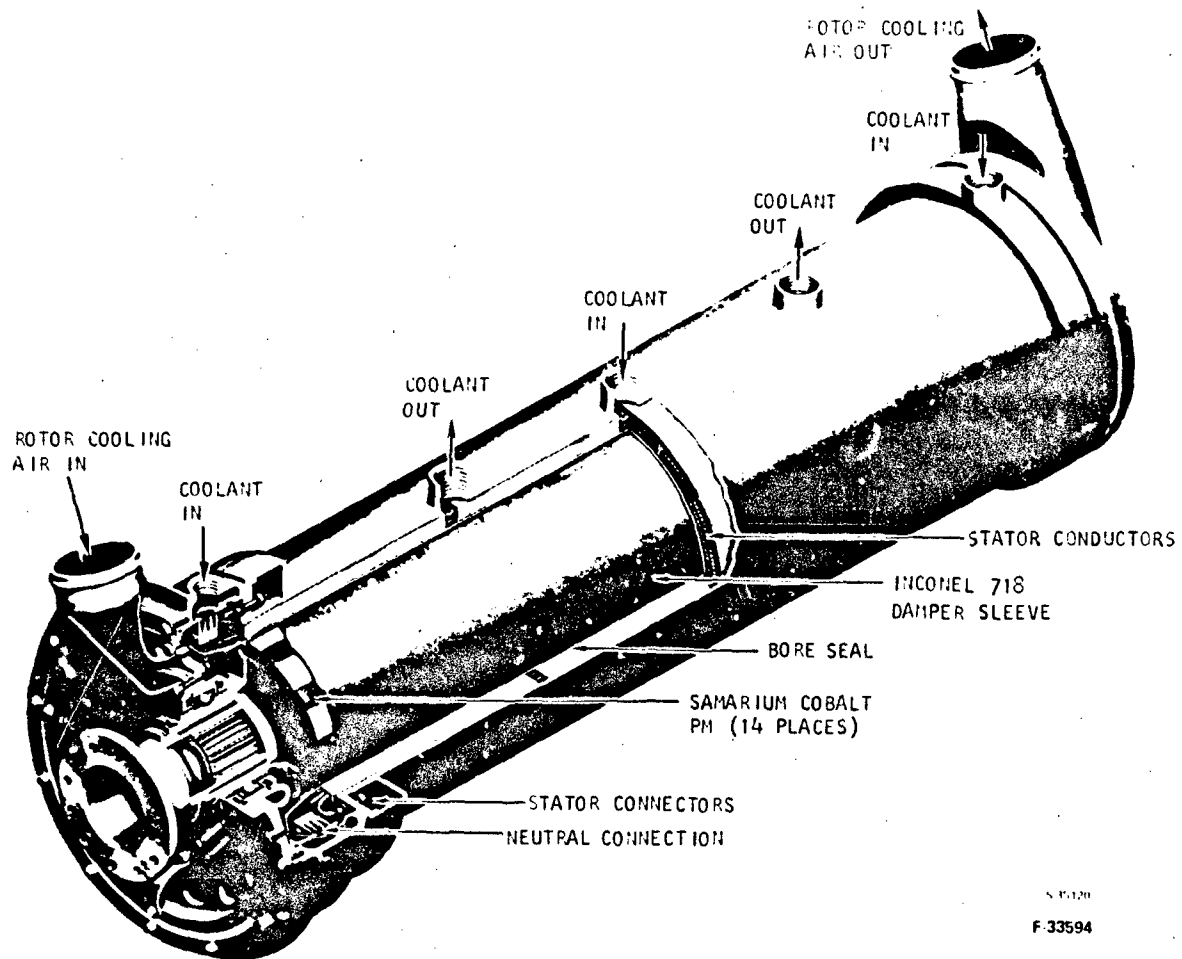


Figure 1-1. Complete 5-Mw Generator Design

2. GENERAL REQUIREMENTS

2.1 TEST SETUP

The overall test setup schematic is shown in AiResearch Dwg. 94-38-0401.

Major design parameters for the generator are listed in Table 2-1.

TABLE 2-1

5-MW GENERATOR DESIGN PARAMETERS

Parameter	Value
Rating into 3-phase, full-wave bridge	1,046 vdc, 4,780 adc @ 18,000 rpm 648.3 v/phase (air gap), 3638 amp/phase
Current density, amp/in. ²	36,270
Stator temperature, °F	450
Rotor temperature, °F	200
Overall length, in.	43
Overall diameter, in.	16.25
Total weight, lb	500

2.2 COOLING REQUIREMENTS

2.2.1 Rotor

The permanent magnet rotor will be cooled by forced air generated by a test chamber centrifical blower and measured with an orifice or venturi section. Cooling air will be discharged into the test chamber (see Figure 2-1).

Operating parameters are the following:

<u>Parameter</u>	<u>Requirement</u>
Airflow	100 to 300 cfm
Air pressure	
Inlet	Ambient plus 0.5 psig
Outlet	Ambient
Air temperature	
Inlet	Ambient
Outlet	To 210°F

2.2.1.1 Blower Power Requirements

Power requirements for the blower are 230-460 vac, 3-phase, 60 Hz, 2 hp.

2.2.1.2 Instrumentation

Instrumentation requirements are as follows:

<u>Parameter</u>	<u>Requirement</u>
Flow	Measuring section inlet static pressure transducer (1) and delta pressure transducer (1)
Pressure	Unit inlet pressure transducer (1)
Temperature	
Inlet	Thermocouples (2)
Outlet	Thermocouples (2)

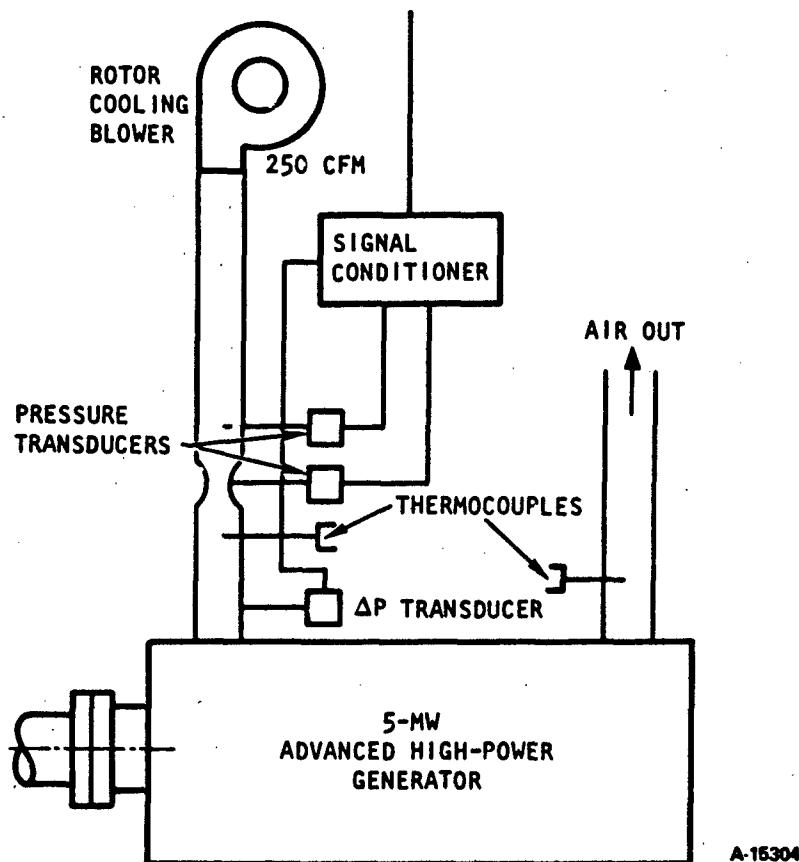


Figure 2-1. Rotor Cooling System

2.2.1.3 Alarms

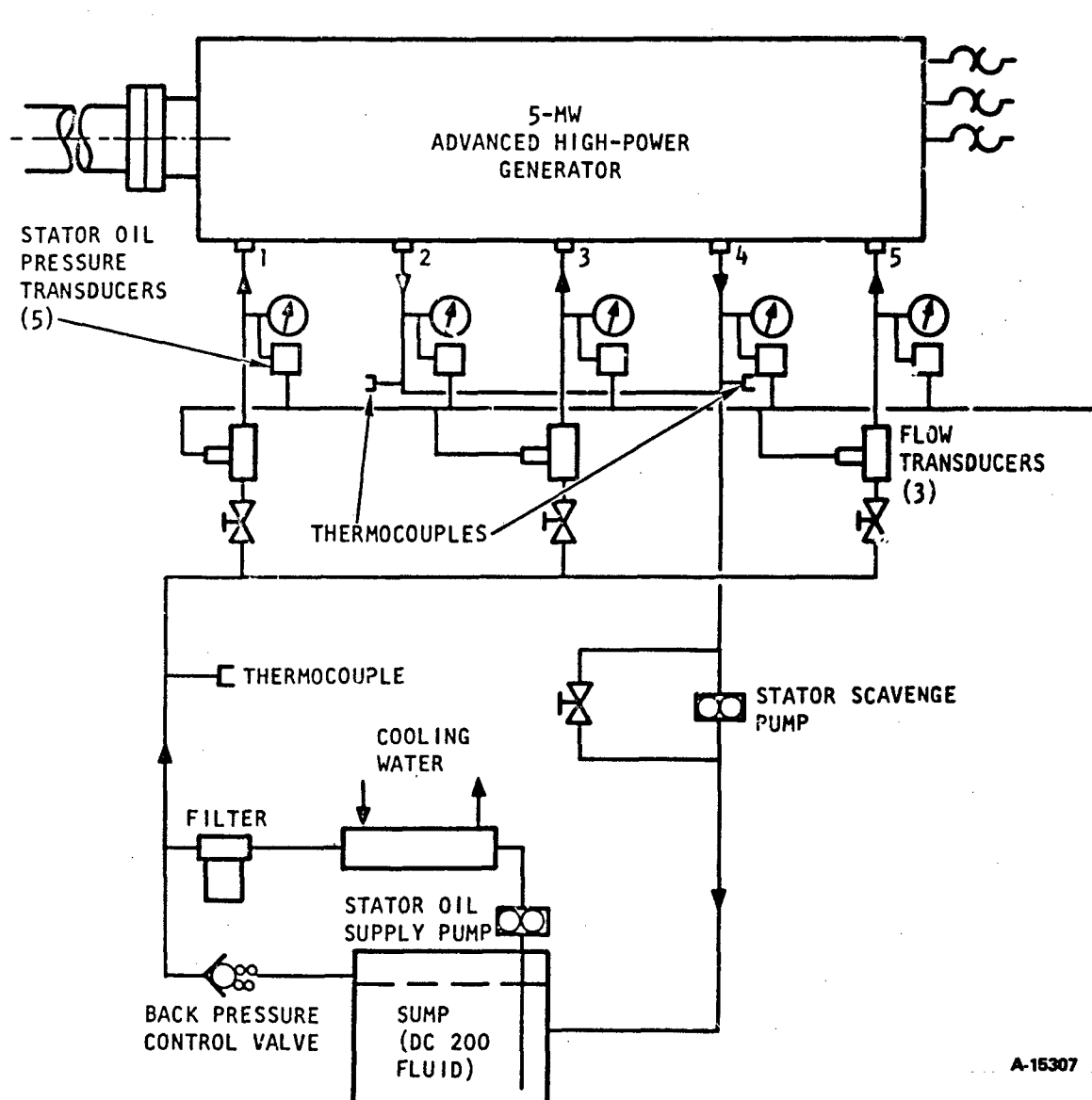
Alarm requirements are the following:

<u>Parameter</u>	<u>Requirement</u>
High discharge temperature	1
Low airflow	1

2.2.2 Stator

Stator conductors will be cooled by oil pumped through passages around the conductors. The cooling system (see Figure 2-2) will utilize a two-pump approach because of the requirement for a subatmospheric discharge pressure (7 psia) and a vented sump.

Operating parameters are shown in Table 2-2.



A-15307

Figure 2-2. Stator Cooling System

2.2.2.1 Pump Power Requirements:

Power requirements for the pumps are as follows:

<u>Parameter</u>	<u>Requirement</u>
Supply	230 to 460 vac, 3-phase, 60 Hz, 1 hp
Scavenge	230 to 460 vac, 3-phase, 60 Hz, 3 hp

TABLE 2-2
STATOR OPERATING PARAMETERS

Parameter	Requirement
Oil	Dow Corning 200
Oil Flow	
Inlet No. 1, gpm	6.25
Inlet No. 3, gpm	12.5
Inlet No. 5, gpm	6.25
Total, gpm	25.0
Outlet No. 2, gpm	12.5
Outlet No. 4, gpm	12.5
Pressure	
Inlet, psia	19
Outlet, psia	7
Temperature	
Inlet, °F	120
Outlet, °F	To 250
Filtration, μ	25
Sump capacity, gal	50
Ultimate heat sink	CRF cooling tower water at TBD Btu/hr rate

2.2.2.2 Accessories

One level sight gage and five mechanical pressure gages are required.

2.2.2.3 Instrumentation

Instrumentation is required as follows:

<u>Parameter</u>	<u>Requirement</u>
Flow	Inlet transducers 0 to 6.25 gpm (2)
	0 to 12.5 gpm (1)
Pressure	Inlet transducers (psia) (3)
	Outlet transducers (psia) (2)
Temperature	Inlet thermocouple (1)
	Outlet thermocouples (2)

2.2.2.4 Alarms

Alarm requirements are the following:

<u>Parameter</u>	<u>Requirement</u>
High outlet temperature	2
Low oil flow	3

2.2.3 Bearings

The rotor bearings will be cooled and lubricated by a system providing air-oil mist under pressure (see Figure 2-3).

Operating parameters are shown in Table 2-3.

2.2.3.1 Instrumentation

Instrumentation requirements are the following:

<u>Parameter</u>	<u>Requirement</u>
Pressure	Inlet transducer (psia) (1)
Temperature	Inlet thermocouple (1)
	Outlet thermocouples (2)

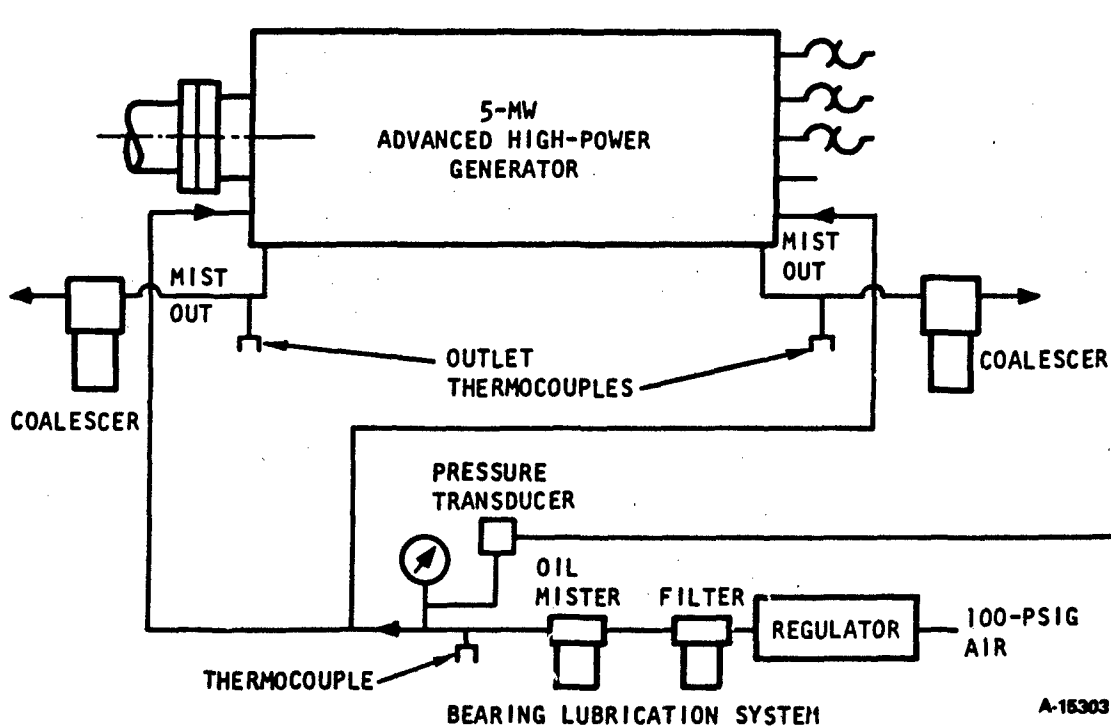


Figure 2-3. Bearing Cooling and Lubrication System

2.2.3.2 Alarms

Alarm requirements are the following:

<u>Parameter</u>	<u>Requirement</u>
High outlet temperature	2

2.2.4 Rectifier

The 3-phase bridge rectifier will be convection cooled by the CRF test article cooling system that circulates air inside the test chamber at 15,700 scfm and 100°F maximum temperature.

2.2.5 Water-Cooled Load

The load bank will consist of a submerged conductor tapped resistor array. Cooling will utilize the latent heat of vaporization of water primarily, plus convection.

TABLE 2-3
BEARING OPERATING PARAMETERS

Parameter	Requirement
Oil	Mobile Jet II (MIL-L-23699)
Flow	
Air, lb/min	0.045
Oil	TBD
Pressure	
Inlet, psia	15.3
Outlet	Ambient
Temperature	
Inlet	Ambient
Outlet	TBD
Filtration, μ	10
Sump capacity, oz	10

2.3 MECHANICAL DRIVE SYSTEM REQUIREMENTS

The 5-Mw advanced high-power generator and support/shield will be installed in the test chamber with attach points at the bulkhead and the front mount plate (see Figure 2-4).

The generator will be driven by the high- or low-speed motor in combination with high-speed gearbox 3 (refer to Figure 2-5). This drive system will provide the necessary power over a speed range from 2,000 to 18,000 rpm (Figure 2-6).

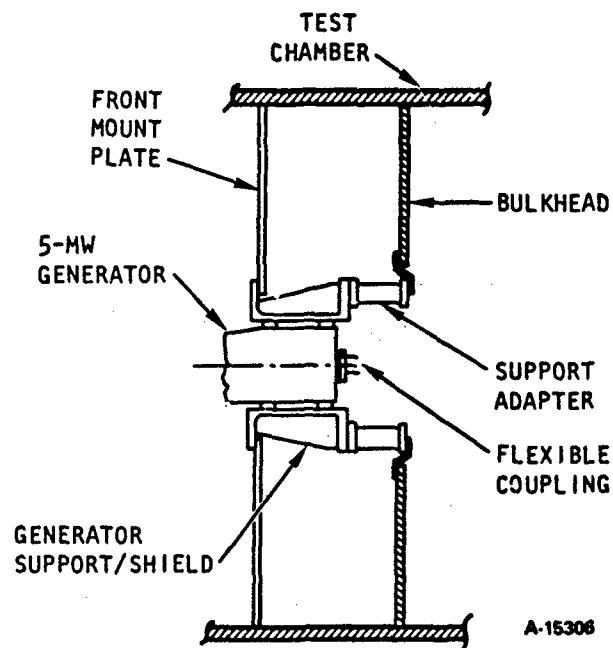


Figure 2-4. Generator Mounting

2.3.1 Power Requirements

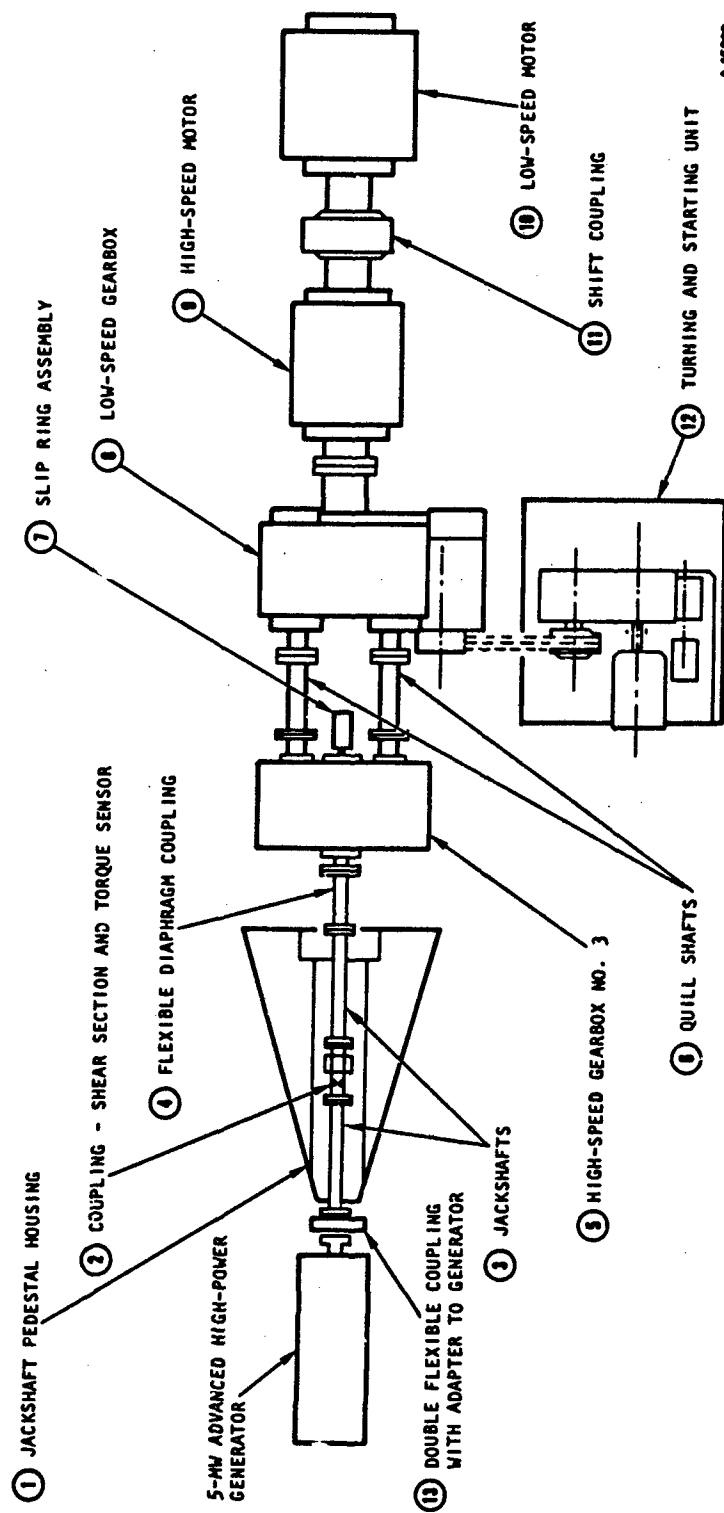
Horsepower and torque requirements are estimated below.

Generator input hp

$$\frac{5 \times 10^6 \text{ w}}{746 \text{ w/hp} \times 0.96 \text{ eff}} = 6982 \text{ hp}$$

Generator input torque

$$\frac{6982 \text{ hp} \times 33,000 \text{ lb-ft/min./hp}}{2\pi \times 18,000 \text{ rpm}} = 2037 \text{ lb-ft}$$



A-16300

Figure 2-5. Mechanical Drive System

HIGH-SPEED GEARBOX 3

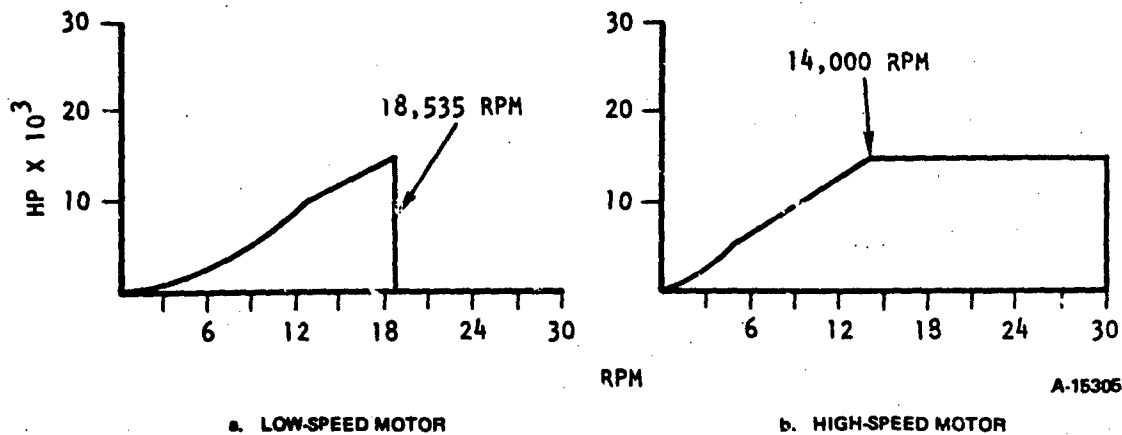


Figure 2-6. CRF Power/Speed Range

2.3.2 Special Drive System Components Required for Testing

Special drive system components required for testing are:

Item No. From Figure 2-5	Requirement
13	a. Adaptor, generator to flexible diaphragm coupling b. Double flexible diaphragm coupling
2	a. Torque sensor, range to provide usable sensitivity at 2037 lb-ft b. Shear section, to provide protection for torque sensor and generator, not to exceed 2240 lb-ft

2.3.4 Existing Drive System Components Required for Testing

Existing drive system components required for testing are listed in Table 2-4. Component numbering corresponds to the numbering in Figure 2-5.

A drive system analysis will be required to examine thoroughly the compatibility between the generator and CRF drive with respect to axial, radial, and torsional excitation frequencies.

2.4 INSTRUMENTATION REQUIREMENTS

Table 2-5 provides a preliminary list of the instrumentation needed for generator testing.

TABLE 2-4
EXISTING DRIVE SYSTEM COMPONENTS
REQUIRED FOR TESTING

Item No. From Figure 2-5 (Component)	Requirement
1 (Jack shaft pedestal housing)	Standard installation
3 (Jack shafts)	High speed Per CRF Dwg. 78-M10-0053 Speed range, 16,000 to 30,000 rpm
4 (Flexible diaphragm coupling)	Condition 3 Per CRF Dwg. EDS-76-M10-0006 Speed range 16,242 to 17,820 rpm Torque max. 58,205 lb-in.
5 (High-speed gearbox No. 3)	Speed range to 30,000 rpm Ratio, 7.8125 to 1
6 (Quill shafts)	Standard installation
7 (Slip ring assembly)	For transmission of up to ten two-wire thermocouple channels at 18,000 rpm
8 (Low-speed gearbox)	Standard installation Ratio 3.4896 to 1
9 (High-speed motor)	Standard installation 30,000 hp
10 (Low-speed motor)	Standard installation 30,000 hp
11 (Shift coupling)	Standard installation
12 (Turning and starting units)	Standard installation

2.5 ELECTRICAL CONNECTION AND LOAD REQUIREMENTS

The electrical system diagram, Figure 2-7, provides a schematic of the generator connection and a component layout corresponding to the items listed in Table 2-6.

TABLE 2-5
INSTRUMENTATION REQUIRED FOR GENERATOR TESTING

Component or System	Measurement	Sensor Type	Quantity	Alarm	Automatic Shutdown
Rotor	Temperature rotating, °F	T	10	High temperature (5)	No
Stator	Temperature in conductors and housing, °F	T	12	High temperature (6)	No
	Vibration in drive end	TBD	2	High vibration (2)	Excessive vibration (2)
	Vibration in non-drive end	TBD	2	High vibration (2)	Excessive vibration (2)
Rotor cooling	Air inlet temperature, °F	T	2	No	No
	Air outlet temperature, °F	T	2	High temperature (2)	No
	Air inlet static pressure,	TBD	1	No	No
	Static and delta pressure in airflow measuring section	TBD	2	Low flow	No
Stator cooling	Oil inlet temperature, °F	T	1	No	No
	Oil outlet temperature, °F	T	2	High temperature (2)	No
	Oil inlet pressure, 0 to 25 psia	Strain gage	3	No	No
	Oil outlet pressure, 0 to 25 psia	Strain gage	2	No	No
	Oil flow, 0 to 15 gpm	Turbine	3	Low flow (3)	No
Bearings	Mist inlet temperature, °F	T	1	No	No
	Mist outlet temperature, °F	T	2	High temperature (2)	No
	Mist inlet pressure, psig	Strain gage	1	Low pressure (1)	No
Drive	Speed, rpm	Monopole	1	No	Excessive rpm above set point
	Torque	TBD	1	No	Excessive torque
Electrical	Phase balance	AIResearch special test equipment	1	Phase imbalance	Phase imbalance
	Dc voltage	TBD	1	No	No
	Dc current	Millivolt shunt	1	No	No
	Dc breaker position	Auxiliary contacts	1	No	No
	Load control contactor position	Auxiliary contacts	8	No	No

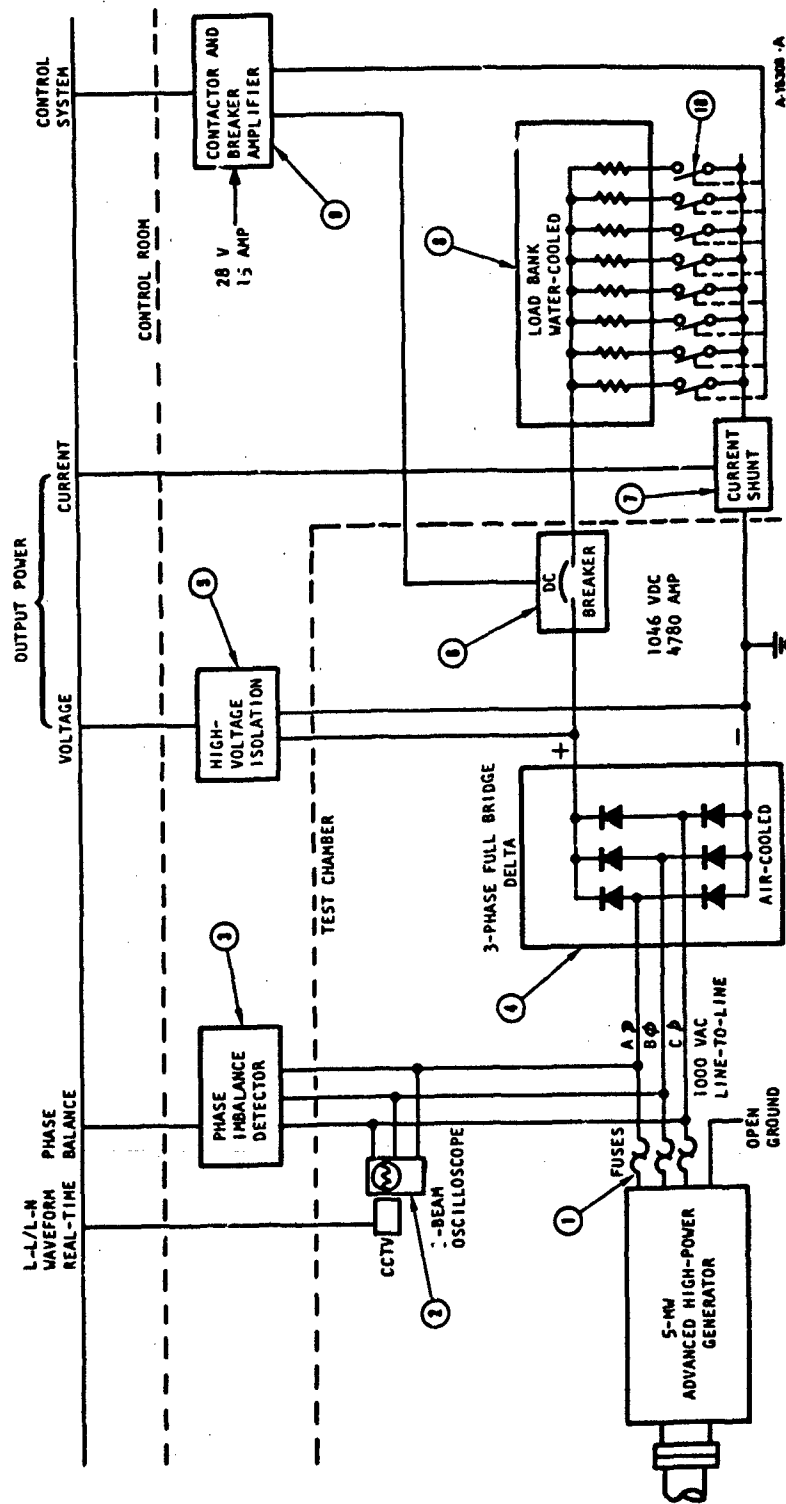


Figure 2-7. Electrical System Diagram

TABLE 2-6

ELECTRICAL CONNECTION AND LOAD REQUIREMENTS

Item No. From Figure 2-7 (Component)	Requirement
1 (Fuzes)	Manufacturer, J. Shanut Rated voltage, 2000 Rated amperage, 5000 Quantity, 3: 1 per phase
2 (Oscilloscope, three beam, and closed-circuit television camera)	Allows real-time viewing of 3-phase voltage without the capacitance effects of a 500-ft cable run to control room.
3 (Phase imbalance detector) (AiResearch special test equipment)	This device will provide a signal for dc breaker opening and rotation shutdown in the event of an unbalanced generator load. This condition might result from a single phase short or open circuit, internal or external to the generator.
4 (Rectifier, 3-phase delta-connected)	Manufacturer, PSI Inc., PN JD2300-40 Rating, 1500 vac, 2500 Hz, 5000 amp Cooling, convection air cooled
5 (High-voltage isolation)	Provides voltage scaling and isolation for the data acquisition system.
6 (Dc breaker)	Provides primary control of generator load Manufacturer, Siemens Rating, 1500 vdc 5000 amp Includes overcurrent trip Power required, 28 vdc at 5 amp
7 (Current shunt)	Manufacturer, Empro, Inc. P. O. Box 26064 Indianapolis, IN 46226 Model, WT-5000-50 Rating, 5000 amp at 50 mv output to data system
8 (Load bank)	The load will consist of an array of eight equal resistors each composed of nicrome ribbon of high surface-to-cross-section area. The resistors will be in turn connected across the output of the rectifier in parallel by dc contactors. This will provide an eight-step generator load zero to 5 Mw at full rotational speed of 18,000 rpm. The total resistor assembly will be submerged under water in a tank made of nonconducting material. The tank may require a water makeup system if high-load testing is conducted for extended periods.

TABLE 2-6 (Continued)

Item No. From Figure 2-7 (Component)	Requirement
9 (Contactor and breaker amplifier)	Provides power amplification from control system to dc breaker and eight load-control contactors. Input, low-level signal from control system Input power, as required Output, 28 vdc at up to 15 amp
10 (Load control contactors)	Manufacturer, Cutler Hammer Rating, 1000 amp, 1000 vdc Power required, 28 vdc at 1.2 amp

3. TEST DATA ACQUISITION

Exhibit 3A contains a description of the high-speed data acquisition system that will be utilized for all generator testing.

The selection of interface equipment, cabling, signal conditioning, and programming necessary for data system use will be the responsibility of CRF personnel. The thermocouples installed in the rotor and stator will be the only instrumentation provided with the generator at the time of shipment to the CRF.

EXHIBIT 3A

HIGH-SPEED DATA ACQUISITION SYSTEM

**HIGH SPEED DATA ACQUISITION SYSTEM
(HPDAS)**

1. This multi-channel, high performance data acquisition system consists of the following:

- 475 channels of digital data
- 48 channels of recorded analog data
- 12 channels for use by other systems
- 5 frequency-to-voltage converters

2. Component Breakdown:

- 391 Preston Scientific Model #8800 Universal Signal Conditioners; supplies excitation voltage, bridge balance, calibration, and signal return circuitry for various types of pressure and position transducers.

- 144 Preston Scientific Model #8800 Thermcouple Signal Conditioners; provides calibration and signal return circuitry for thermcouple and EMF signals.

- 5 VIDAR Model #323 frequency-to-voltage converters.

- 535 Preston Scientific Model #8300-XWBRC Amplifiers; each with computer controllable gain and filter selection; the filters are low pass, 3 pole filters and have the following cutoff frequencies: 10 Hz, 40 Hz, 120 Hz, 400 Hz, 1200 Hz and 4 wide band 100 KHz. The gains result in full scales of ± 5 , ± 10 , ± 20 , ± 40 , ± 160 , ± 1250 and ± 5120 millivolts.

A. 321 high performance amplifiers; no special options.

B. 104 high performance amplifiers; with a dual output capability.

C. 50 high performance amplifiers; with a linear overload capability to linearly handle an analog voltage up to five (5) times the maximum rated input.

D. 48 AC/DC amplifiers; converts AC signals from strain gages or other dynamic sensors into a DC analog voltage.

E. 12 moderate performance amplifiers; with no special options has a narrower bandwidth than the high performance.

- One 512 channel differential multiplexer
- One analog-to-digital converter with a conversion rate of 100 KHz
- 100 sample-and-hold circuits; for precise time correlation of data; S&H acquires data for the first 100 channels simultaneously and has a time displacement of 100 nano-seconds between any two channels.

3. Data System Performance:

- Overall system accuracy of 0.1% FS output.
- Throughput rate of 100,000 samples/second.
- A channel check subsystem is provided for on-line calibrations of the amplifiers to maintain the accuracy of this data system.

4. FM Playback System

- This system is also part of the HPDAS and consists of 48 channels of test article data monitored by small oscilloscopes. The main function of this system is to record, via four analog tape drives, high speed transient signals which can then be played back at slower speeds, amplified, multiplexed, and digitized. This information is then passed on to the main computer for data reduction via the DAC and the AUX computers.

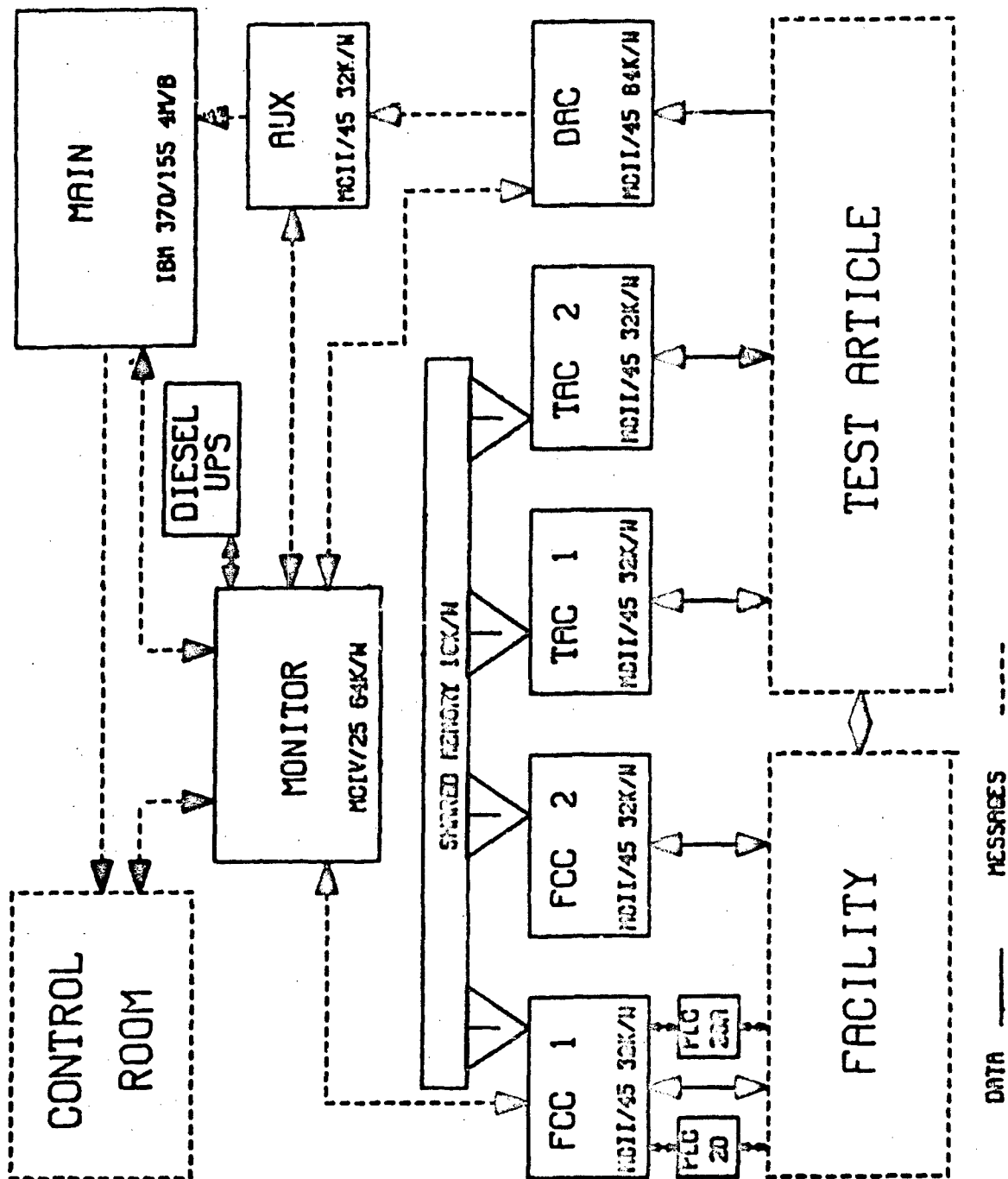
COMPUTER POWER

<u>COMPUTER(s)</u>	<u>MAIN FUNCTION(s)</u>	<u>FEATURES</u>
Test Article Control (TAC 1 and TAC 2) 2 - MODCOMP II/45	- Provides automatic control of the CRF inlet valves, test article discharge valves and test article variable geometry items such as stator vanes and stage bleeds.	- 32K of Private core memory (each) - 16K of shared memory - Adds 880 alphanumeric CRT console device (each) - 2.6 Mbyte removable cartridge disk drive (each)
Facility Control (FCC1 and FCC2) 2 - MODCOMP II/45	- Acquires Facility Data, drive system data and time data - Controls Drive System operation - Controls message traffic between the monitor computer and TAC 1, TAC 2, FCC1 and FCC2 computers.	- 32K of private core memory (each) - 16K of shared memory - Adds 880 alphanumeric CRT console device (each) - 2.6 Mbyte removable cartridge disk drive (each)
Monitor MODCOMP IV/25	- Operator-Facility Interface - Drives RAMTEK real time graphic displays, console switches and lights - Accepts and executes test segment displays - Central communications computer	- 64K of private core memory - 2.6 Mbyte removable cartridge disk drive - Adds 880 alphanumeric CRF console device - Two 4411 Card Readers - Three 9 TRK Tape Drives - One ISS Disk Drive - One Tektronix 4010-1 CRT Console Device

COMPUTER POWER (Cont'd)

<u>COMPUTER(s)</u>	<u>MAIN FUNCTION(s)</u>	<u>FEATURES</u>
Auxiliary (AUX) MODCOMP II/45	- Transfers data from the DAC computer to the main computer for data reduction - Acquires test article data - Executes transducer calibrations	- 32K memory - 64K of private core memory - 2.6 Mbyte removable cartridge disk drive - 4214 line printer - Adds 880 alphanumeric CRT console device - One 9 TRK tape drive - One 1403 line printer - 4M byte of private core memory - 4 Intel 3330 disk drives - 3 STC 9 TRK 1600/6250 tape drives - 1 STC 9 TRK 800/1600 tape drive - Ten 3277 alphanumeric CRT console devices - Two 2250 IBM graphics - One electrostatic Gould plotter
Data Acquisition (DAC) MODCOMP II/45		
Main IBM 370/155	- Data Reduction, on-line and and post processing - Drives 2250 real time graphic displays	

COMPUTER CONFIGURATION



ON-LINE DATA REDUCTION

Two independently operated IBM 2250 Vector-Graphic CRTs allow engineers to organize and graphically present either real-time or post processed test data. There are three modes of operation, i.e., static, transient and monitor. Data taken in the static mode is used to generate map, profile and X vs Y type displays. Data taken in the transient and monitor mode is used to generate transient type displays.

Four types of engineering displays are available:

- 1) Compressor Rigs
- 2) Profiles
- 3) X versus Y1, Y2, Y3, Y4
- 4) Transient Displays

Typical Displays are:

- 1) Pressure ratio vs % corrected flow (Map)
- 2) Compressor efficiency vs % corrected speed (X vs Y)
- 3) Wall static pressure vs axial location (Profile)
- 4) Stage pressure ratio vs % corr flow (X vs Y)
- 5) Stage efficiency vs % corr flow (X vs Y)

A light pen is used on the 2250 graphics for quick selection of mode and definition of displays.

Off-Line Data Reduction

Consists of various printouts and graphics from the IBM 370/155 and playback from the FM analog recording system.

4. TEST CONDUCT

The various tests outlined in the procedures that follow will be used to determine the actual operating characteristics of the 5-Mw generator.

The operating characteristics of the advanced high-power generator as specified in the Air Force statement of work (Section F, para. 4.6.1, F33615-76-C-2168) include the following important requirements:

<u>Parameter</u>	<u>Specification</u>
Output power	5 Mw
Specific weight	0.1 lb/kw
Efficiency	95 percent or greater

4.1 NO-LOAD TEST

4.1.1 Scope

The no-load test entails measuring no-load phase voltages at 2,000, 4,000, 6,000, 8,000, 10,000, 12,000, 14,000, 16,000 and 18,000 rpm and the input torque at these points.

4.1.2 Objective

The objective of the no-load test is to determine the no-load losses from the input torque measurement and the no-load operating point between 2,000 and 18,000 rpm.

4.1.3 Procedure

<u>Settings</u>	<u>Procedure</u>
1. Rotor, stator, and bearing cooling systems, ON	3. Drive generator at 2000 rpm
2. Dc breaker, OPEN	4. Measure phase A, B, and C peak-to-peak voltages on oscilloscope; measure rpm and drive torque.
	5. Increase speed by 2000 rpm and take measurements of step 4.
	6. Repeat steps 4 and 5 until 18,000-rpm point is reached.
	7. Calculate the maximum difference between phase peak-to-peak voltages.

The input torque will be proportional to the generator's no-load losses.

4.2 LOAD TEST

4.2.1 Scope

The load test entails measuring a set of output voltages and currents at 18,000 and 9,000 rpm.

4.2.2 Objective

The objective of the load test is to develop in graph form the voltage-versus-current characteristics of the 5-Mw generator and determine its operating efficiency.

4.2.3 Procedure

The load test is conducted as described below.

- | <u>Settings</u> | <u>Procedure</u> |
|---|--|
| 1. Rotor, stator, and bearing cooling systems, ON | 3. Drive generator according to test 1 of Table 4-1. |
| 2. Dc breaker, CLOSED | 4. Measure dc voltage and current, rpm, and input torque. |
| | 5. Repeat steps 3 and 4 until all the tests listed in Table 4-1 have been run. |
| | 6. Calculate the efficiency from input torque and output power measurements |
| | 7. Plot dc voltage versus dc current at 18,000 and 9,000 rpm. |

4.3 COMMUTATING REACTANCE TEST

4.3.1 Scope

The commutating reactance test entails measuring rpm and dc voltage and current and obtaining an oscillograph of the line-to-neutral voltage at the 5-Mw, 18,000-rpm point.

4.3.2 Objective

The objective of the commutating reactance test is to determine the commutating reactance of the generator and the time required to complete commutation.

TABLE 4-1
SEQUENCE OF LOAD TESTS

Test No.	Revolutions per Minute	Load-Bank Sections	Resistance, Ω	Dissipative Power, kw
1	9,000	1	1.751	156.2
2	9,000	2	0.876	312.4
3	9,000	3	0.584	468.4
4	9,000	4	0.438	624.8
5	9,000	5	0.350	781.0
6	9,000	6	0.292	937.2
7	9,000	7	0.250	1,093.5
8	9,000	8	0.219	1,249.7
9	18,000	1	1.751	624.8
10	18,000	2	0.876	1,249.0
11	18,000	3	0.584	1,873.4
12	18,000	4	0.438	2,498.0
13	18,000	5	0.350	3,126.0
14	18,000	6	0.292	3,746.9
15	18,000	7	0.250	4,374.0
16	18,000	8	0.219	5,000.0

4.3.3 Procedure

The test is conducted as described below.

Settings

1. Rotor, stator and bearing cooling systems, ON
2. Dc breaker, CLOSED
3. All eight load switches, CLOSED

Procedure

4. Adjust the oscilloscope to display one cycle of line-to-line voltage.
5. Drive the generator to 18,000 rpm, 5 Mw.
6. Record dc voltage and current and rpm.
7. Photograph oscilloscope waveform.

The commutation angle (μ) is calculated by measuring the duration of the line-to-line zero voltage and comparing it to the overall duration. The commutating reactance is calculated using the following equation:

$$X_{com} (\Omega) = (\cos \mu - 1) \frac{\sqrt{1.5} \cdot V_{LNO} \text{ (rms)}}{I_{DC}}$$

where

V_{LNO} is the line-to-neutral rms open-circuit voltage, which is calculated from the oscilloscope picture of the rectified line-to-line voltage

and

$$V_{LNO} \text{ (rms)} = \frac{V_{LLO} \text{ (peak)}}{\sqrt{6}}$$

$$V_{LLO} \text{ (peak)} = (V(60 \text{ deg}) + I_{DC} \cdot 2 \cdot R_o) / \sin 60 \text{ deg}$$

where

$V(60 \text{ deg})$ is the instantaneous voltage, line-to-line, at 60 deg on the oscilloscope picture

I_{DC} is the measured dc current

R_o is the phase resistance of the generator

5. SYSTEM SAFETY/HAZARD ANALYSIS

A preliminary hazard analysis has been completed for the advanced high-power generator test. All hazards found appeared to be adequately controlled except that of dropping the generator during installation. Extreme care should be exercised in lifting the generator since no dedicated attachment points have been provided. This document supplements AiResearch Report 80-17402.

5.1 ANALYSIS

The preliminary hazard analysis for the advanced high-power generator test is contained in Table 5-1. Column 1 of the table lists the hazardous conditions that are or may be present during testing or installation of the generator. The possible causes of these conditions are listed in Column 2. The third column lists the possible effects of the hazardous condition. Hazard levels were assigned to the hazardous condition effects per MIL-STD-882A categorized as follows:

<u>Hazard Category Classification</u>	<u>Description</u>
I (Catastrophic)	May cause death of personnel or loss of generator or test facility (unrepairable).
II (Critical)	May cause severe injury to personnel or major damage to generator or to test facility (repairable).
III (Marginal)	May cause minor injury to personnel or minor generator or test facility damage.
IV (Negligible)	Will not result in injury to personnel or damage to the generator or to the test facility.

These hazard levels are applied in the fourth column of Table 5-1. The last column lists recommended corrective action and describes the protective features of the generator and test facility.

5.2 CONCLUSIONS AND RECOMMENDATIONS

There are four Category II hazards, four Category III hazards, and one Category IV hazard associated with the installation and testing of the advanced high-power generator. Adequate protection has been provided against all hazards except those associated with lifting the generator. Special care must be taken to prevent damage to the generator or injury to personnel when the unit is moved.

TABLE 5-1
PRELIMINARY HAZARD ANALYSIS

AREA OR SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DESCRIPTION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Bearing Seizure	- Contamination of bearing. - Foreign material between rotor and bearing. - Loss of bearing lubrication.	Large inertia loads leading to possible fracture of fixture mounts and fixed rotor/bearing assembly.	II	- Bearings are ABEC 7 quality with oil spray lubrication. - Personnel will not be permitted in the test chamber during testing. - Test fixture will be designed to hold the generator in the event of rotor lock up at maximum speed.
Large Mass Of Generator	Absence of lifting provisions allows generator to be dropped during transportation or installation.	- Possible fracture of generator parts. - Possible injury to personnel moving the generator.	III	Appropriate provisions should be made to enable safe movement of the generator, e.g., lifting eyelets.
Rotor Over-speed	- Generator loses its load. - Test equipment malfunction.	Possible rotor burst, releasing fragments of steel into the test chamber.	II	- Shaft speed is instrumented. Test fixture contains provisions for emergency shutdown in case of over-speed. - Shields are provided to contain fragments to the test facility. - No personnel will be permitted in facility during testing.

TABLE 5-1 (Continued—Page 2 of 3)

AREA OF SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DESCRIPTION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Fire	1. Bearing overheat from contamination or too much oil during operation. 2. SC 200 cooling oil igniter (flash point 175°F, Autoignition Temp. 800°F). a) From overheat. b) From electrical spark.	1. Possible injury to personnel or equipment damage.	III	1. Oil/air mixer should filter oil. 2. Facility is equipped with fire detection and a tone of 300 Hz CQ for total flooding extinguishment. 3. Inlet & outlet oil/air mixture pressure and temperature will be monitored and alarm will sound if temperature is excessive or pressure is too low. 4. Outlet cooling oil temperature will be monitored and alarm will sound if temperature becomes excessive.
High Voltage	1. Exposed terminals may come into contact with personnel or equipment.	1. Possible injury to personnel or equipment damage.	IV	1. Personnel will not be in vicinity when test is in progress. 2. An insulating cover will be provided.
Static Electricity	1. Building during test due to improper grounding.	1. May cause personnel injury, equipment damage or initiate a fire.	III	1. Generator will be grounded during test by bolting to the test fixture.
Excessive Vibration	1. Bearing failure. 2. Bearing support failure. 3. Rotor imbalance due to internal fracture.	1. Damage to generator and test equipment; may lead to fatigue failure of generator parts.	II	1. Test fixture contains provisions for quick shutdown in case of excessive vibration. 2. Bearings are resilient-mounted. 3. Structural integrity has been verified by rotor test & stress analysis.

TABLE 5-1 (Continued--Page 3 of 3)

AREA OF SYSTEM ADVANCED HIGH POWER GENERATOR TEST

HAZARDOUS CONDITIONS	HAZARD CONDITION CAUSAL EVENT DISCUSSION	HAZARDOUS CONDITION EFFECT	HAZARD LEVEL	RECOMMENDED CORRECTIVE ACTION
Excessive Torque at Shaft	1. Malfunction of test equipment. 2. Bearing failure. 3. Motor becomes locked with stator.	1. Possible overstress of generator parts; e.g., windings, shaft or bearing.	II	1. Torque sensor is provided on the input shaft; alarm will sound if torque is excessive.
Short Circuit	1. Damaged winding. 2. Misconnection of windings.	1. Loss of load. 2. Overheated windings. 3. Fire.	III	1. Fire balance is sensed and there will be quick shutdown if imbalance is excessive.