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**NASA CONTRACTOR REPORT**

**NASA CR-1451**

NASA CR-1451

# ALTERNATOR AND VOLTAGE REGULATOR-EXCITER FOR A BRAYTON CYCLE SPACE POWER SYSTEM

## I - Design and Development

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*Prepared by*
GENERAL ELECTRIC COMPANY
Erie, Pa.

*for Lewis Research Center*

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16. Abstract

A homopolar inductor alternator and voltage regulator-exciter delivering 15 KVA, 0.8 power factor 120/208 volts, and 400 hertz power for a Brayton Cycle space power system has been developed and tested. Design objectives included high reliability, 90 percent efficiency, and aircraft alternator power quality. Manufacturing objectives included two (2) stators, three (3) rotors, and two (2) "Flyable" voltage regulator-exciters for use in gas bearing turboalternators. Two (2) Alternator Research Packages were also manufactured for separate component testing. Design philosophy and test results are presented. A Load Bank was also designed and built for use in a gas bearing test rig.

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# FOREWORD

The research described herein, which was conducted by General Electric Company of Erie, Pennsylvania under subcontract to Pratt and Whitney Aircraft Division of United Aircraft Corporation, was performed under NASA contract NAS 3-6013. The Project Manager for NASA was Mr. Henry B. Tryon, Space Power Systems Division, Lewis Research Center. The report was originally issued as General Electric report A69-003, Vol. I.

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# SECTION I

## SUMMARY

An alternator and voltage regulator-exciter have been developed and tested for application in a 15 KVA, 120/208 volts, 400 hertz, 0.8 lagging power factor Brayton Cycle space power system. An Alternator Research Package (ARP) consisting of the alternator operating at 12,000 rpm on oil-lubricated rolling-element bearings and a breadboard voltage regulator-exciter (VRE) have been manufactured and tested.

The alternator is a liquid-cooled ($200^{\circ}$F) homopolar inductor designed for high reliability and efficiency. Its design features include electron-beam-welded laminated pole tips to reduce pole face loss, hermetic sealing, unique stator coil design, polyimide insulation, and stand-off terminals for hermetic terminal protection.

The ARP efficiency is 91.7% at 11.25 KVA, 0.8 power factor. Experimental data indicate that efficiency exceeds 90% over a range of power output between 4.5 and 15 KW at 0.8 power factor, and peaks at 9 KW. The system met or exceeded the following specification requirements:

| | |
|---|---|
| Frequency Range | 400 ± 20% |
| Voltage Regulation | ± 1% from 10% Load to Full Load |
| Recovery Time on Application or Removal of Full Load | 0.25 seconds |
| Voltage Excursion | 36.4% on Removal of Full Load |

The voltage regulator-exciter and alternator acted to limit voltage recovery time to less than 0.2 seconds with the application of one per unit load transients. For applied loads the voltage dropped to 78% of rated. For load removal the voltage increased to 128% of rated. The regulation, that is the change in voltage from no load to full load, was ± 0.13%.

## SECTION II

### INTRODUCTION

The NASA has envisioned the future need for large blocks of power for space applications, and one of the energy conversion schemes being investigated is the Brayton Cycle Power Plant, one form of which is shown in Figure 1. The turboalternator, Figure 2, uses argon gas as the working fluid and runs on hydrodynamic gas bearings to provide long life and eliminate the problem of working fluid contamination that would exist if conventional oil lubricated bearings were used. This report, Volume I, describes the design, manufacture and testing of the alternator and voltage regulator-exciter. A second report, Volume II, covers an investigation into the nature and magnitude of the unbalanced magnetic forces existing in the alternator so that proper gas bearing design could be accomplished.

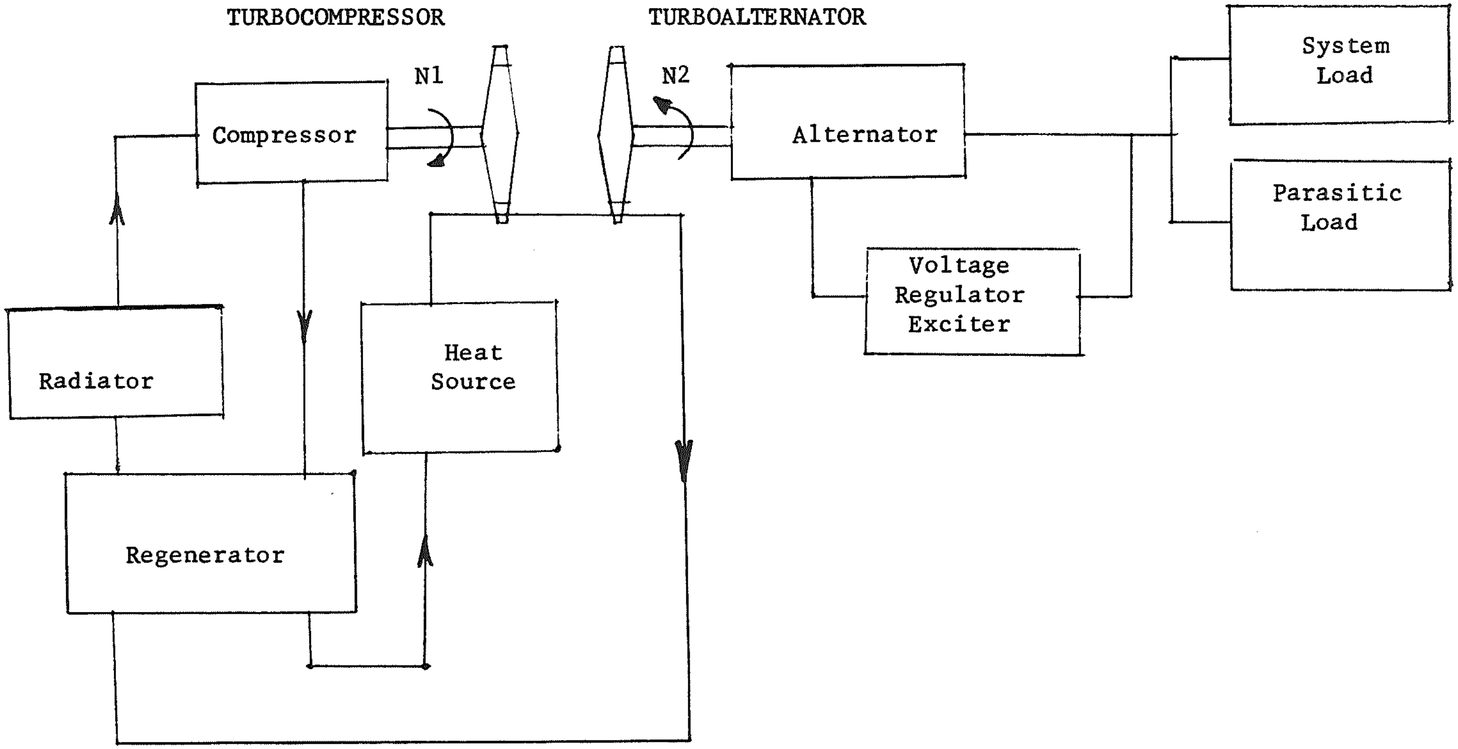
Design objectives for the alternator and voltage regulator-exciter in their order of priority are given below:

1. High reliability
2. 90% efficiency
3. Aircraft alternator power quality
4. Weight

In addition, double load capability, alternator hermetic sealing, and low unbalanced magnetic forces were also required.

Manufacturing objectives included two (2) stators, Figure 3, and three (3) rotors for use in the gas bearing turboalternator of Figure 2. To provide hardware for separate component evaluation, two (2) Alternator Research Packages (ARP) consisting of an alternator and breadboard voltage regulator-exciter (VRE), Figure 4 and 5, were manufactured. The alternator utilized the same stator design generated for the turboalternator, but had a redesigned rotor that operated on oil lubricated rolling contact bearings housed in stainless steel end shields. The ARP was thus a self contained unit that could be tested independently under a variety of conditions including rotor cavity evacuation. Pictures of the two different rotors can be found in Section III, Figure 10 and 11. Two (2) flyable VRE's for use with the turboalternator were manufactured. Each unit was packaged as shown in Figures 6 and 7. The Figure 6 package contains the voltage regulator components and the rectifiers of the static exciter. The reactor-transformer, which is the main component of the static-exciter, is housed in the package of Figure 7. These units are truly flyable units except for hermetic-sealing which was eliminated to facilitate ground testing.

Practically all of the design objectives and all of the manufacturing objectives given above were met. Other sections of this report cover the design philosophy utilized to meet the design objectives and also the design decisions made to enhance reliability at the sacrifice of some power quality. Performance test data is given as well as detailed design calculations. A detailed report on the development of the electron beam welding technique for securing laminated pole tips to the rotor is given in Section VIII.



BRAYTON CYCLE SYSTEM

Figure 1

# BRAYTON CYCLE TURBOALTERNATOR

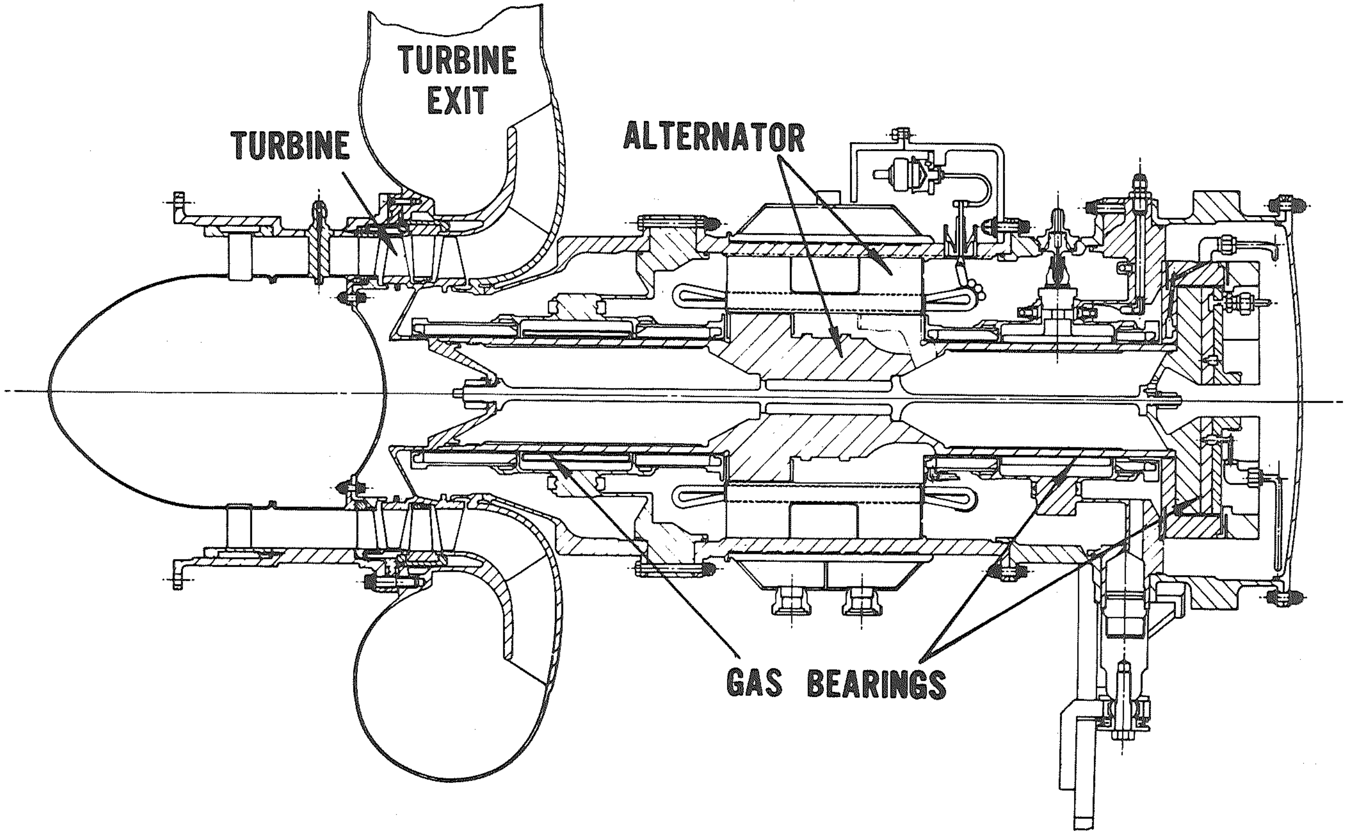
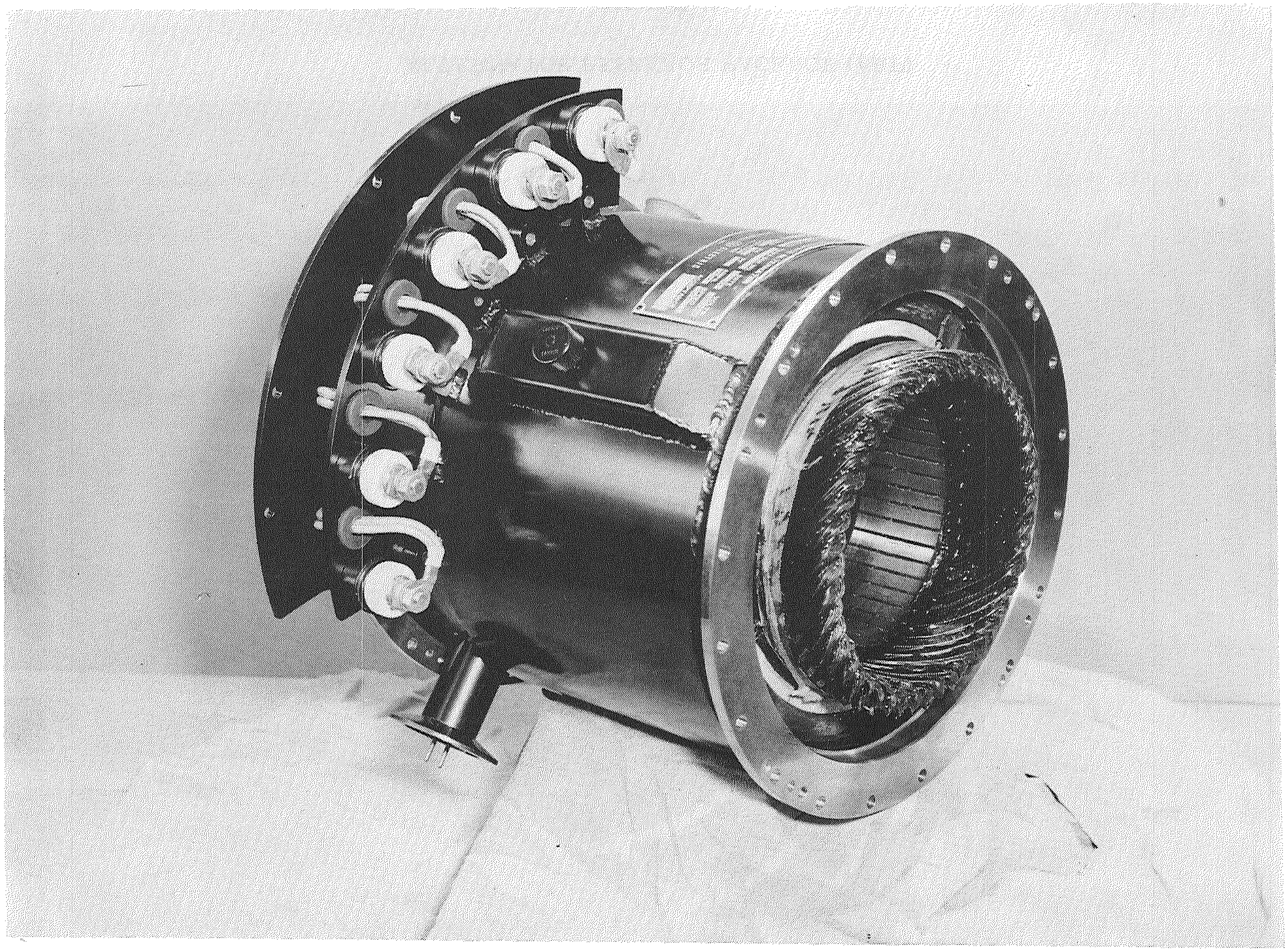
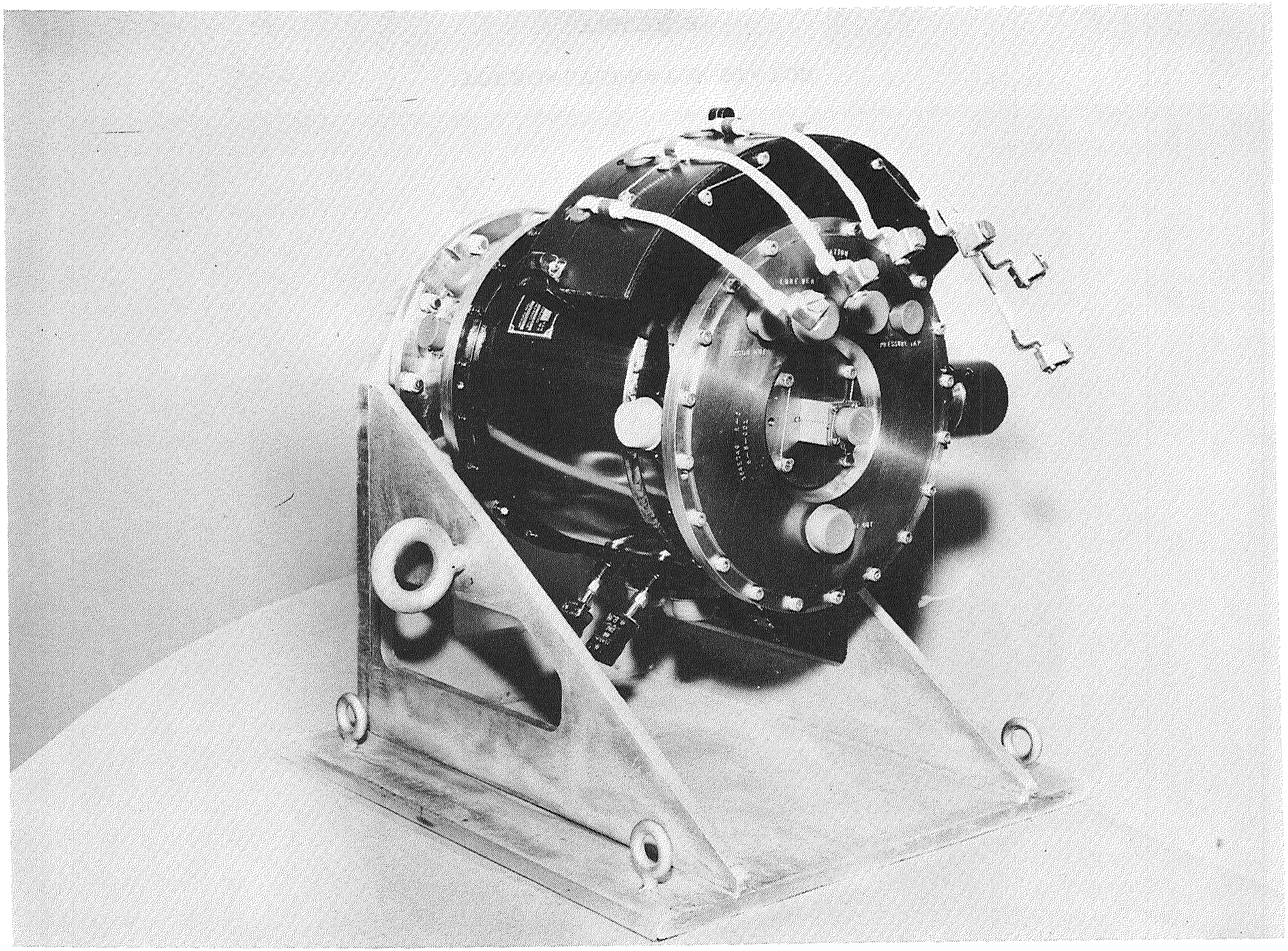


FIGURE 2



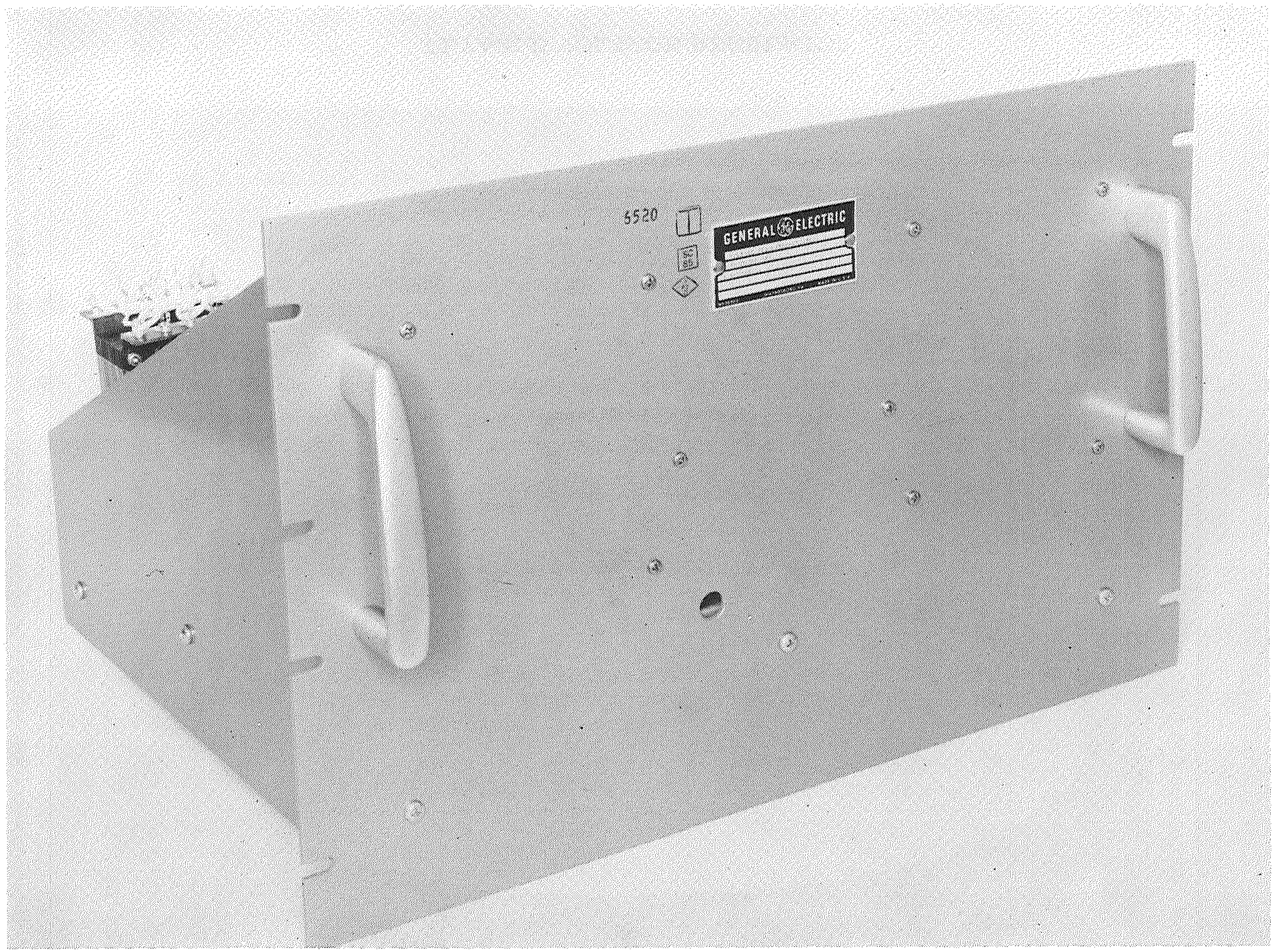
TURBOALTERNATOR STATOR

FIGURE 3



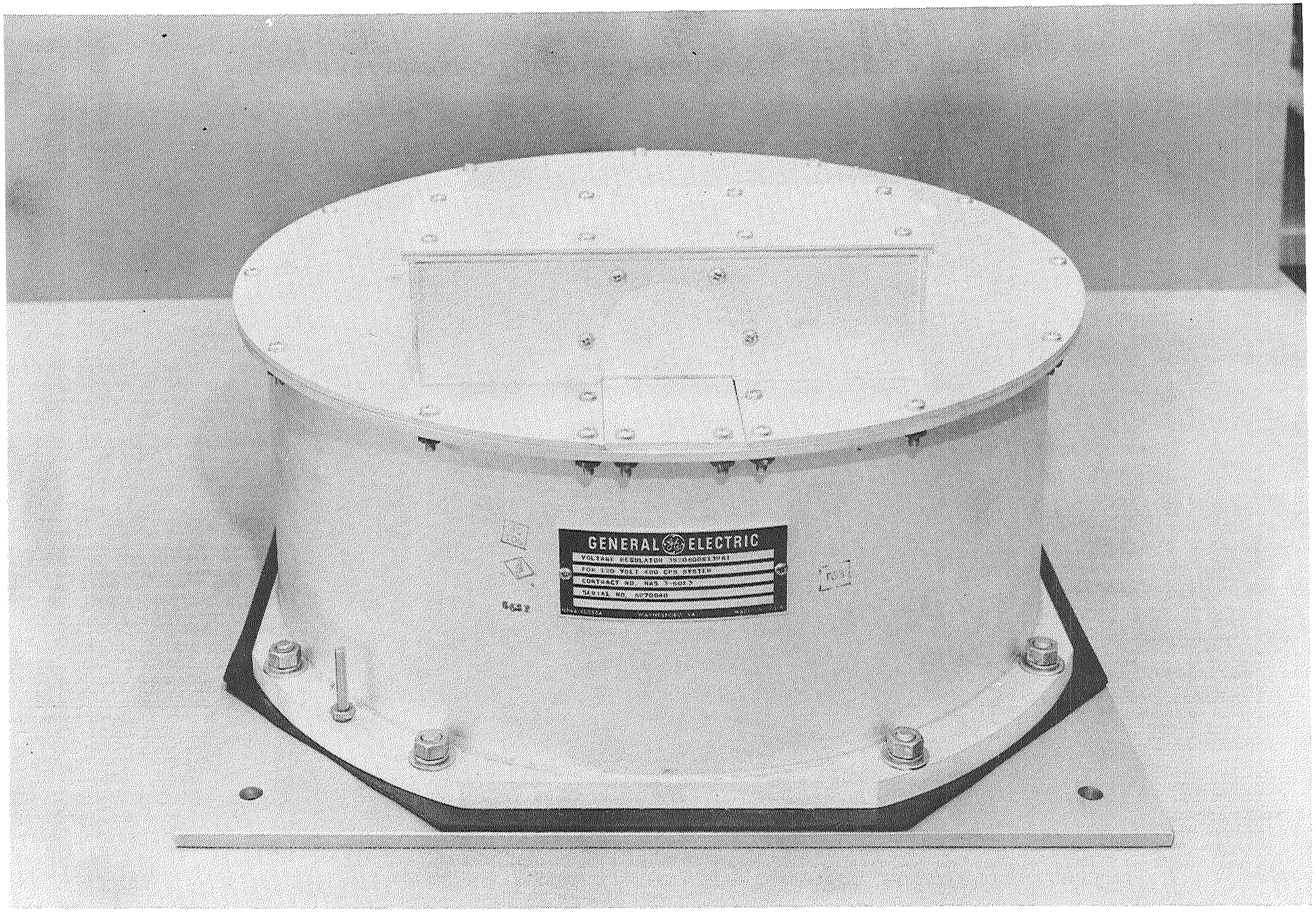
ALTERNATOR RESEARCH PACKAGE (ARP)

FIGURE 4



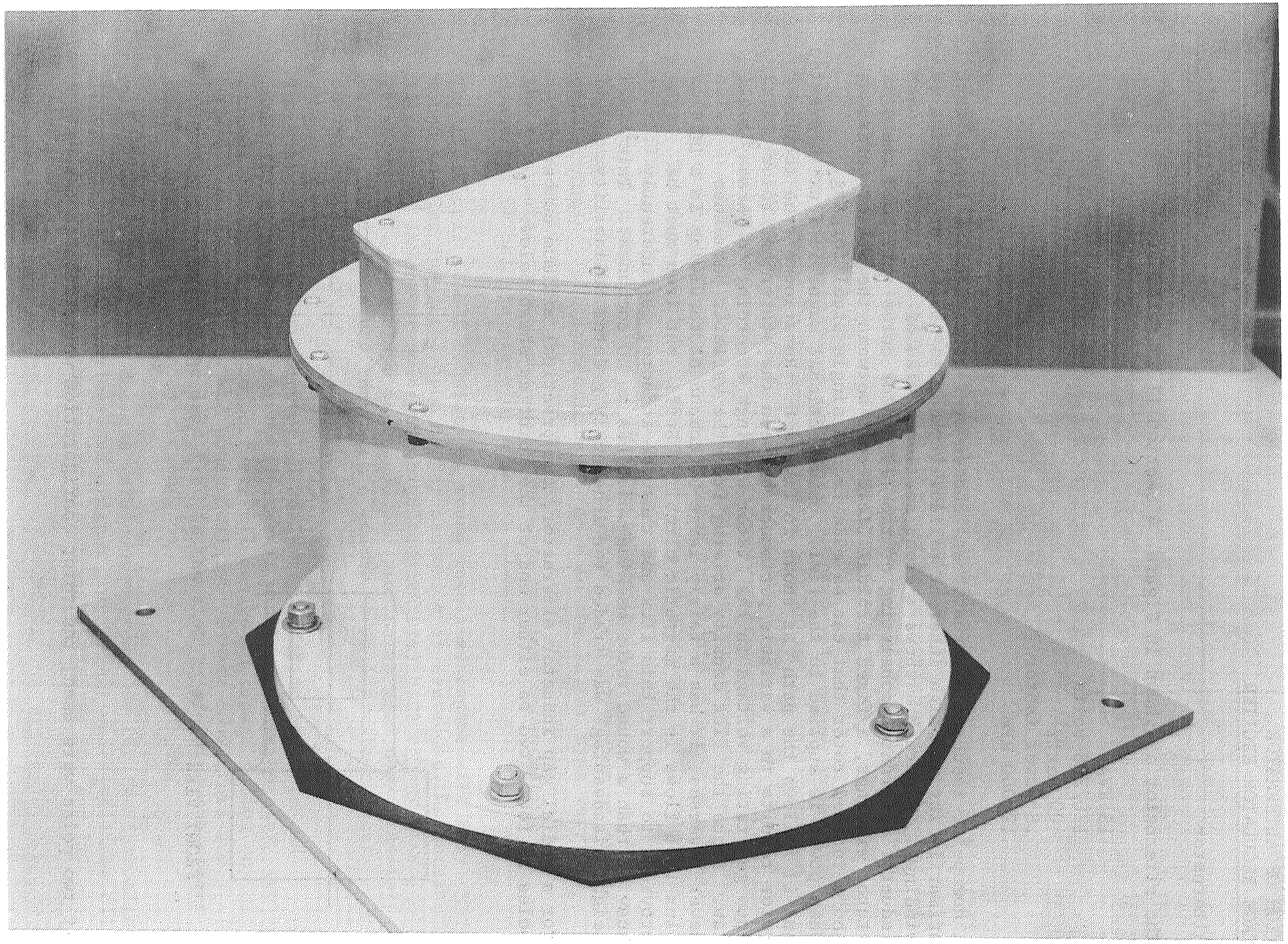
BREADBOARD VOLTAGE REGULATOR - EXCITER (VRE)

FIGURE 5



FLYABLE VOLTAGE REGULATOR

FIGURE 6



FLYABLE EXCITER

FIGURE 7

# SECTION III

## DESCRIPTION OF ALTERNATOR AND VOLTAGE REGULATOR-EXCITER

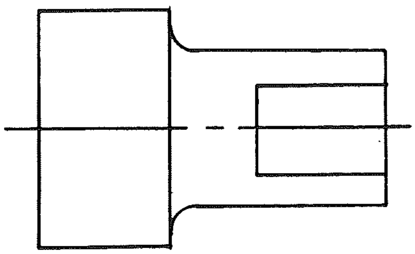
### A. Alternator

The alternator as shown in Figure 4 Section II is rated at:

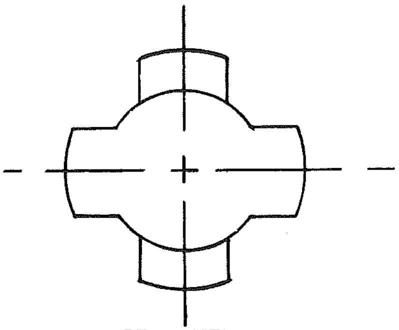
15 KVA
120/208 volts
400 hertz
.8 power factor
12,000 RPM

A homopolar inductor alternator was chosen over other machine types primarily for its high inherent reliability due to absence of rotating windings. Figure 8 shows a cross sectional view of the ARP inductor alternator consisting of two (2) stator cores that hold the stator windings, a fixed toroidal field coil between the stator cores, and a toothed rotor that can be made from a single steel forging. When power is applied to the field, unidirectional magnetic flux is created and it follows the path as shown in figure 8. Rotation of the toothed rotor results in a variable permeance between the stator and rotor thus generating voltage in the stator windings according to Faraday's law. Since the flux density arising from the variable permeance never reverses, it has a fairly large DC component resulting in a DC flux that flows in the magnetic circuit. Sufficient iron must be provided to support this flux and thus the inductor is inherently heavier than a wound rotor machine which has no DC component. This weight disadvantage was traded for inherently greater reliability.

For a radial gap inductor alternator, the practical minimum number of poles is four, two on either end of the rotor as shown below:

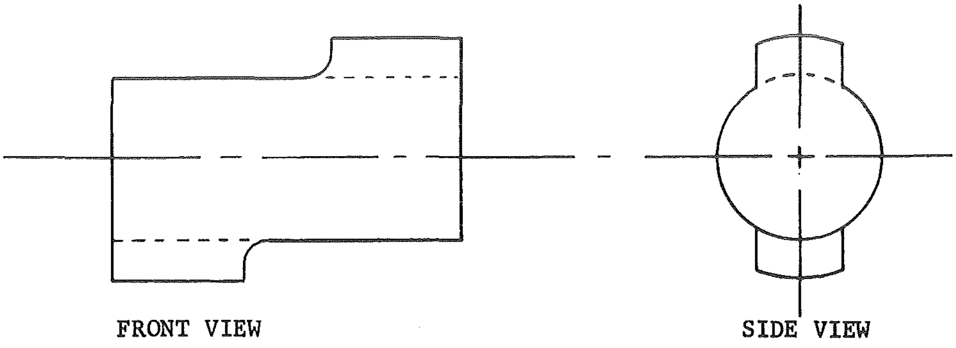


FRONT VIEW



SIDE VIEW

If two poles were used, the rotor configuration would have to be:



Such a configuration creates mechanical unbalance which must be eliminated by attaching a stainless steel member opposite each magnetic pole. Manufacturing difficulties, although not insurmountable, thus occur and in order to avoid them a four pole design running at 12,000 RPM was chosen to produce the 400 hertz power required.

The stator consists of two (2) stacks of .007" electrical sheet steel laminations, field coil, and AC winding all housed in an ingot iron frame as shown in Figure 9 . Heat is removed from the stator by a liquid coolant which flows in the circumferential grooves of the frame outer diameter. An Inconel shroud, welded at both ends to the frame, covers the coolant grooves and contains the liquid within the passageways. Two flanges of heat treatable steel are welded to the ingot iron frame, and provide a good wearing surface for the flange rabbets. Electrical power from the AC winding is available externally at six (6) hermetic terminals which are connected to a like number of standoff terminals. All connections are made to the latter type terminal so as to avoid damage to the hermetics. Field power is supplied to the alternator through a 2-prong hermetic terminal whose mating connector is held in place by a Marman clamp.

The field coil itself consists of round insulated copper wire wet-wound into an insulated spun copper can which is seated at the outer diameter by layers of soldered (high temperature) bare copper wire. This type of construction is rugged and provides a good heat transfer path to the frame since the outer diameter is in intimate contact during operation.

The stator winding consists of 48 coils lap wound in 48 slots and connected so as to form a two (2) circuit winding. This 48 slot, two circuit, design offers the best overall design in regard to low unbalanced magnetic forces and power quality. Stator conductors are stranded, form wound, and laid flat in the slot to minimize the effect of long and short path eddy current losses.

Two (2) different rotor designs were constructed, one for the turboalternator to operate with gas bearings and another for the ARP which utilizes oil bearings. Pictures of the rotors are shown in Figures 10 and 11 respectively.

Both rotors are made from AISI 4620 steel and have laminated pole tips (.014" electrical sheet steel ) which are electron beam welded to the main body of the rotor to reduce pole face loss. The successful application of electron beam welding in this manner represents a major manufacturing accomplishment of the program.

Amortisseur bars made of zirconium copper have been placed in the pole tips to improve unbalanced load performance and rotating windage baffles fastened to the pole ends reduce windage loss. The rotating baffles run approximately 0.05" from a set of stationary baffles thus giving the effect of two (2) smooth disks rotating next to each other. General Electric In-House tests have determined that this arrangement substantially reduces the windage loss, and tests on the ARP have verified these findings.

Stainless steel end shields (Type 304) support the rotor on the ARP and house the bearings, seals, and bearing cartridges. Figures 12 and 13 show the drive-end and anti-drive end end shields respectively. The bearing design utilizes low loss oil lubricated bearings (Conrad 203 type) and rotating face type carbon seals. Bearing lubrication and seal cooling are provided on the drive end by two (2) 0.03" jets each delivering a flow of 0.5 lb/minute (7808 oil) when operating under approximately 15 psi above breather pressure. Breather openings have been provided for both bearings and may be used to introduce an Argon atmosphere to the bearing cavity if required.

Oil is scavenged from both sides of the bearings, and the ratio between scavenge area and jet area is 150. Since only one (1) seal is required on the anti-drive end, a single jet (.042") with a flow of 1 lb/minute at 15 psi above breather pressure provides both lubrication and cooling. Details of the bearing and seal assembly are shown in Figures 40. and 41 of Section V.

Ten (10) Chromel-Alumel thermocouples are installed in the stator to measure temperature during operating conditions. These thermocouples exit through the frame by way of two (2) 10-prong hermetic connectors which provide simple and reliable access to recording equipment. Thermocouples have also been installed in the Inlet-Outlet coolant chambers to measure the temperature of the coolant. On the ARP units, thermocouples located close to the bearing outer diameter provide a means for monitoring bearing temperatures during operation.

## B. Voltage Regulator-Exciter Description

### 1. General information

The Brayton Cycle voltage regulator-exciter (VRE) program called for development of two types of hardware, breadboard and flyable. The breadboard, Figure 14 , was to be a laboratory model designed for rack mounting and convection cooling. The flyable models, Figures 15 and 16 , were to be packaged for operation in a space environment and were to be conduction cooled. Although this particular application did not include a nuclear heat source, radiation resistant components were used to make the design versatile. (See Section VIII).

The "flyable" models were originally hermetically sealed, but this provision was deleted in order to reduce the size and thus the shadow cast on the mirror of a solar heat source. A variable voltage setting was also provided on the "flyables" to permit adjustment during ground test. A fixed resistance should be incorporated when the system requirements are determined to improve reliability.

An engineering breadboard, Figure 17 , was also built for circuit evaluation. When the engineering breadboard was operated with the alternator for the first time, it was found that some component changes were necessary to improve the system stability margin and to make the high phase takeover circuit inoperative during normal operation.

These component changes were made in the breadboard and it was tested with the Alternator Research Package. The tests showed that performance was well within the specifications.

## 2. Theory of operation

The VRE is designed to regulate the output of General Electric alternator Model 2CM393A1 and 2CM393B1 rated 15 KVA, 0.80 PF, three phase, 4 wire 115/208 volts, 400 hertz.

The VRE can best be understood in terms of a block diagram of the system and a brief outline of the general scheme of operation. The major circuits of the VRE are shown in the block diagram, Figure18 Referring to Figure 18 , the VRE functions as follows:

> A reference voltage is supplied by the reference circuit to the comparison circuit. A signal voltage is supplied to the comparison circuit by the voltage sensing circuit. The reference and signal voltages are compared, and the error current, which indicates that a change in voltage is necessary, is amplified by a transistor and magnetic amplifier. The output current, supplied by the magnetic amplifier to the control winding of the exciter, changes the exciter output so that line voltage is restored to the correct value. The stabilizing circuit is designed to provide fast response while preventing oscillation. A separate high phase takeover circuit limits the maximum voltage on any phase to approximately 110% of normal during single phase short or open circuits.

## 3. Packaging

The VRE will be cooled by conduction to cold plates, one at 150°F and one at 250°F. Since the two major magnetic devices, the saturable current potential transformer (SCPT) and the linear reactor, are capable of operating at the higher temperature over the required mission time, these two components are packaged as a complete assembly for mounting on the 250° sink, Figure 16.

All other components, which included those making up the complete voltage regulator plus the field rectifier subassemblies, were packaged as a complete assembly for mounting on the 150°F sink, Figure 15.

Other cooling methods may be used, so long as the base plate temperatures do not exceed the values stated above.

4. Environment Specifications

The Brayton Cycle system will be exposed to different environments as it progresses through the manufacturing, storage, transportation, lift off, boost, orbit and orbit transfer stages. The expected values of shock, vibration, acceleration and accoustical noise which accompany these stages are tabulated in Table I.

Although not listed as a requirement on the contract, it is desirable to use components which will operate in a nuclear radiation environment similar to other NASA space programs. The expected radiation dosage for the system is $1 \times 10^{11}$ NVT fast neutrons and $1 \times 10^{6}$ rads (carbon) of gamma rays. Accordingly, parts have been selected with this in mind, but the parts should be proved by test before being used in a nuclear environment.

Although the packages are not hermetically sealed, the parts are designed to operate for 10,000 hours in a space vacuum. The tolerance to vacuum has been achieved by potting the components in a hard epoxy, which has a very low sublimation rate at the expected operating temperature. Connecting wires within the enclosure have insulation which also has a very low sublimation rate.

Although not required by the specifications, the VRE should not be harmed by -55°C temperatures during launch and startup.

5. Electrical Performance Specifications

In general, the regulator is to maintain alternator line to neutral voltage at 120 volts from no load to double load, and to recover promptly and stably after load change. Furthermore, the regulator must supply sufficient field power to provide for 3.0 per unit line current for both three phase and single phase short circuits. The electrical performance specifications are summarized in Table II . How well the system performed to these requirements is given in Section VI "Test Results and Discussion".

## C. Load Bank

A Load Bank, Figure 19, for use in a gas bearing test setup was designed and manufactured. It consisted of an Avtron Model T-80 Load Bank, instrumentation, and circuit breakers for applying a variety of fault conditions to the system. Circuit diagram and other detail drawings appear in Section VIII.

# BRAYTON CYCLE
# ALTERNATOR RESEARCH PACKAGE

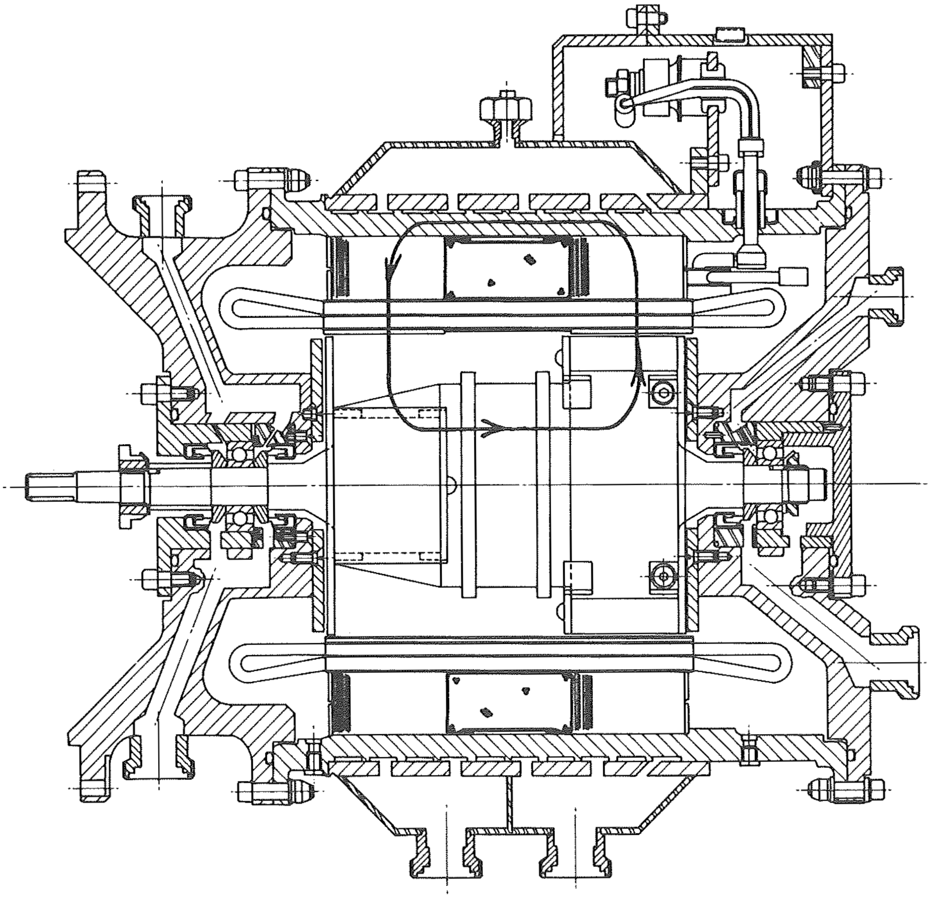
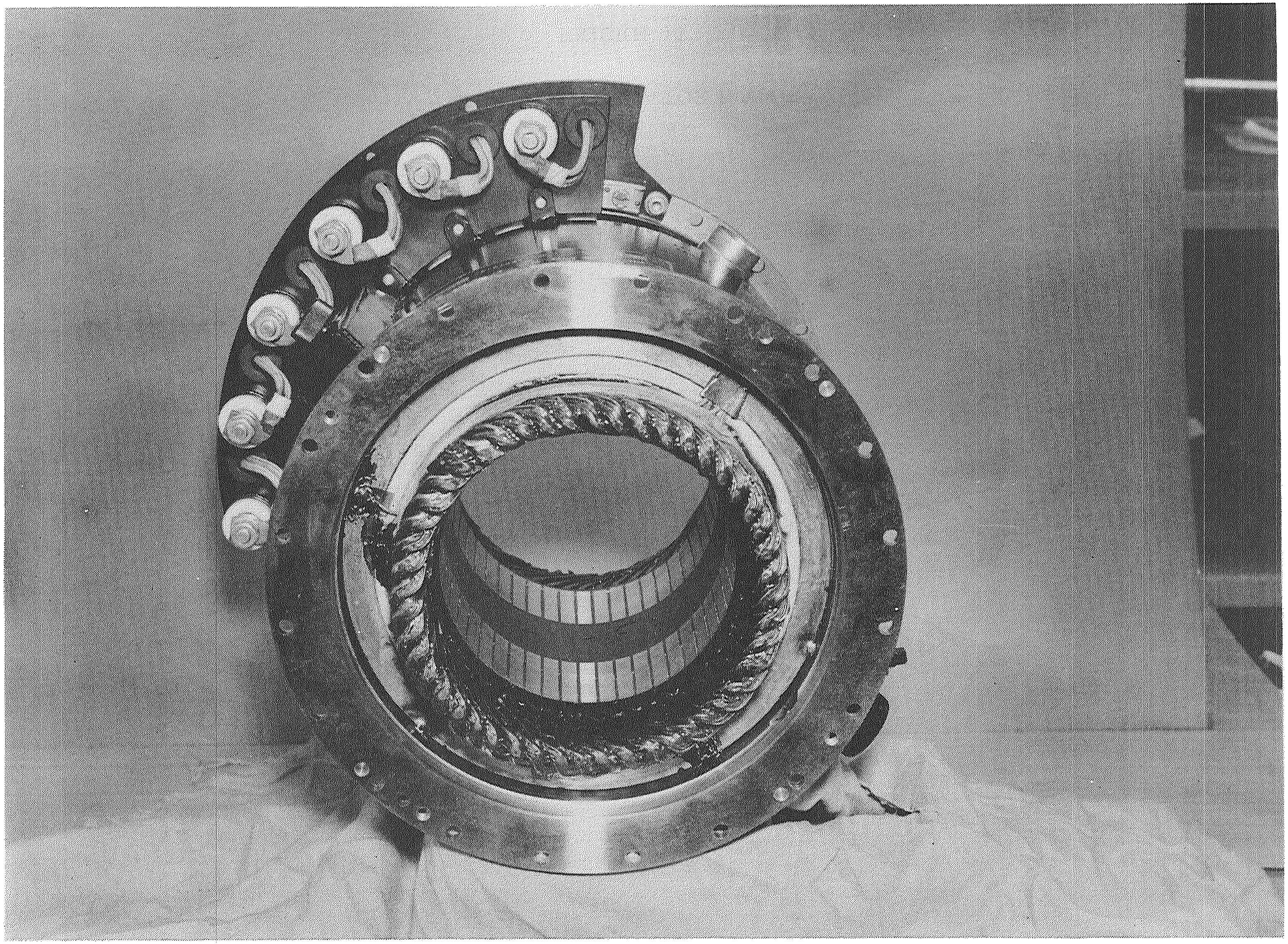
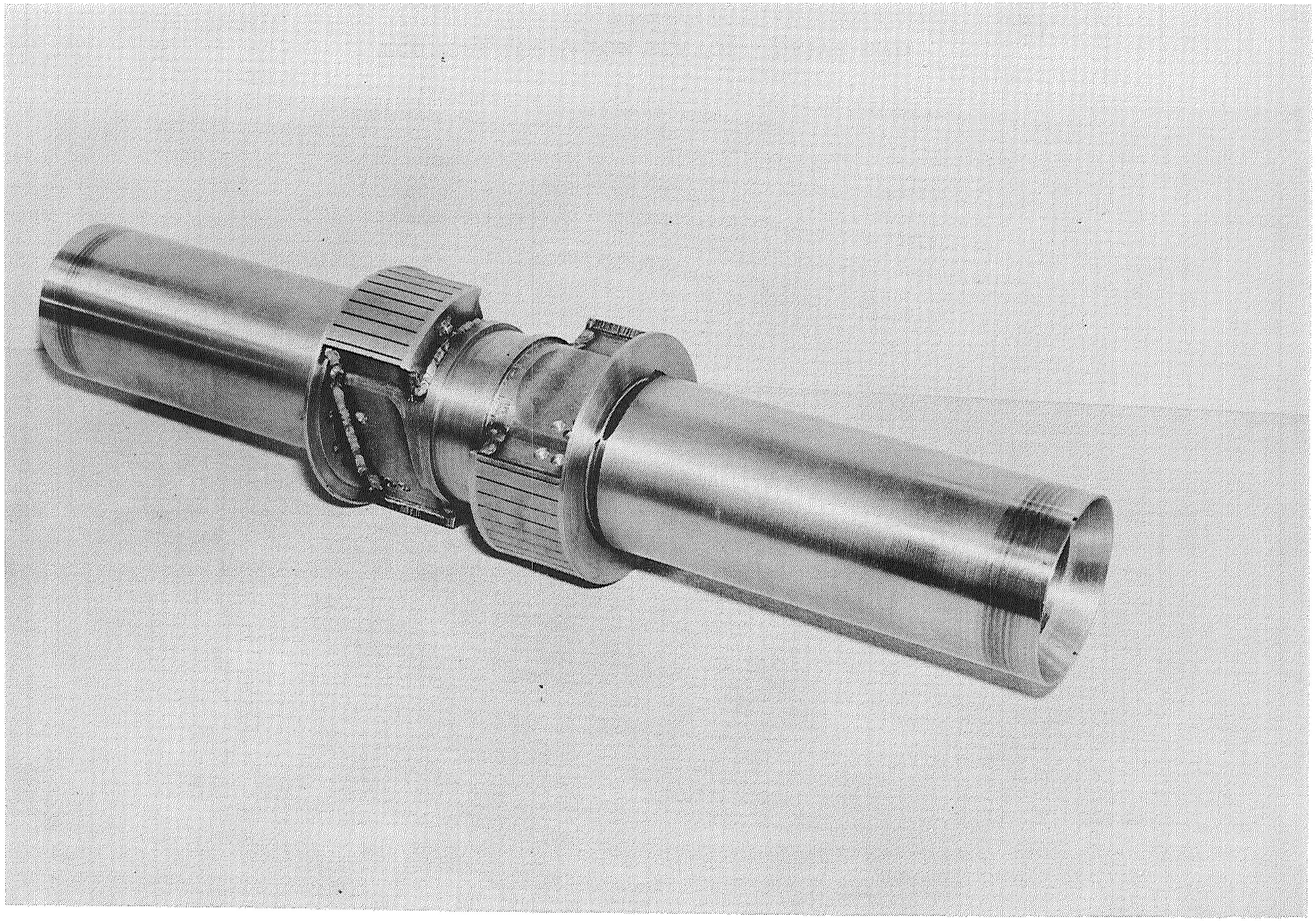


FIGURE 8.



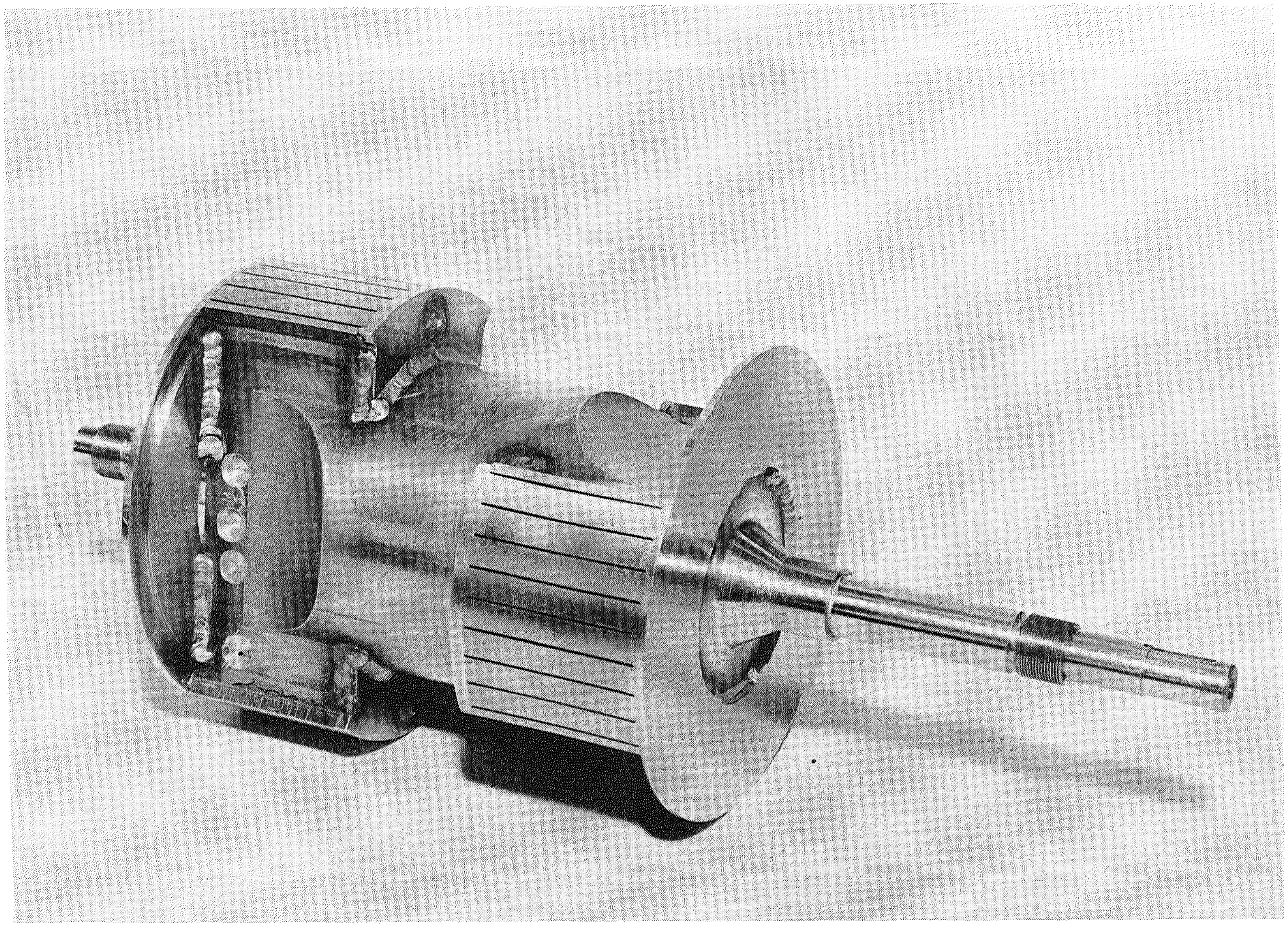
TURBOALTERNATOR STATOR - DRIVE END

FIGURE 9



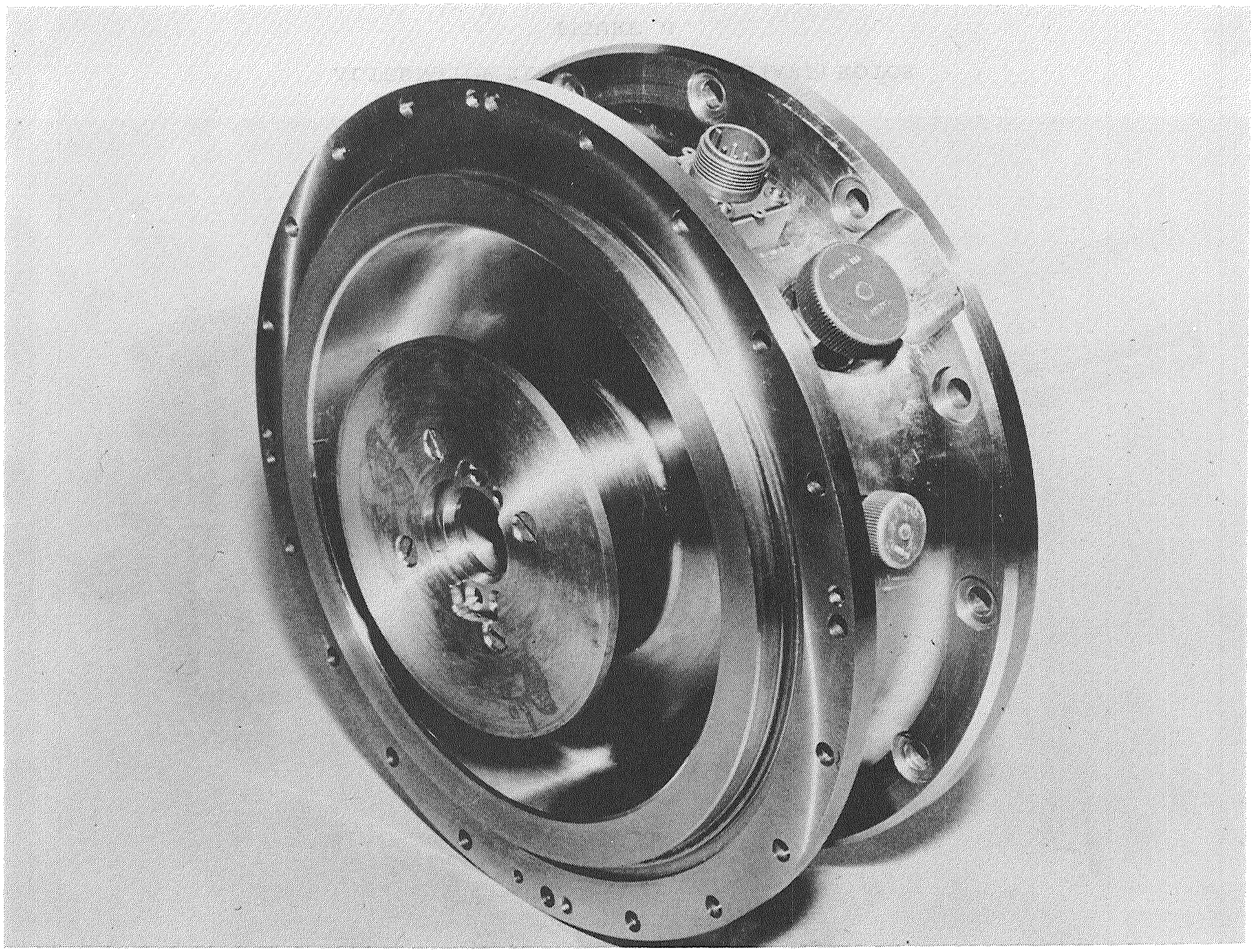
TURBOALTERNATOR ROTOR

FIGURE 10



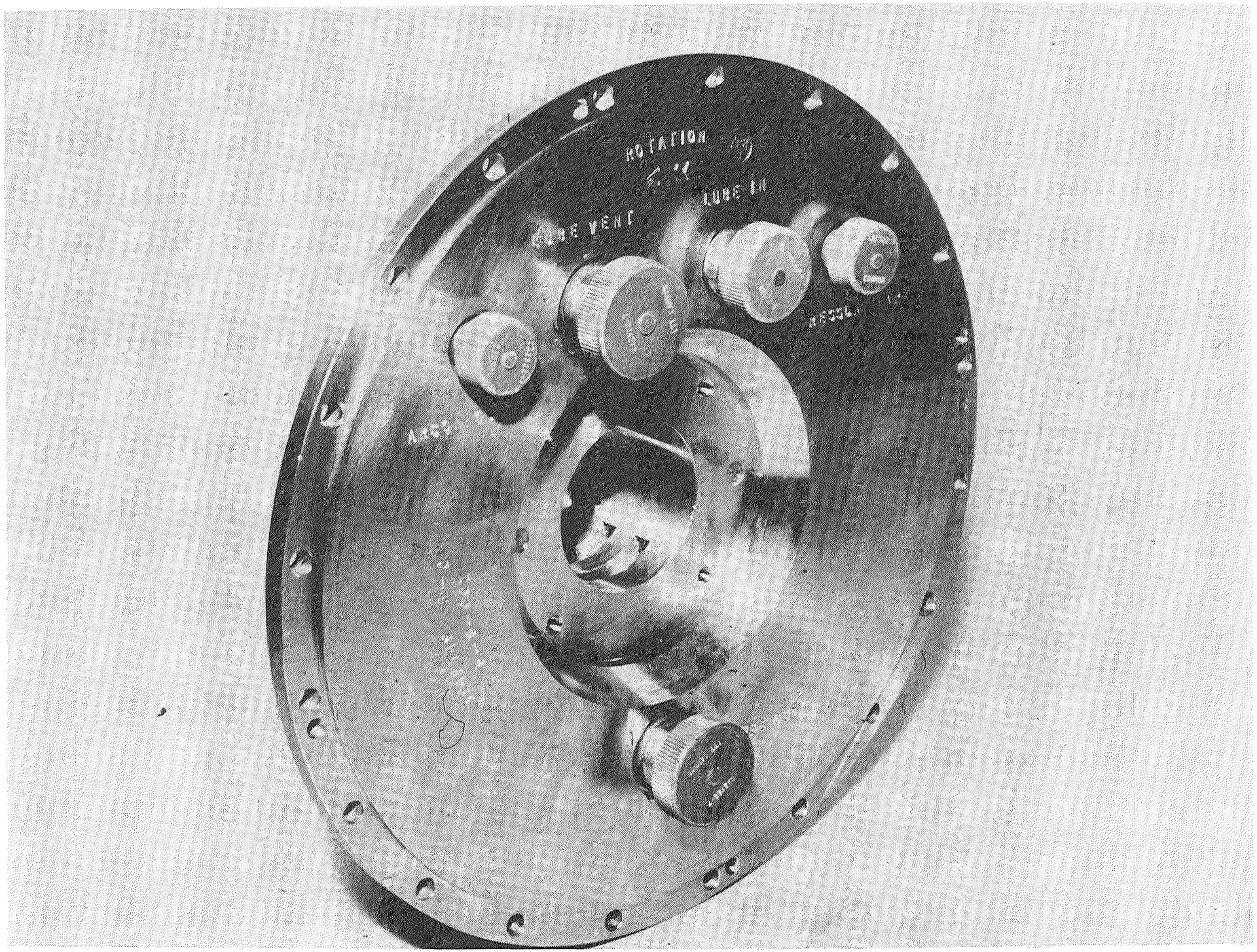
ALTERNATOR RESEARCH PACKAGE (ARP) ROTOR

FIGURE 11

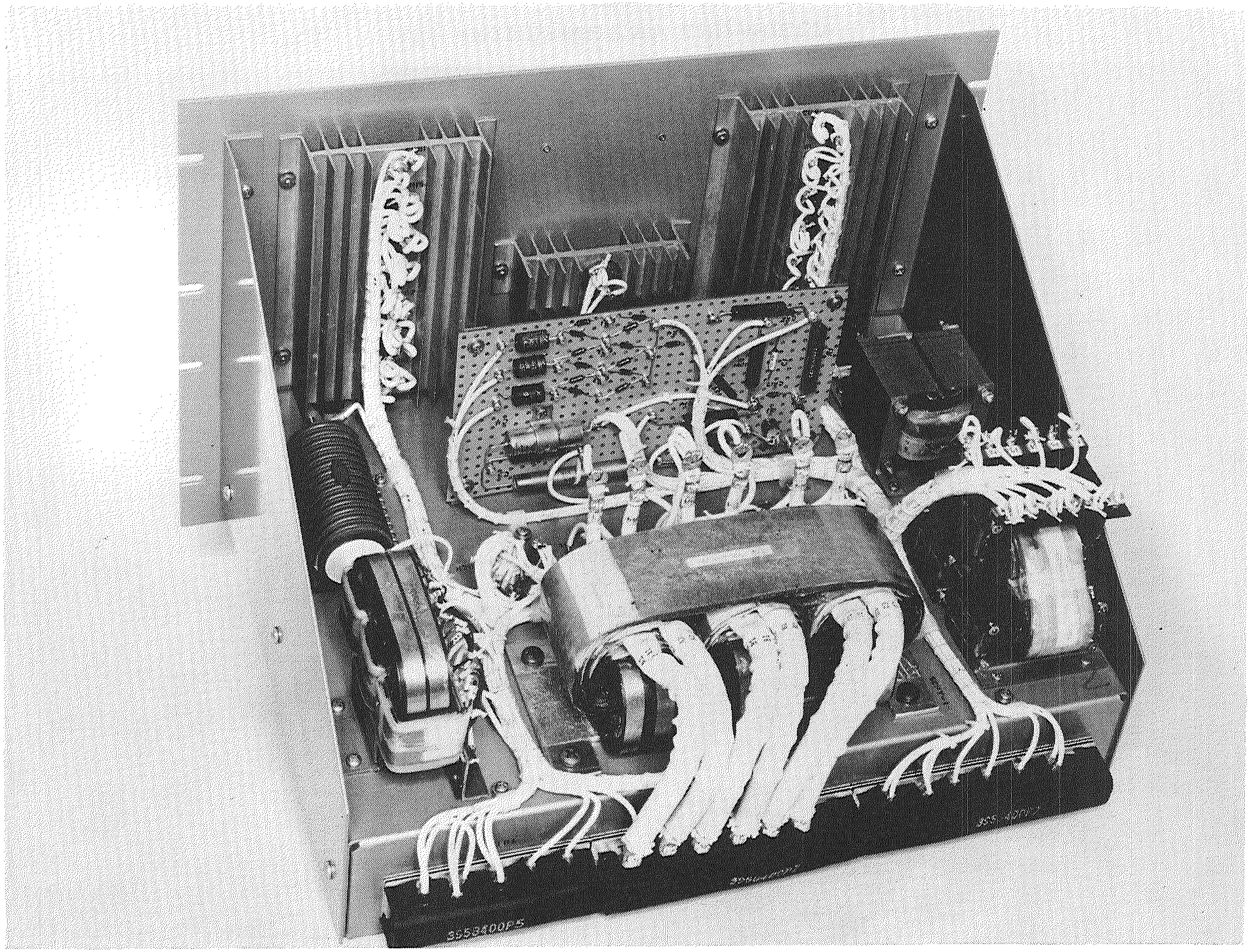


ARP DRIVE END END SHIELD

FIGURE 12

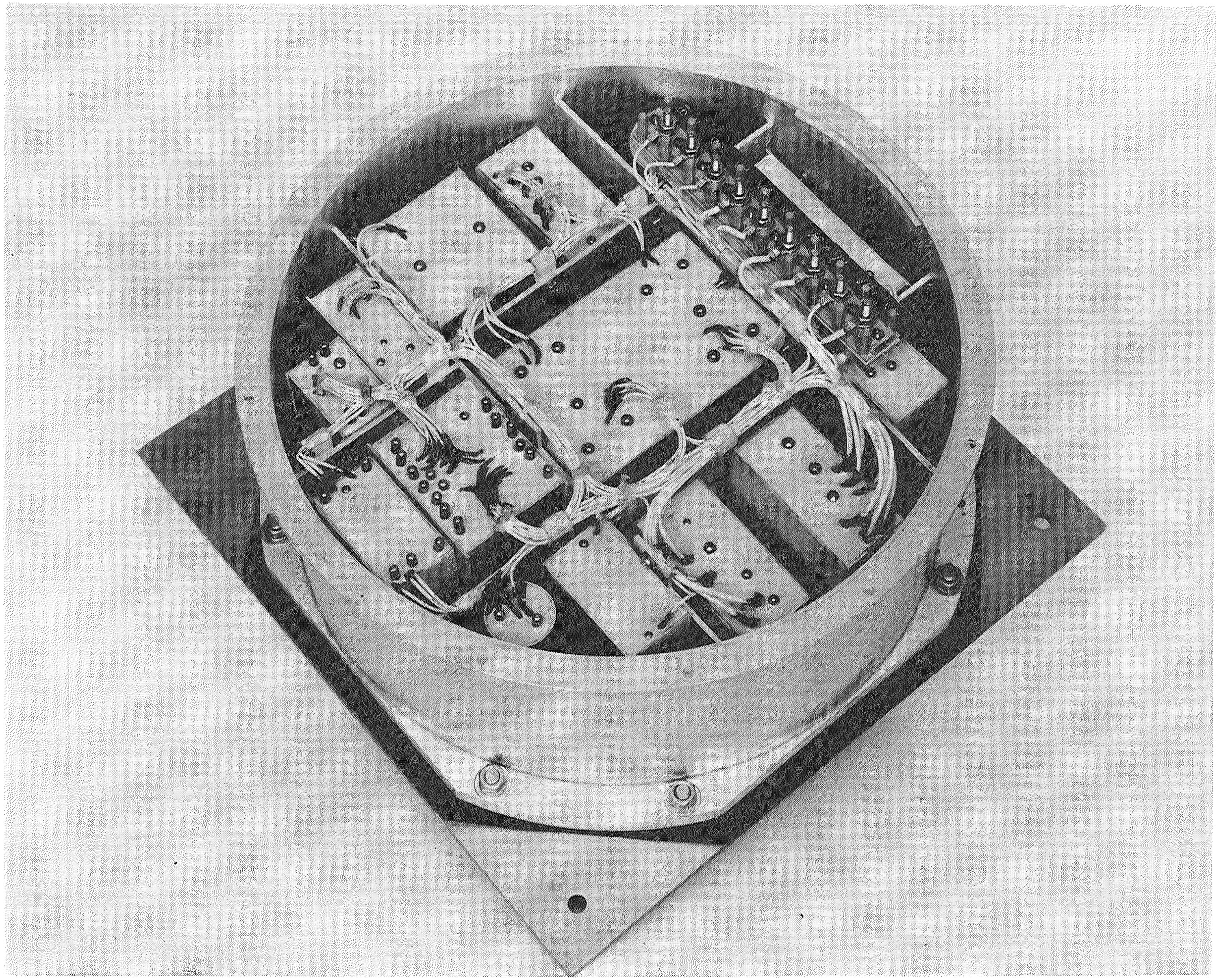


ARP ANTI-DRIVE END END SHIELD
FIGURE 13

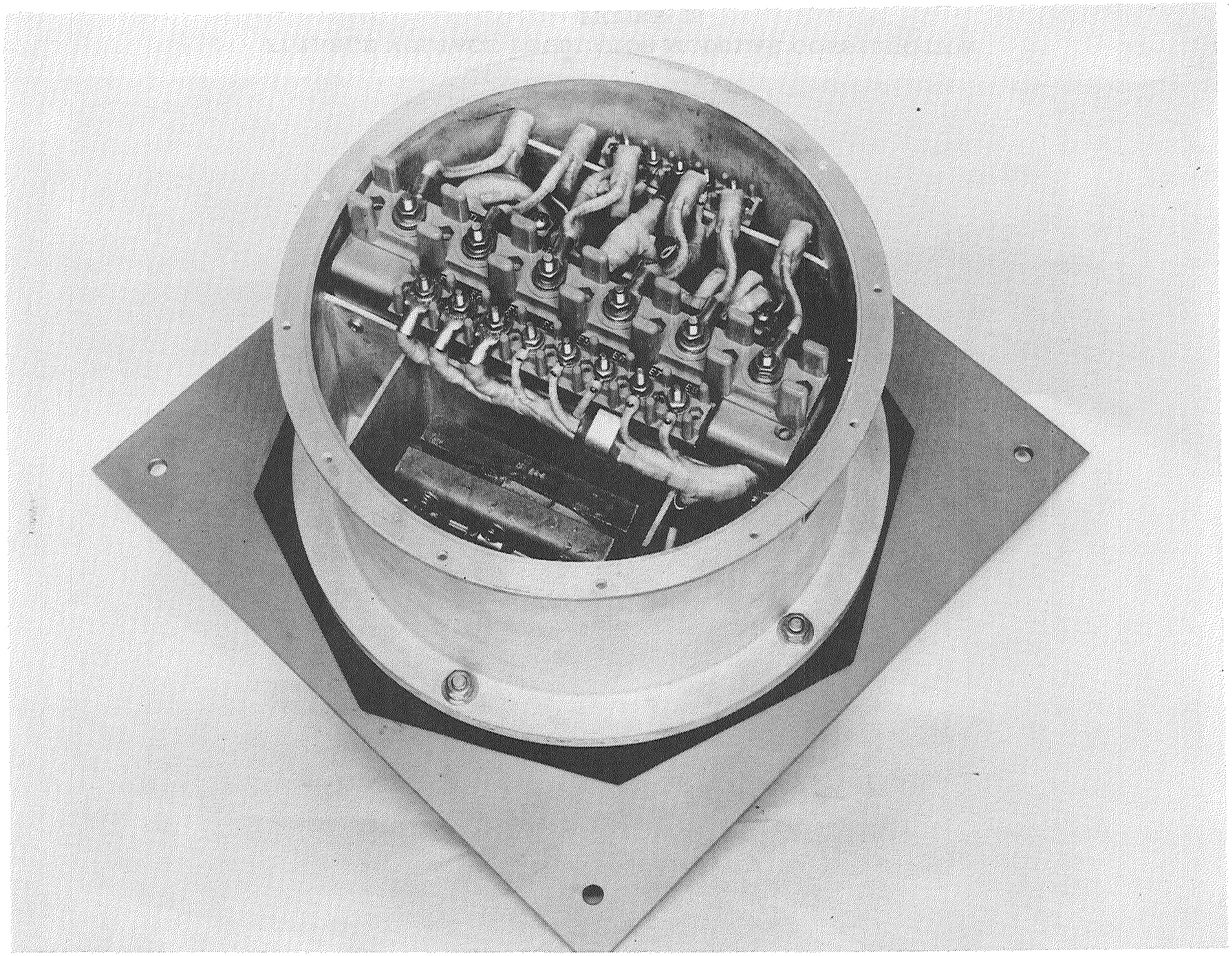


BREADBOARD VRE - REAR VIEW

FIGURE 14

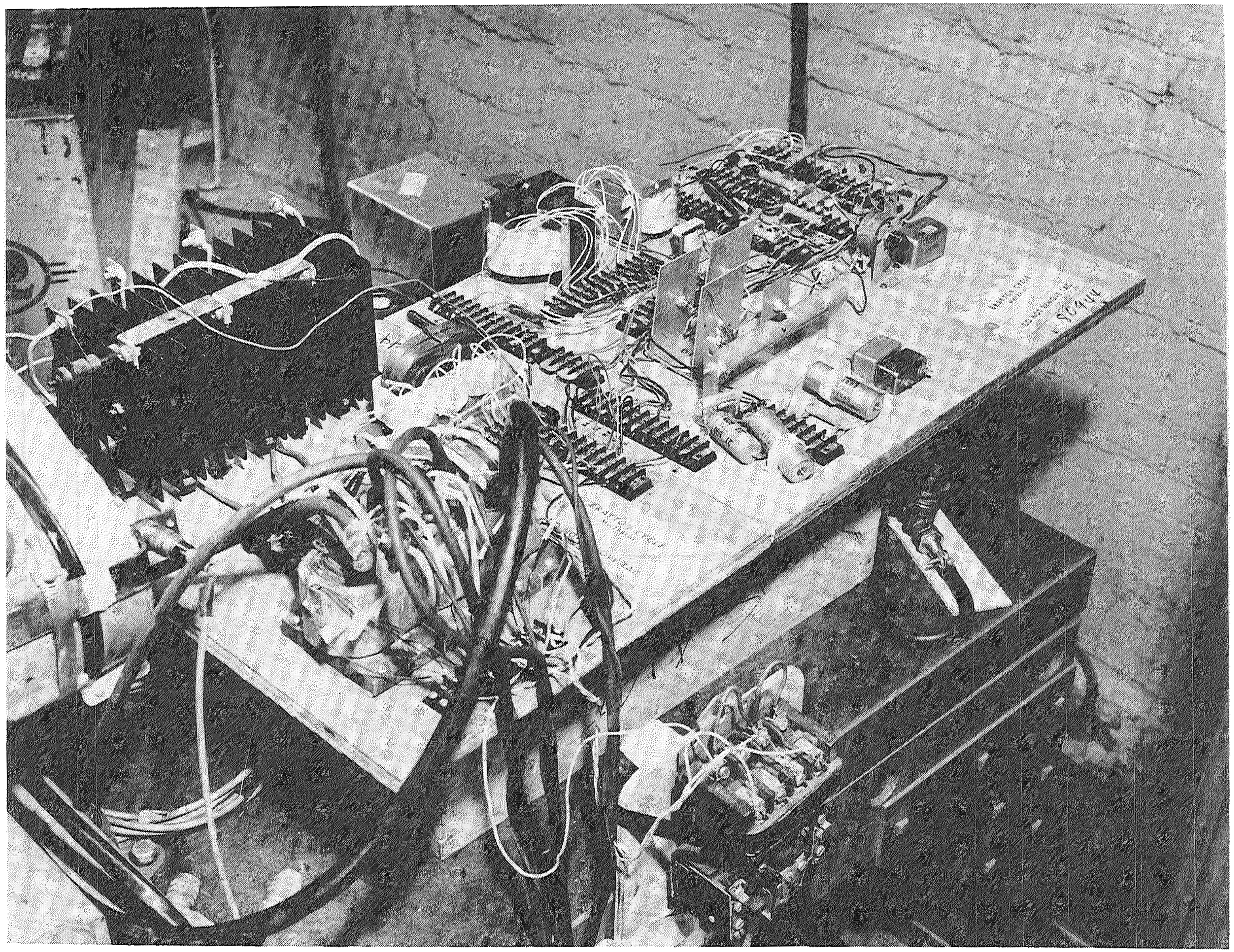


FLYABLE VOLTAGE REGULATOR MODULAR CONSTRUCTION
FIGURE 15



FLYABLE EXCITER SHOWING REACTOR - TRANSFORMER

FIGURE 16



ENGINEERING BREADBOARD VRE
FIGURE 17

BLOCK DIAGRAM OF ALTERNATOR RESEARCH PACKAGE

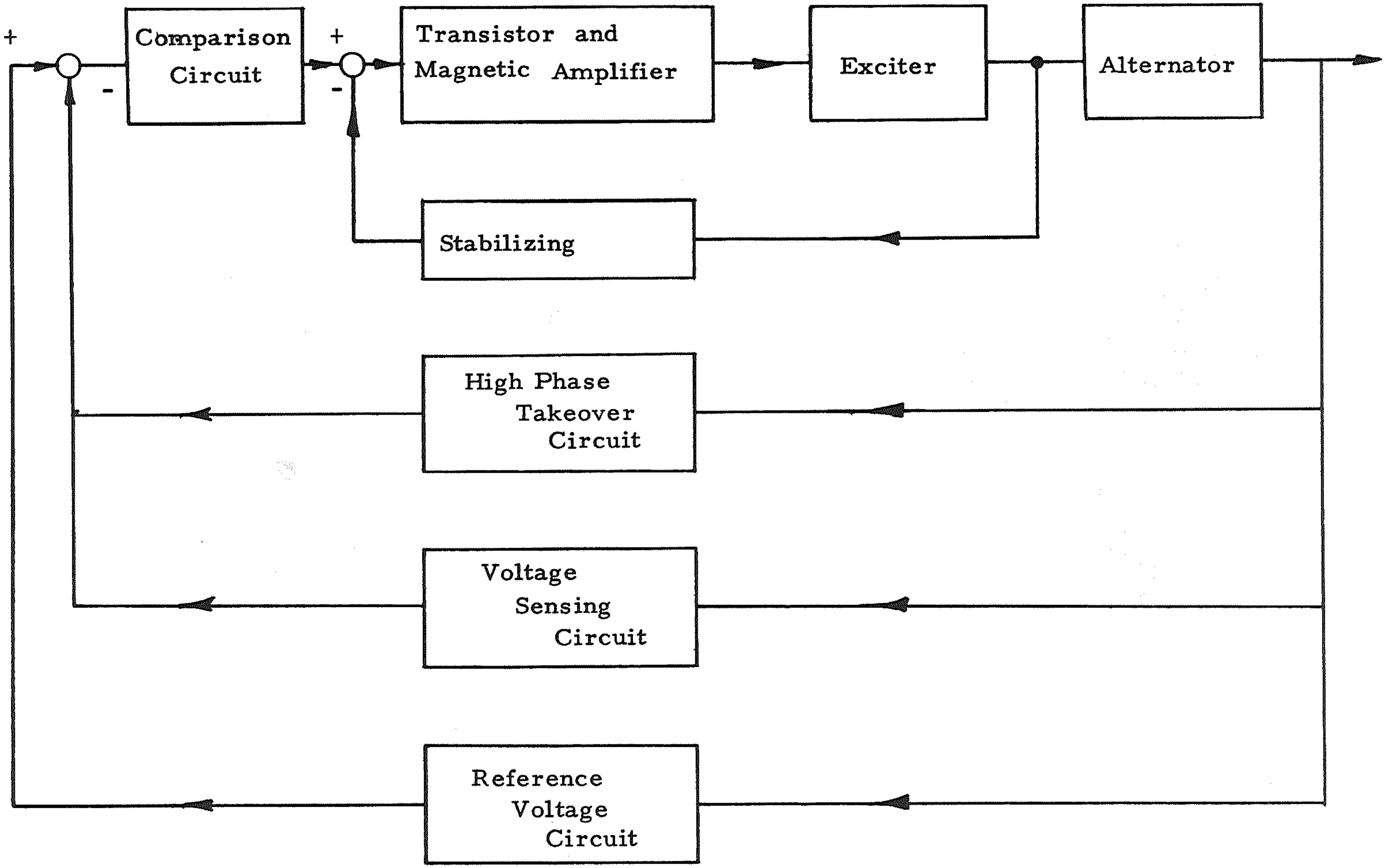


FIGURE 18

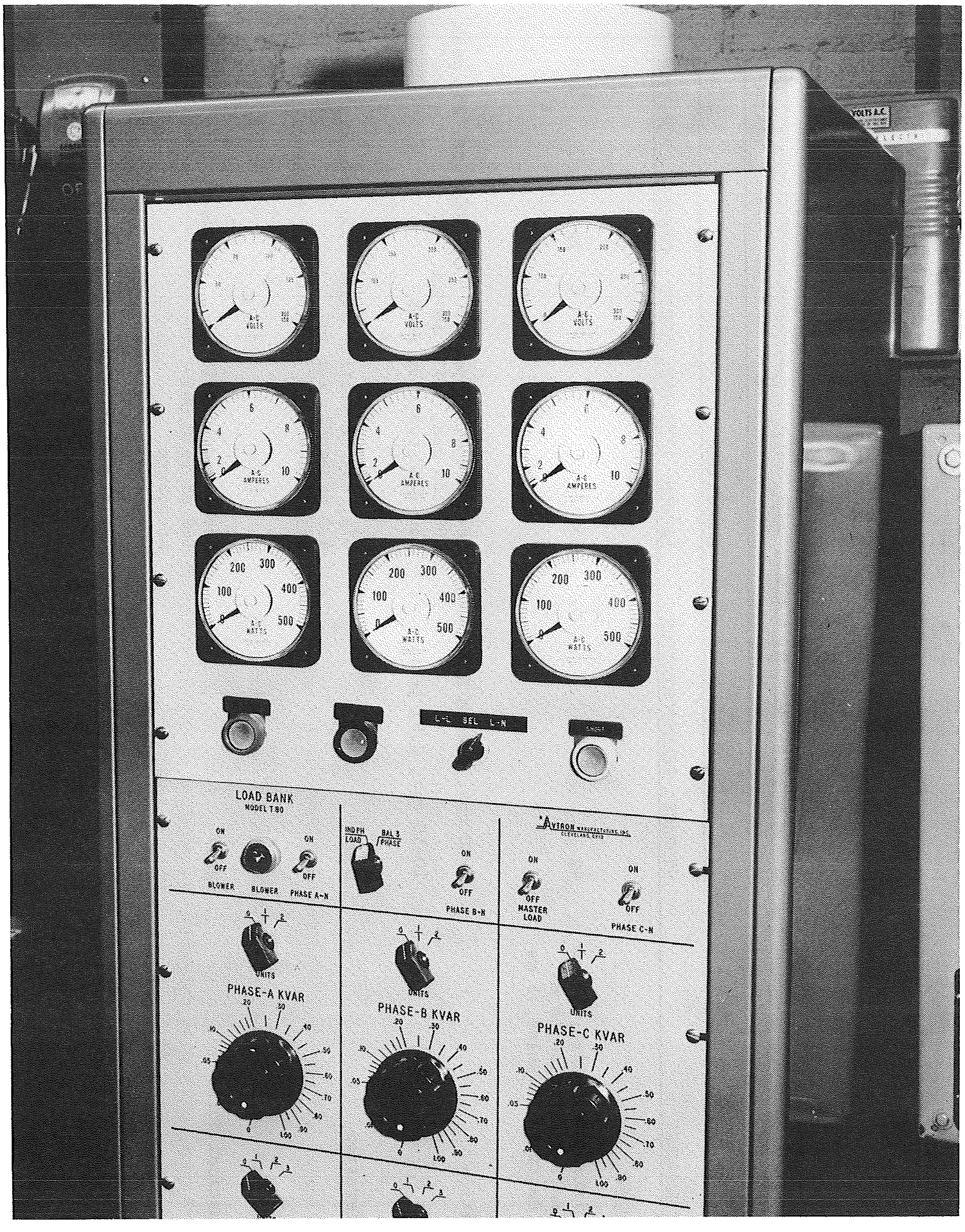


FIGURE 19
LOAD BANK

## TABLE I

## ENVIRONMENT SUMMARY

| | CONDITION | | |
|---|---|---|---|
| ENVIRONMENT | STORAGE; TRANSPORTATION | LAUNCH, LIFT-OFF, BOOST | ORBITAL OPERATION |
| Shock | | | |
| Triangular pulse, 10 ms | 4g | 35g | 7g |
| Half-sine pulse, 8 ms | | | |
| Rectangular pulse, 5 ms | | | |
| Vibration | 2-10 cps, 0.4 in D.A.<br>10-50 cps, 2.0g peak | 16-100 cps, 6g peak<br>100-180 cps, .0118 in D.A.<br>180-2000 cps, 19g peak | 5-2000 cps, 25g peak |
| Acceleration | None | +7g, -3g or vehicle axis 4.5 perpendicular to axis | 3.5g or vehicle axis<br>±1g perpendicular to axis |
| Accoustical Noise | None | Accoustical field of 148 db re 0.002 microbars | None |

## TABLE II

## ELECTRICAL PERFORMANCE SPECIFICATION SUMMARY

1. Voltage Regulation - The VRE shall regulate the steady state line-to-neutral voltage within ±1% of the nominal voltage when balanced load is varied from 10-100% of rated at rated power factor and frequency.

2. Voltage Adjustment - The line-to-neutral voltage shall be adjustable from 95% to 105% of the rated 120 volts in steps not exceeding 0.25%.

3. Frequency Effect - The VRE shall operate without discontinuity over the range 320 to 480 hertz.

4. Voltage Modulation - The voltage modulation shall not exceed 1% from 10%-100% load under all operating conditions.

5. Recovery Time - While operating at a line voltage of 120 ±0.5% volts, the voltage shall recover within 0.25 seconds to ±5% of the initial voltage with no sustained oscillations following application or removal of one per unit load at rated power factor.

6. Voltage Excursion - Upon removal of one per unit load while operating at rated temperature, the maximum excursion shall not be greater than 136.4% of the voltage prior to removal.

7. Short Circuit Capacity - The VRE shall furnish sufficient power to the alternator to enable it to deliver at least 3.0 per unit current into a three phase or a single phase line-to-neutral short circuit for a minimum of 5 seconds.

8. Overload - The VRE shall regulate the voltage within ±3% under the following overload conditions:

   a) 150 percent rated current at rated power factor for 2 minutes.

   b) 200 percent rated current at rated power factor for 5 seconds.

9. Voltage Drift - The voltage drift shall not exceed 1 volt at any fixed load for 10% load to full load in any 1000 hour period of continuous operation.

10. Electrical Interference - The VRE shall meet the electrical interference requirements of MIL-I-26600.

11. Wave Form - Paragraph 4.5.16 of MIL-G-6099A. In addition, the total RMS harmonic content of the voltage wave, when the alternator is operating into a linear load, shall be less than 7% when measured line-to-neutral at 1.0 P.F. load from 10% to 100% load.

12. Phase Balance - Paragraphs 4.5.10, 4.5.10.1, and 4.5.10.2 of MIL-G-6099A.

13. Output Voltage Modulation - Paragraph 4.5.13 of MIL-G-6099A.

TABLE II (continued)

14. Efficiency - The alternator efficiency shall be designed to be the maximum at an 11.25 KVA power output. As a design goal, this value of efficiency shall be 90% including rotor windage loss, but excluding bearing losses. Furthermore, the alternator shall be designed to maximize efficiency over a power range of 5 to 15 KVA.

# SECTION IV

## ALTERNATOR DESIGN

### A. Alternator Design Objectives

Design philosophy has been based on the following order of priorities:

1. Reliability
2. Efficiency
3. Power Quality
4. Weight

The choice of an inductor alternator was made primarily to achieve a high degree of reliability. This is possible with an inductor since an unwound rotor can be used and both the field and stator windings can be stationary. Disadvantages of the inductor are higher weight and less than optimum power quality but these have been sacrificed in accordance with the above priority system. Reliability has been further enhanced by derating a standard aircraft insulation system and employing state of the art materials and components.

Several design techniques were employed to obtain a high degree of efficiency. Both stationary and rotating baffles were used to decrease the windage loss and laminated pole tips were attached to the rotor hub as a means of reducing pole face losses. The laminated pole tips were electron beam welded to a solid rotor hub and this technique represented one of the significant manufacturing contributions of the program. Copper loss and core loss were held to a minimum by employing low current and flux densities. In addition, stranding the stator conductors and placing them flat in the slot reduced deep bar losses.

Inductor power quality was improved by use of an amortisseur winding which decreased the voltage unbalance under unbalanced load conditions. The very prominent third harmonic was eliminated by using a 2/3 pitch in the coil winding, but no attempts were made to reduce the stator slot harmonics since skewing of either the rotor or stator would probably decrease the reliability. The voltage overshoot or dip on the removal or application of one per unit load current was purposely designed to be just within the specification, and it along with the other power quality areas represent the best overall design. All of this is in accordance with the aforementioned priorities.

Since the generator was to operate on gas bearings, it was necessary that a low radial bearing force be achieved and thus a relatively large air gap and low gap flux density have been used. However, the method of calculating bearing force was somewhat in question since significant differences existed in the answers obtained from various methods. As a result, a bearing force program was initiated and is documented in Volume II of this report.

More detailed design philosophy covering design decisions and tradeoffs is given in the paragraphs below.

## 1. Electromagnetic design

### a. Stator slot design

The choice of stator slots is probably the most important design decision that must be made for it determines practically all of the machine parameters as well as its performance. Three slot combinations were evaluated, namely, 36, 48, and 60 slots. These slot combinations produce integral slots per pole for a four pole alternator and were deliberately chosen in order to avoid a fractional slot design. Fractional slots produce even harmonics in the armature reaction wave and result in very high pole face losses. Figure 27 shows a comparison between the slot combinations, but the most important parameters are bearing force, efficiency, and voltage rise which are reproduced below for the slot combinations.

| Slots | 36 | 48 | 60 |
|---|---|---|---|
| Bearing Force (#/mil) | 10.8 | 6.45 | 4.3 |
| Efficiency (%) |  | 91.3 | 90.7 |
| Voltage Rise (%) | 18 | 34 | 46.3 |

Bearing force is very important from a reliability standpoint since gas bearings will be used in the turboalternator. Notice how the bearing force decreases as the number of slots increase. A larger number of slots results in more turns in the stator winding and thus a lower flux density in the air gap for a given stator length. Since bearing force is proportional to the square of the flux density it naturally will decrease as slots increase. A larger number of slots, however, has a detrimental effect on both efficiency and power quality. Since more turns are in the stator winding copper loss increases and thus efficiency goes down. Machine reactance varies as the square of the stator turns, and thus increases for the larger slot designs resulting in higher voltage rises on removal of load. A glance at the data shows that a sixty slot design has little hope of meeting the specification on voltage rise of 36.4 percent and that the calculated efficiency is not much greater than the design goal of 90 percent. On the other hand, the 36 slot design results in quite a large bearing force but considerably better power quality. Based on the above reasoning, the 48 slot configuration was chosen since it offered the best overall design consistent with the priorities mentioned previously.

Since bearing forces play such a vital role in the reliability of the turboalternator they were calculated by four different means as shown in Figure 28 . Results varied significantly between authors but the larger values were used in the calculation. It was also assumed that the bearing force varied inversely proportional to the number of circuits in the machine and that saturation further reduced the bearing force. Due to the uncertainty of the calculations, a bearing force program was initiated by NASA to more fully understand the nature of these forces and in particular the time varient terms.

b. Air gap design

The air gap in the Brayton Cycle Alternator is relatively large for a 15 KVA machine operating at 12,000 rpm, but the following design criteria dictated a large gap:

1. Pole face losses
2. Bearing forces
3. Reactances

The air gap length has a very significant effect on both components of pole face losses; namely, the no load loss caused by the presence of stator teeth and the load loss resulting from the various harmonics in the armature reaction wave. Large air gaps result in high air gap reluctances and as a consequence smaller voltage induction in the pole face. Large air gaps also reduce the net magnetic unbalance since this force is proportional to the ratio of the rotor eccentricity to the air gap. In other words, a given amount of eccentricity has far less effect on a large air gap than on a small. The machine reactances are also affected by the gap and decrease as the gap increases thus improving power quality. Therefore, a large air gap improves all three of the above design criteria.

The main disadvantage of a large air gap is increased air gap ampere turns which can result in a very large field coil which in turn affects both the efficiency and the power quality of the machine. However, close attention to detail resulted in a good compromise and test results indicate that a proper choice of air gap (0.040") was made.

c. Conductor size design

Both the field and stator winding conductor size were dictated primarily by the amount of copper loss that was permissible for the specified efficiency. Other machine parameters that are important include the stator and field leakage reactances. Copper size determines the depth of the slot and also the depth of the field coil which in turn affects the leakage reactances. Therefore, copper size is a compromise between efficiency and power quality, but for the Brayton Cycle Alternator efficiency was given the highest priority.

The Brayton Cycle Alternator has 48 stator coils with each coil having four turns. Each turn is made up of two strands of .14 X .025 enameled polyimide wire. The conductor has been stranded and is placed flat in the slot in order to reduce the deep bar loss. A cross sectional view of one stator slot and the insulation system is shown in Figure 29.

The field coil conductor is made from .0571 inch diameter enameled polyimide round wire and consists of 520 turns. This conductor size was chosen as the best compromise between efficiency and power quality. Cross Sectional area of the coil is 1.1 inches by 2.2 inches and the amperes per square inch is approximately 2500 at full load. This compares with 3100 amperes per square inch in the stator conductors, both of which represent a drastic departure from standard aircraft practice where the amperes per square inch may be 8000 and up.

d. Rotor diameter design

The rotor diameter was dictated by the following three factors:

1. Windage loss
2. Axial flux in the rotor hub
3. Rotor pole saliency

Since windage losses vary at about the fifth power of the diameter, it was very important that the diameter be made as small as possible.

However, rotor axial flux and rotor pole saliency impose limitations on the amount by which the rotor diameter can be decreased. Sufficient area must be provided in the rotor hub section so that the inductor DC flux can be carried adequately without saturating this member. Output of an inductor alternator is affected by the amount of rotor saliency present which in turn is a function of the ratio of rotor slot depth to air gap length. This ratio should be maintained at about 25 to 1, and thus with a large air gap the rotor slot depth becomes deep and affects the rotor diameter. All of the above factors were taken into account in arriving at the rotor outside diameter of 5.2 inches.

e. Pole face loss design

Pole face losses in the rotor are caused by two components, the no load loss and the load loss. The no load loss is generated by the presence of stator teeth, and is a function of the stator slot opening and the air gap. The latter has been discussed in (b). If the stator slot opening is made large, it results in a large variation in flux density along the pole surface and increases the loss. Thus the slot opening was made as small as possible and became a function of the stator conductor wire size. It was set at .065 inches which permitted the passage of one conductor strand at a time.

The load pole face loss is caused by the harmonics existing in the armature reaction wave. These harmonics travel at a speed other than that of the rotor and thus produce losses in the pole faces. If a fractional slot design is used, even as well as odd harmonics exist. In particular, the second and fourth harmonics are usually very large and can cause severe pole face losses. Therefore, an integral slot per pole design was used in order to eliminate all even harmonics. Section VI shows output sheet from the computer run that calculated the load pole face loss. No-load pole face loss is calculated from an equation by Gibbs (Reference 3).

Total pole face loss is obtained by adding the no load loss to the load loss. Previous experience has shown that the test pole face losses are about double the calculated losses and therefore the Brayton Cycle calculated loss was doubled. The equations used for calculating the pole face loss are all based on a solid pole configuration. Since laminated pole tips were used, the solid pole tip loss was arbitrarily divided by three to obtain the final loss. This number is conservative since previous tests by General Electric on many machines indicated the ratio between solid and laminated losses to be greater. However, the area of pole face loss in both the calculation procedures and experimental methods leaves much to be desired and more work is definitely needed.

f. Machine parameters

A list of the various machine parameters, flux densities, and losses is given in Table IV.

2. Mechanical design

a. Rotor design

Initial design of the rotor envisioned the use of rotor punchings held in place on the solid rotor hub by either an interference fit, keying, or a combination of both. Such a design is easy to assemble and facilitates the placement of the amortisseur winding. However, since a yoke is needed to hold the punchings together, this particular design resulted in a greater rotor diameter and thus a greater windage loss. In order to retain the laminated pole tip structure and eliminate the rotor yoke, the pole tips were electron beam welded onto the solid rotor hub. A full report on the development of this technique is given in Section VIII, but in brief the manufacturing procedure is as follows:

1. Stack the punchings and lay a sealant weld on the surface to be electron beam welded.
2. Machine the sealant weld to a final dimension.
3. Place the pole tip on the rotor and electron beam weld.

A sealant weld is necessary on the bottom of the pole tips in order to keep the silicone and oxide of the electrical sheet steel from penetrating into the electron beam welded area. If this should happen, gas bubbles result and the weld is filled with porosity. The electron beam can penetrate about 1 and 1/4 inches and therefore two passes are needed in order to weld the two inch pole face to the rotor. Integrity of weld is determined by X-raying at 90 degree angles in order to determine the amount of porosity present. Some porosity always exists, but if it is small in size and well distributed, the weld is acceptable. A further check on weld integrity was done by spin testing the rotor at 20,000 rpm and at a temperature of 500 degrees F. Figure 31 shows the turboalternator rotor and laminated pole tips prior to electron beam welding.

The amortisseur bars and copper end plates are made from zirconium copper in order to reduce the creep over the 10,000 hour life. Zirconium copper at 300 C has a creep stress of approximately 35,000 psi. The amortisseur bars are welded to the copper end plate and then this subassembly machined prior to fitting of the stainless steel retainers. Retainers must be used in order to keep the copper end punchings from moving outward due to centrifugal force. On the outboard ends of the rotor, the retainers also act act as windage baffles and are made from Type 321 stainless steel so as to decrease the flux leakage from stator to rotor. The retainers are held in place by a rivet through each pole whose ends are welded to the retainers. Further support is afforded by welding the retainers directly to the rotor structure.

### b. Stator mechanical design

#### (1) Core construction

The stator cores are made from .007 inch electrical sheet steel because this particular steel has a very low core loss per pound. The stator slot is overhung to keep no load pole face loss to a minimum. The stator cores are held together by six equally spaced welds around the outer diameter of the core. These welds are supplemented by six additional bars also equally spaced and welded to the end of each core. The cores are then placed in Novolac insulation compound which penetrates between the laminations and acts as additional interlaminer insulation and also as a bonding agent. When the Novolac compound is cured, the result is a very firm and sturdy core. Insulation punchings are bonded to the end of the stator cores to prevent damage to the stator winding as it exits from the core and begins its bend. The stator cores also have a steel ring attached near the outer diameter which is used to weld the core to the inside of the stator frame.

#### (2) Field coil

Field coil construction begins with a spun copper can into which round enameled polyimide wire is wound. Before winding, polyimide glass insulation is placed on the inside of the can to insulate the field wire from ground. The coil is wound in two (2) parts as shown in Figure 30, and polyimide glass insulation placed between the two coil halves. This method of winding allows both ends of the field coil to exit at the top and eliminates the need to bring one of the leads up the side of the coil. The coil is wound using epoxy insulation which is then baked and cured. After the winding is in place, insulation is wrapped around the outer diameter of the coil and the ends of the copper can are bent inward. In order to provide good heat transfer to the frame inner diameter, copper wire is wound on the coil outer diameter and held firmly in place by a high temperature solder. One layer of copper wire is laid at a time and then the diameter machined flat permitting the next layer to be wound in a very precise manner. Enough copper is laid on the field coil until the finish dimension is reached. This dimension is about 4 mils less than that of the frame inner diameter and allows for differential expansion between the copper and the ingot iron frame. At operating temperatures, the field coil expands more than the frame and is held firmly in position against the frame providing an excellent heat transfer path for the field coil watts. A finished field coil is shown in Figure 32. Figure 30 also shows the field coil insulation system.

(3) Stator winding

The stator winding consists of twelve groups of coils, each group containing four coils. A picture of one of these groups is shown in Figure 33. The coil differs from the conventional diamond shaped coil in that no twist occurs on either end of the winding, and the rectangular wire is placed flat in the slot rather than standing on end. Such an arrangement keeps deep bar losses to a minimum and increases the efficiency of the machine.

The coils are inserted into the slots from the bore of the machine strand by strand. In order to insert the strand through the .065 inch slot opening the strand is bent slightly, inserted, and then rebent to its original position. This process is somewhat time consuming but worked very well in manufacturing.

After the coils are inserted, they are immediately impregnated with Novolac epoxy which serves as both a mechanical support and also as a heat transfer agent. The stator insulation system is given in Figure 29.

Before the stator winding is inserted, the field coil and stator cores are assembled into a dummy frame as shown in Figure 34. A dummy frame rather than the actual frame is used since coil insertion is greatly facilitated. After the winding is complete, the stator core and field coil assembly is placed on an arbor, the dummy frame removed, and the outside diameter of the cores finished. A photograph of the finished assembly is shown in Figure 35.

(4) Coolant passages

The alternator is cooled by a liquid that flows in ten circumferential paths machined into the outer diameter of the frame. Coolant flow enters a large header and is distributed equally into five of the circumferential grooves. The coolant flow splits into two paths on entering each groove with each path comprising 1/2 of the frame circumference. The paths meet 180° around the machine and the coolant exits into another header where it is carried axially to the next five circumferential grooves. Here the coolant again splits into two paths and eventually comes together and exits at the exit header. An outline of the coolant system and the calculated pressure drop is shown in Figure 36

The coolant paths are enclosed by an inconel shroud which has an interference fit of 3 to 4 mils with the frame. Inconel was chosen since its coefficient of expansion very nearly equals that of the ingot iron frame, and also because it has very good corrosion resistance. The headers are made from stainless Type 304 and are welded to the Inconel shroud. Corrosion of the coolant grooves in the ingot iron frame is prevented by a nickel plating of the grooves. This is done by the Kanigen* process and was chosen because it creates a very uniform plating on the surface and thus requires no machining after plating. The shroud and nickel coated frame are shown in Figure 37 and as assembled in Figure 38

(5) Frame flanges

The frame flanges are made from 4140 steel and were welded to the ingot iron frame. The flange material is different from the frame since a Rockwell C-26 hardness was required on the rabbets and faces of the flange to prevent wearing. The hardness is obtained by heating the 4140 to about 1600°F and then allowing it to air cool. During the manufacturing stage, weld porosity was a continuing problem in the frame-flange weld. Each weld required several attempts before a porosity free weld was obtained. The drive end flange is welded to the ingot iron frame before the coolant grooves are machined. However, the anti drive end flange must be welded to the frame after the shroud assembly has been shrunk in place and welded to the frame. Weld problems were also encountered in making the Inconel shroud to ingot iron frame weld in that cracking occurred during the welding process. This was finally traced to a prestress in the Inconel shroud and was eliminated on later units by annealing the shroud prior to welding. The above problems are covered in more detail in Paragraph C of this Section.

(6) Terminal configuration

After the frame shroud assembly is complete, the stator winding

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*Trademark of General American Transportation Corporation is removed from the dummy frame and shrunk into this assembly. The stator cores are tack welded to the frame and the power leads welded to the coil connections. These power leads are also welded to hermetic terminals which in turn are welded to the frame. Since the alternator must operate at a pressure less than atmospheric, hermetic sealing is required. In order to preserve the integrity of this seal, a second series of terminals is provided to which load leads can be connected. Connections between the so called "stand-off" terminals and the hermetic terminals are made by two #10 braided copper wires which provide the required amount of flexibility. The terminal configuration is protected by steel plates and covers. A gang channel is also provided on the inside of one of these protective plates so that the stator can be attached to the end shield without using wrenches or other tools near the hermetic terminals. Figure 39 shows the terminal configuration.

(7) Machining tolerances and concentricities

The stator tolerances on rabbet diameters are held to 0.0004" and on the bore diameter to 0.002". Concentricity between the frame rabbets and the stator bore must be 0.001" TIR. Such tight tolerances and concentricities are achieved by machining and grinding the stator bore, rabbets, and flange faces after all windings and connections are in place or have been made. In order to prevent metal chips from being embedded in the winding, the entire stator winding is incased in wax prior to any metal working operations. After the machining is finished, the wax is cleaned and melted out at a very low temperature and then the entire stator wound cleaned in an ultrasonic cleaner.

(c) End Shields

Each end shield is made from a single piece of stainless Type 304 steel. The end shields must be made from nonmagnetic material in order not to short circuit the flux path across the air gap. Stainless Type 304 was chosen since it has relatively good welding properties. During the manufacturing process, holes are drilled into the end shield to serve as oil channels or breather holes. In some cases, these must be plugged with stainless steel plugs and then welded. Thus the need for a good weldable stainless steel. The bearing cavity breather passages and the oil passages all exit through Conoseal flanges which are welded into the end shield. This type of flange provides a good reliable connection between the machine and any connecting tubing. The frame rabbet of the end shield and the bearing housing inner diameter are held to .0005 inches TIR. Pictures of the drive-end and anti-drive end end shields are shown in Figures 12 and 13 of Section IV.

(d) Bearing and Seal Design

The ARP utilizes two Conrad Type 203 bearings and three face type rotating seals. Two of these seals are located on the drive end and the third is on the inboard side of the anti-drive end. Oil is supplied to the drive end bearing on its outboard side by a 0.030 inch jet opening. Another jet opening of 0.030 inches is also provided on the inboard side in order to cool the inboard seal. Oil exits from the bearing cavity by gravity into a chamber which is 150 times the area of the jets. The anti drive end bearing is lubricated by a 0.042 inch jet on the inboard side. The outboard side of this bearing is capped and sealed and oil exits from this bearing in a manner similar to the drive end. A pressure of 15 psi applied to either bearing will provide approximately 1 pound per minute of flow to each bearing if 7808 oil is used. An indication of bearing temperatures is provided by thermocouples located in the bearing and seal cartridges. These are shown in Figures 40 and 41 which also shows the bearing and seal configuration. An axial preload of about 25 pounds is provided by using shims and a wavy washer. The wavy washer is placed on the drive end bearing which is free to float axially whereas the anti-drive end bearing is locked firmly in place.

### e. Alternator Assembly

A special assembly fixture was made for assembling the ARP. The rotor is first placed in this assembly fixture and then the anti-drive end end shield put in place. Seal, bearing, and cap are then assembled into the anti-drive end end shield and the cap bolted firmly. The rotor end shield assembly is then removed from the fixture and placed into the stator frame and bolted. After placing wedges between the rotor and the stator bore, this assembly is turned on end and then the drive-end end shield attached. Final assembly includes placement of the inboard seal bearing and then the outboard seal. Details of the complete assembly process are given in Engineering Instruction 718A303JF which is included in Section VIII of this report.

## 3. Thermal Design

### a. Stator and field coil temperature calculations

The stator and field coil temperatures were determined by using a lumped parameter system and setting up an equivalent thermal circuit for the system. Figure 42 gives the results of the temperature calculation which is given in detail in the design calculations and analysis portion of this section. This detailed calculation also includes a thermal analysis of the coolant system. The stator and field temperatures are well below the specified limit of 180°C. Test temperatures are also shown in Figure 42 and compare reasonably well with calculations. Since the thermocouples were electrically insulated from the actual copper, they should read somewhat lower than the copper itself.

### b. Air Gap and Rotor Temperature Calculations

These temperature calculations were also done by using a lumped parameter system and the results are given in Figure 43. A complete detailed analysis is given later in this section.

## 4. Manufacturing Problems

### a. Stator winding

During construction of the In-House ARP, a phase to phase winding failure occurred in the slots of the machine. This failure was traced to coil damage during the forming process and to contamination resulting from the connection welding process. Corrective action included polishing the coil winding fixture and changing the stator winding process to incorporate impregnation of the slots immediately following the coil insertion. This latter action prevented any of the water-alcohol mixture used in the welding operation from flowing into the slots, carrying with it possible contaminants. Epoxy was also placed at the point where the stator coils exit from the stator core so as to seal the stator slots from any contamination. The epoxy placed between the stator cores serves this function on the inboard side. An additional .003 inches of polyimide film insulation was also placed around one of the coils to provide additional phase to phase insulation protection.

### b. Frame-Flange weld

As mentioned previously, problems in the form of porosity occurred in the 4140 to ingot iron weld. The quality of weld here is specified as Standard #1 of MIL-R-11468 and was specified as such to provide a very high degree of reliability. Since the weld is fairly thick (3/4 inch) it is difficult to achieve the porosity free weld on the first attempt. Both machine welding and hand welding were investigated and it was determined that hand welding gave the better results. However, initial X-rays usually indicate some degree of porosity which must be removed by either grinding or machining and then re-welding. This technique must be repeated as many times as it is required to eliminate the porosity from the weld. As a result, the manufacturing cycle on the frames is long forcing these components to become the critical item in the overall manufacturing process.

### c. Shroud-frame weld

Considerable difficulty was encountered in achieving a good weld between the Inconel shroud and the frame. The problem was traced to a prestress existing in the shroud. Very successful welds were obtained by annealing the shrouds prior to welding.

### d. Electron Beam Welding of Laminated Pole Tips

Problems experienced with electron beam welding of laminated pole tips to a solid rotor are covered in Appendix B.

## PRELIMINARY DESIGN

## TRADE-OFF DATA

| Slots | 60 | 48 | 36 |
|---|---|---|---|
| Rotor O.D. | 5.2" | 5.2" | 5.2" |
| Gap | .04" | .04" | .04" |
| Height of Iron | 3.9" | 3.9" | 3.9" |
| Stack Separation | 2.5" | 2.0" | 2.0" |
| A - RELIABILITY CONSIDERATIONS: | | | |
| Rotor Wt - Electromagnetic (Pounds) | 17.1 | 17.1 | 17.1 |
| Air Gap Density (Kilolines/in$^2$) | 40.6 | 49.3 | 64.5 |
| Bearing Force (Pounds/mil) | 4.3 | 6.45 | 10.8 |
| Stator Amps/Ins$^2$ | 3130 | 3130 | 3130 |
| Field Amps/Ins$^2$ | 3910 | 3750 | 4120 |
| B - EFFICIENCY: | 90.7% | 91.3% | - |
| C - POWER QUALITY ( REACTANCES IN PER UNIT): | | | |
| $X_f$ | .72 | .577 | .325 |
| $X_{ad}$ | 1.44 | .964 | .524 |
| $X_{aq}$ | .90 | .600 | .328 |
| $X_a$ | .14 | .0945 | .0636 |
| $X'_d$ | .62 | .456 | .264 |
| $X_2$ | ---- | .163 | ---- |
| Voltage Rise | 46.3% | 34% | 18% |
| D - TOTAL WEIGHT | | | |
| EM (Pounds) | 63.4 | 64.5 | 64.5 |

FIGURE 27

## BEARING FORCE CALCULATION

48 Slot Design          120 Volt Point

| METHOD | Force (#/mil.) (Unsaturated) |
|---|---|
| CENTURIONI (Ansaldo - San Giorgie Bulletin) | 16.1 |
| BEADLE (G.E. DF50MG-110) | 18.9 |
| COVO (Westinghouse AIEE 54-413) | 7.5 |
| PICOZZI (G.E. DF57M140) | 9.33 |

Use average of larger values

$$F = \frac{16.1 + 18.9}{2} = 17.45 \text{ \#/mil.} \quad \text{(Unsaturated)}$$

$$F \propto \frac{1}{N} \quad \frac{\text{Saturation Curve Slope} \begin{bmatrix}\text{Stator Teeth} \\ \text{+ Rotor Teeth} \\ \text{+ Air Gap Only}\end{bmatrix}}{\text{Air Gap Line Slope}}$$

$$F = \frac{17.45 * .74}{2} = 6.45 \text{ \#/mil.}$$

FIGURE 28

## PARTS LIST

| Item | Name | Size | Material |
|---|---|---|---|
| 1 | Slot Coil | .003" | Polyimide film |
| 2 | Separator | .015" | Silicone Glass |
| 3 | Conductor | 0.14 X .025" | Polyimide Enamel |
| 4 | Slot Liner | 2 - 0.0055" | Polyimide film |
| 5 | Topstick | 0.050" | Formed Polyimide |
| 6 | Sleeving | .040" Dia | Unsaturated Fiberglass |
| 7 | Binding Wire | AWG 14 | Copper |
| 8 | Ground Insulation | 2 - 0.0055" | Polyimide Glass |
| 9 | Banding | 0.006" | Copper |
| 10 | Insulation | 0.0055" | Polyimide Glass |
| 11 | Grommet | | Silicone Glass |
| 12 | Coil Separator Insulation | 0.010" | Polyimide Glass |
| 13 | Coil Box | 0.030" | Copper |
| 14 | Conductor | .0571" | Polyimide Enamel |

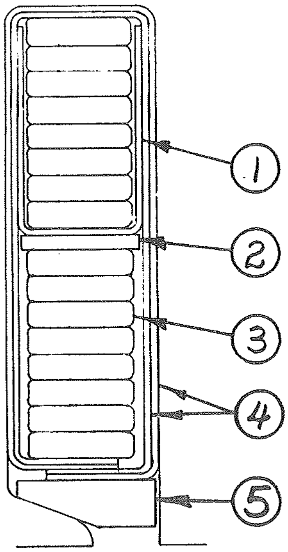


FIGURE 29

STATOR SLOT
(CROSS SECTION)

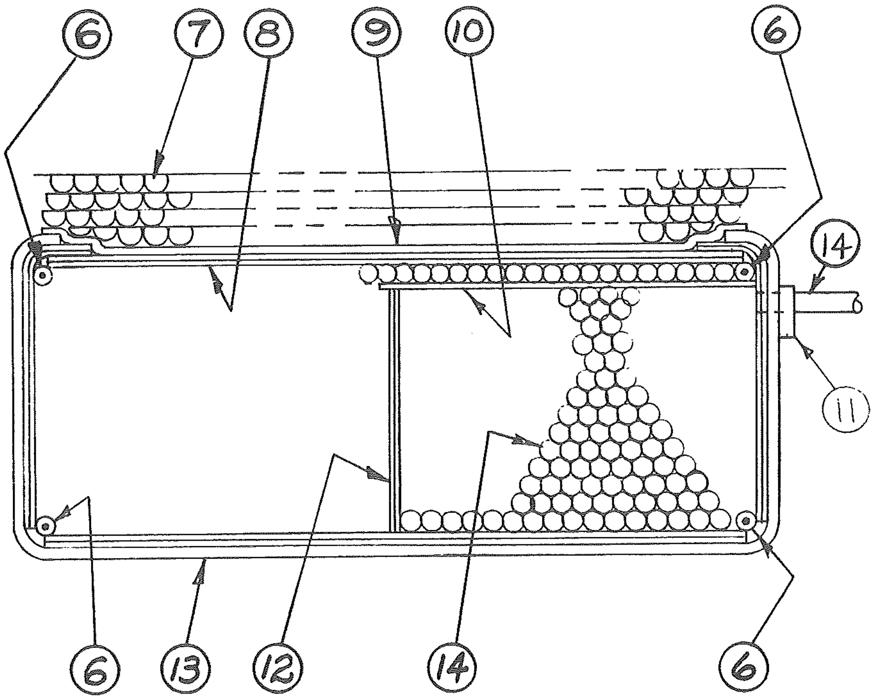


FIGURE 30

FIELD COIL (CROSS SECTION)

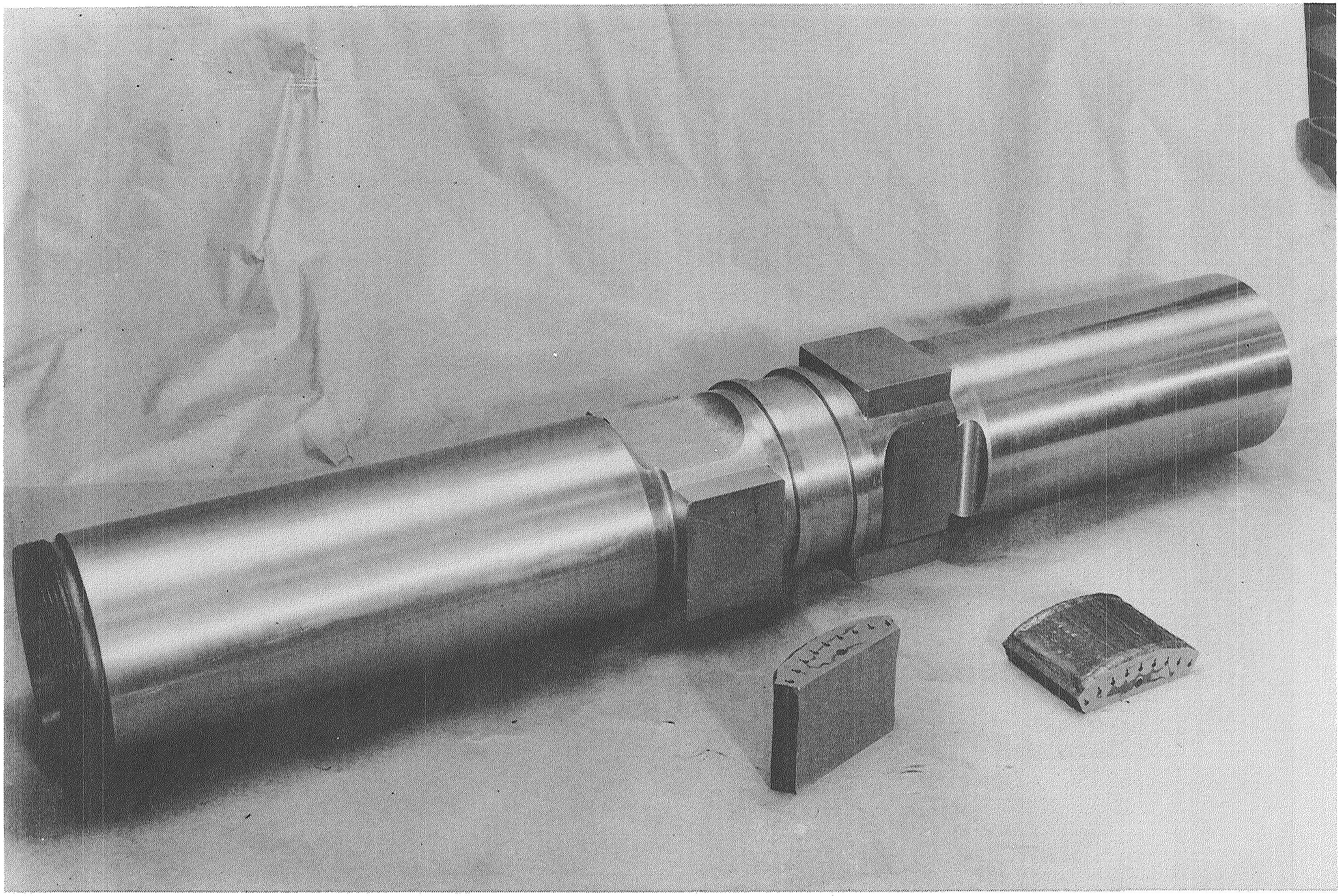
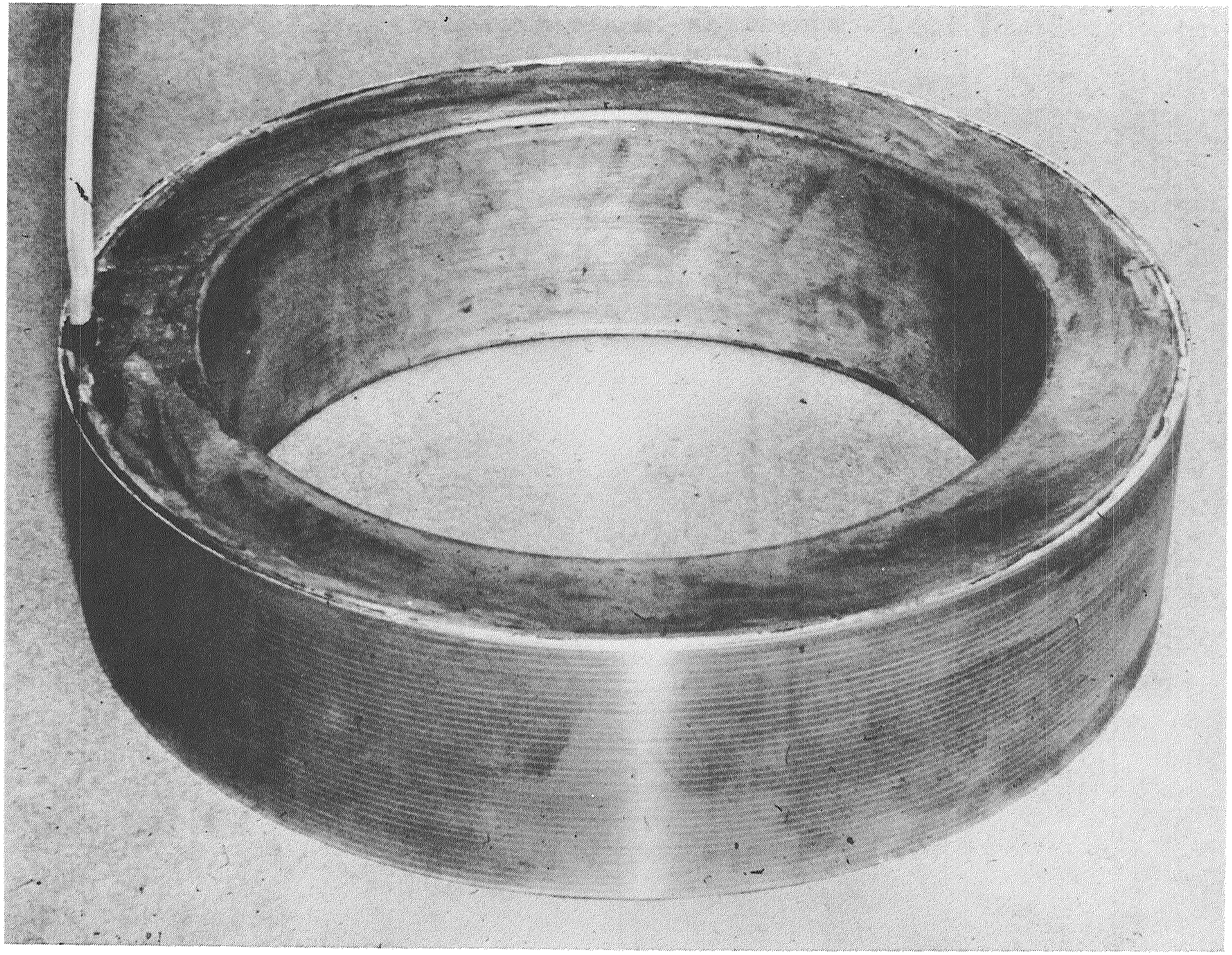


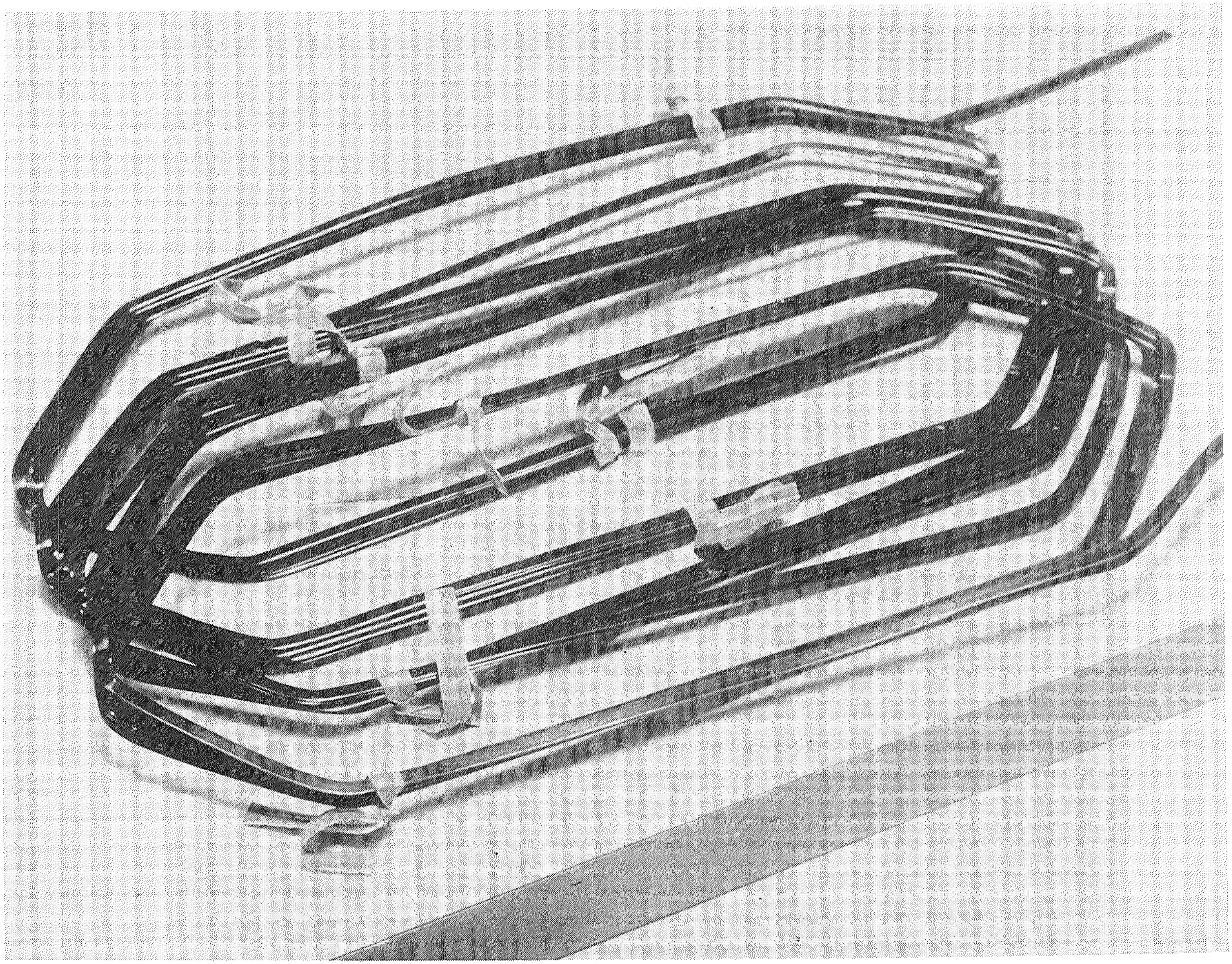
FIGURE 31

**ROTOR - ROUGH MACHINED - AND POLE PIECES**

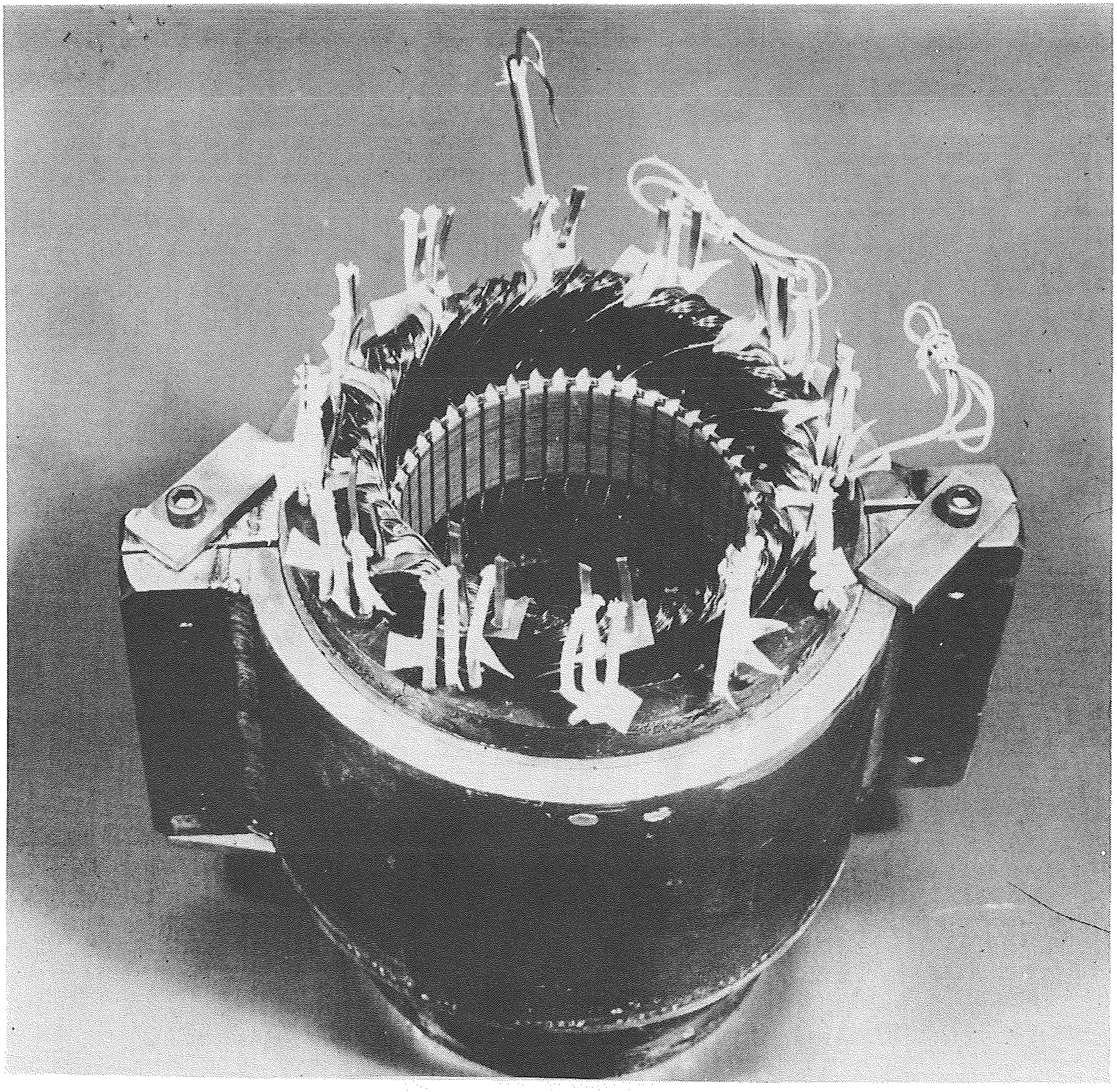


FIELD COIL

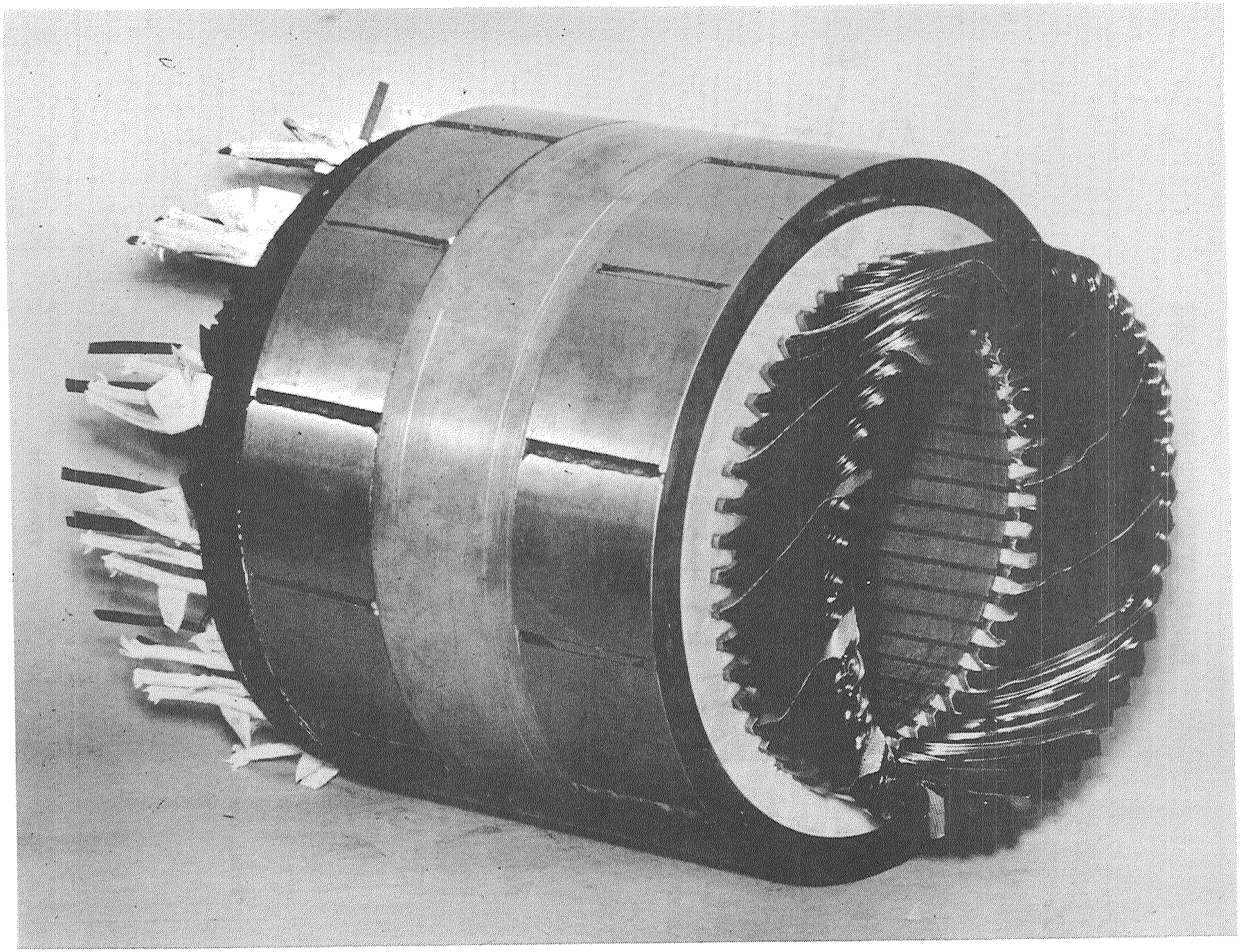
FIGURE 32



STATOR COIL GROUP
FIGURE 33



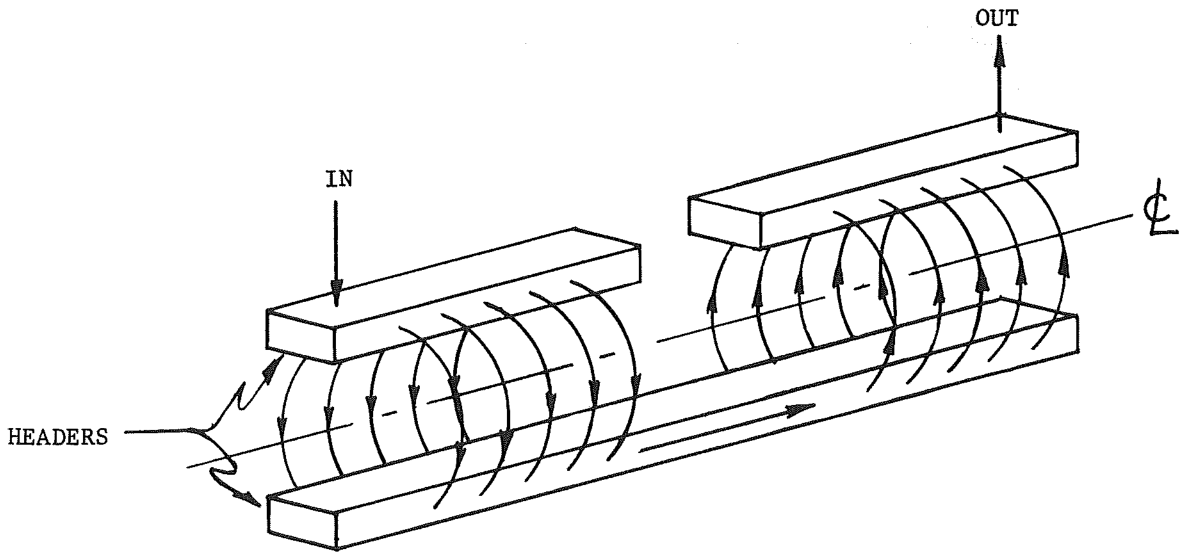
STATOR IN DUMMY FRAME FOR WINDING
FIGURE 34



STATOR WOUND ASSEMBLY
FIGURE 35

## COOLANT SYSTEM AND PRESSURE DROP

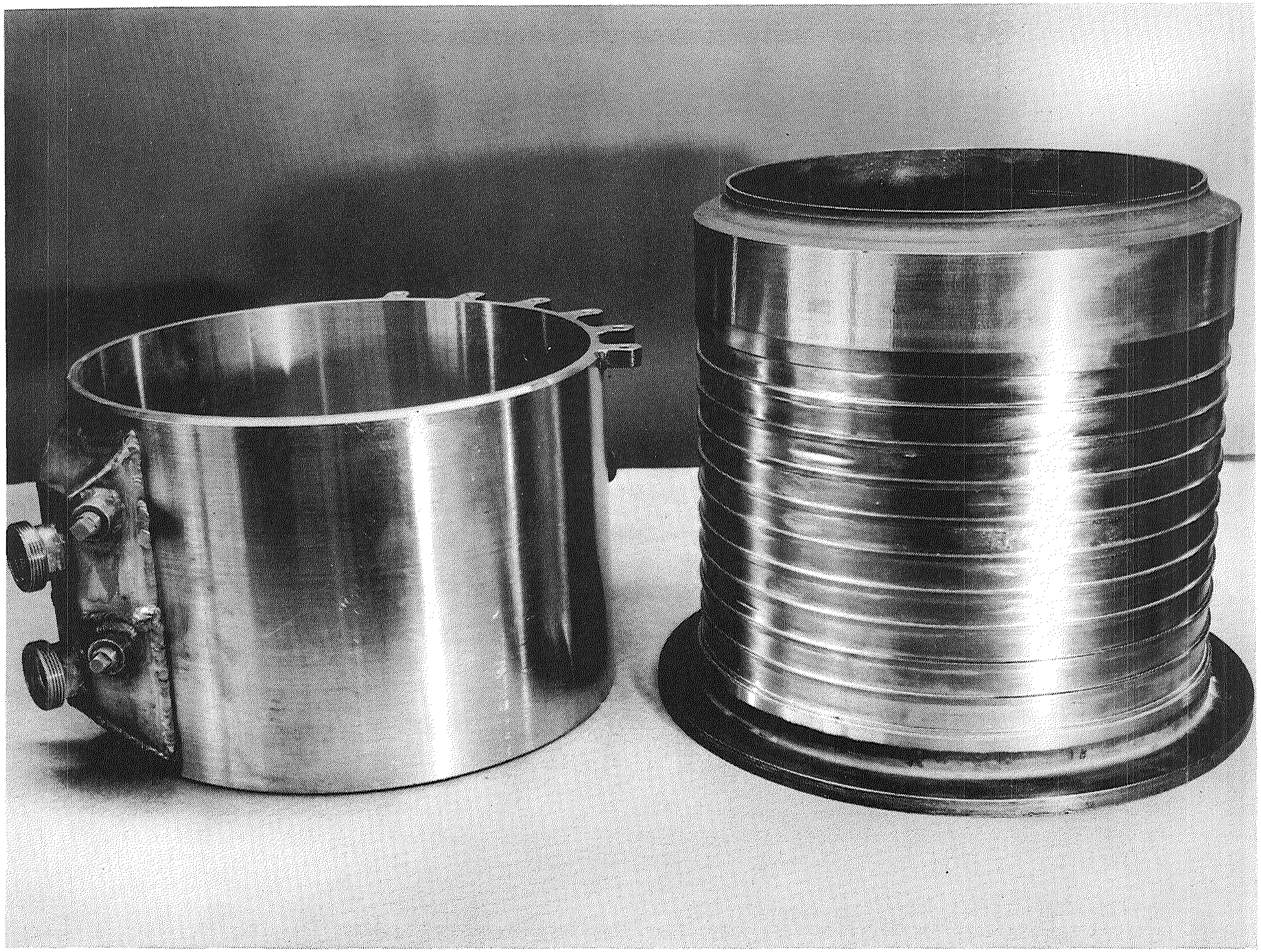
(Based on Versilube F-50)



Pressure drop breakdown (Flow rate = 10 lb/min.)

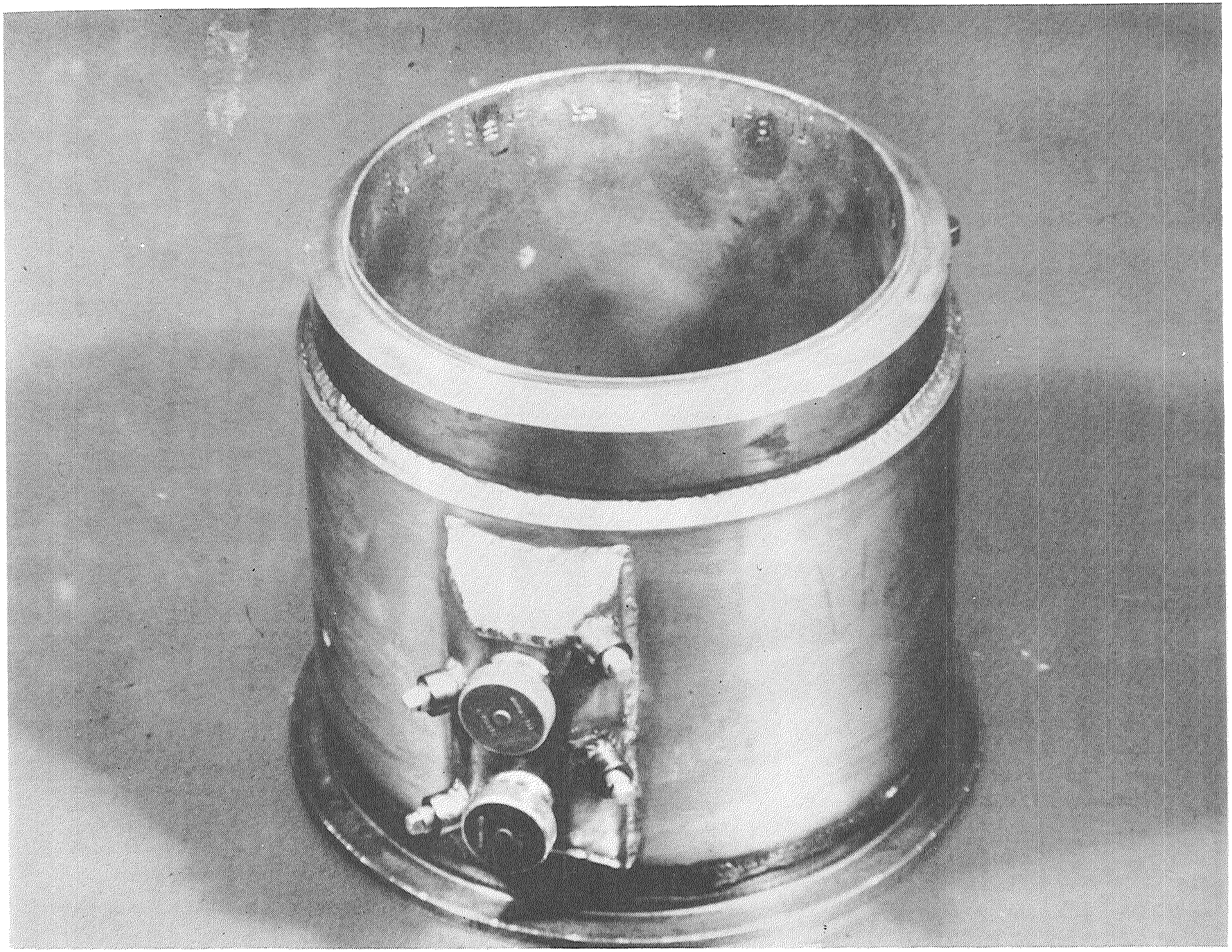
| | |
|---|---|
| Viscous drop in slots | 6.0800 psi |
| Viscous drop in header | negligible |
| Dynamic drops | |
| Entrance | .0750 psi |
| Turn & acceleration into header (2) | negligible |
| Entrance to 1/4" diameter holes (2) | .0508 psi |
| Entrance & turn into cooling passage (2) | .0968 psi |
| Turn & exit into header (2) | negligible |
| Exit from last header | .0744 psi |
| Total pressure drop | 6.377 psi |

FIGURE 36



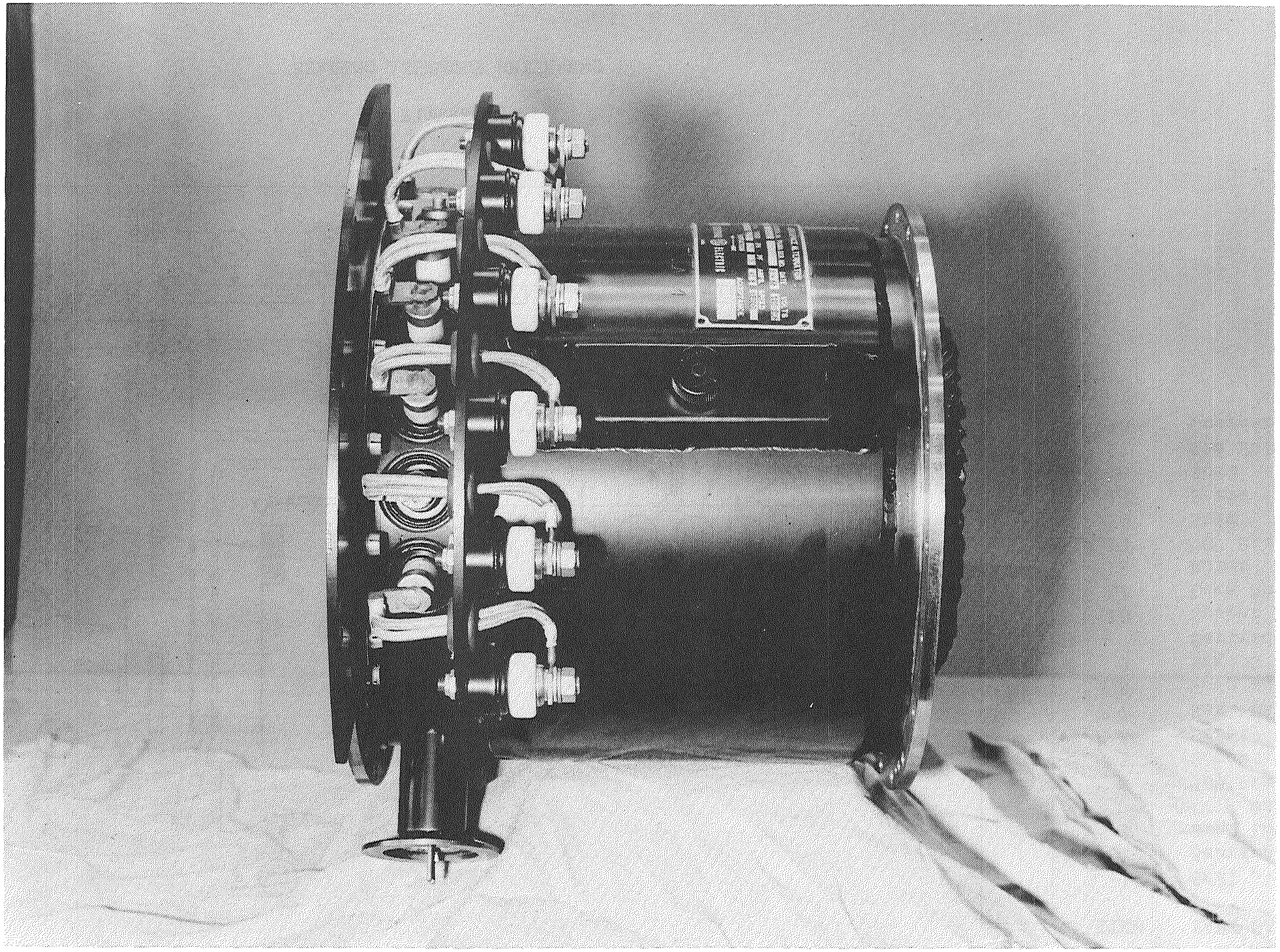
SHROUD AND FRAME

FIGURE 37

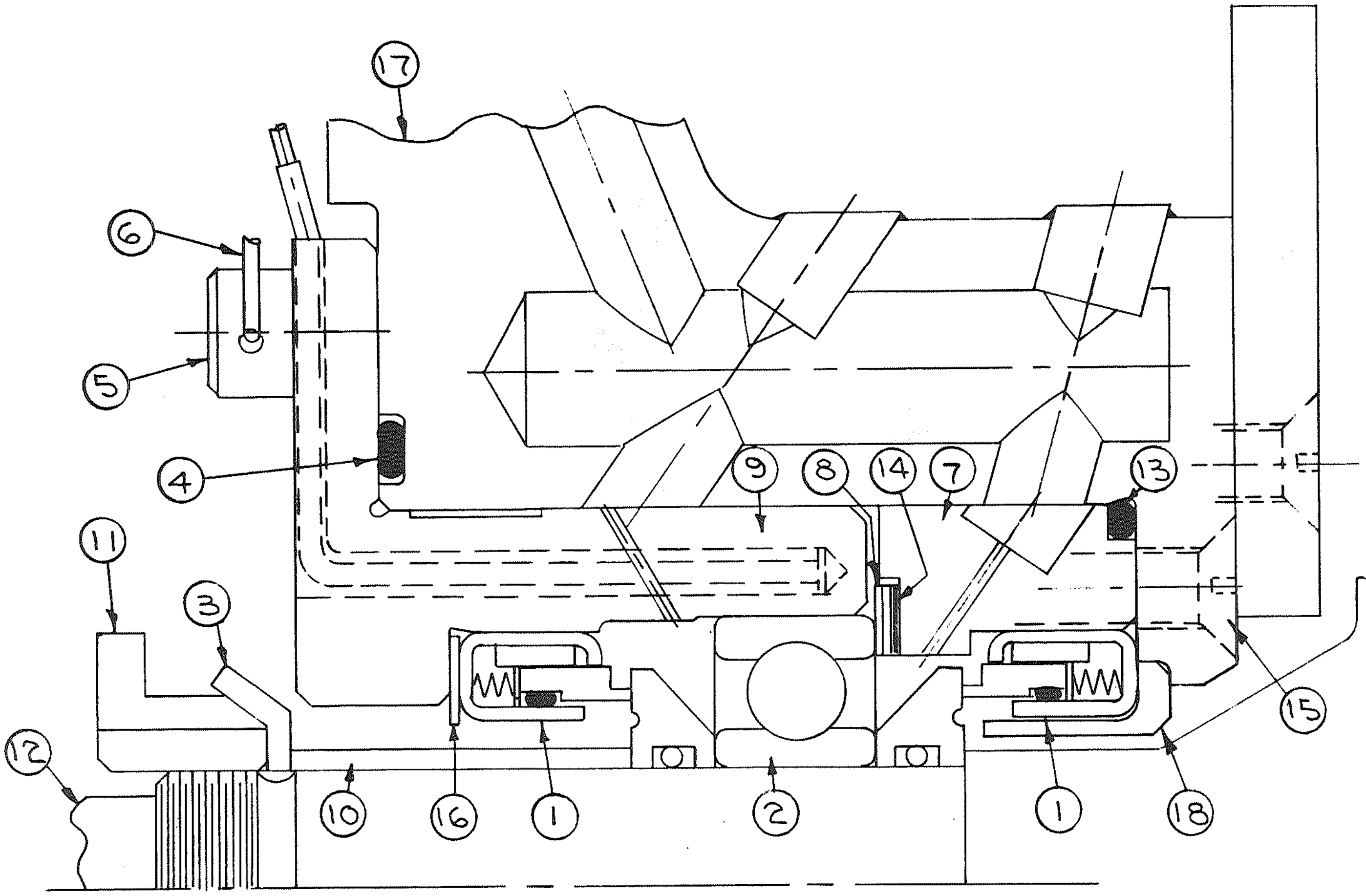


SHROUD - FRAME ASSEMBLY

FIGURE 38



TERMINAL CONFIGURATION
FIGURE 39

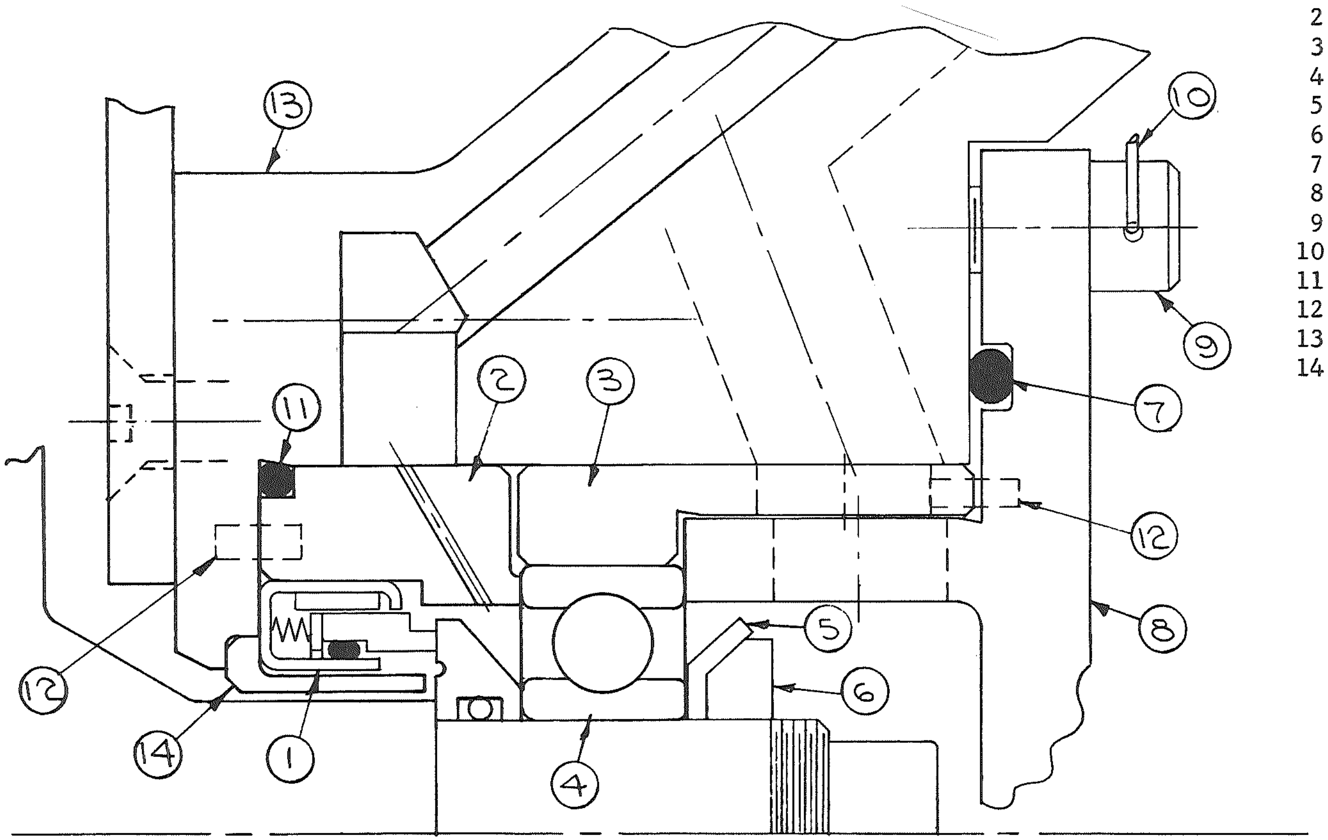


PARTS LIST

| ITEM | PART NAME |
|---|---|
| 1 | Seal |
| 2 | Bearing |
| 3 | Brg. Lock-washer |
| 4 | "O" Ring |
| 5 | Screw |
| 6 | Safety Wire |
| 7 | Seal Cartridge |
| 8 | Wavy Washer |
| 9 | Brg. & Seal Cartridge Asm. |
| 10 | Spacer |
| 11 | Lock Nut |
| 12 | Rotor |
| 13 | "O" Ring |
| 14 | Shim |
| 15 | Screw |
| 16 | Shim |
| 17 | End Shield |
| 18 | Guard-Seal |

FIGURE 40

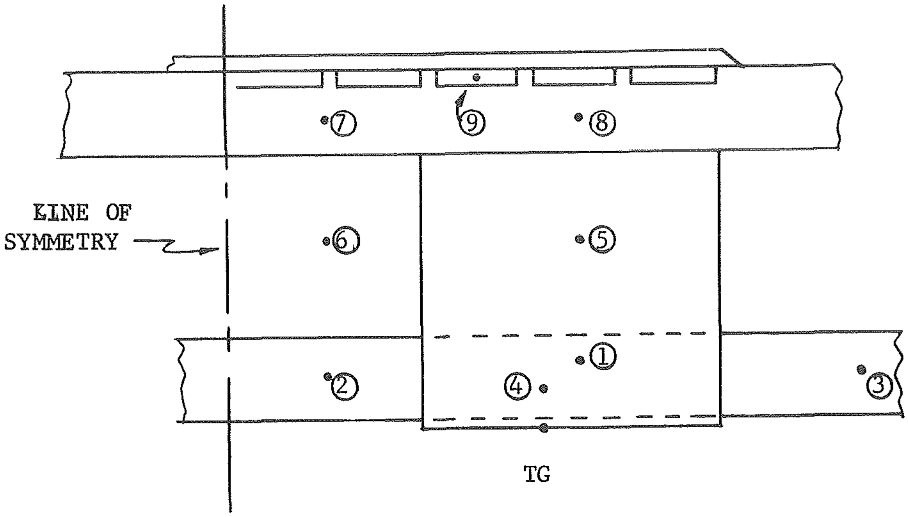
BEARING ASSEMBLY DRIVE-END



| ITEM | PART NAME |
|---|---|
| 1 | Seal |
| 2 | Seal Cartridge |
| 3 | Bearing Cartridge |
| 4 | Bearing |
| 5 | Brg. Lockwasher |
| 6 | Brg. Locknut |
| 7 | "O" Ring |
| 8 | Cap Asm. |
| 9 | Screw |
| 10 | Safety Wire |
| 11 | "O" Ring |
| 12 | Dowel Pin |
| 13 | End Shield |
| 14 | Guard-Seal |

FIGURE 41

BEARING ASSEMBLY ANTI-DRIVE-END



Thermocouples electrically insulated from parts.

| | Calculated ($^{o}C$) | Test ($^{o}C$) | |
|---|---|---|---|
| | | Drive End | Anti-Drive End |
| T1 (slot copper) | 141.5 | | |
| T2 (conductor under coil can) | 142.3 | | |
| T3 (end winding) | 143.7 | 124 | 120 |
| T4 (tooth) | 140.7 | 109 | 117 |
| T5 (yoke) | 129.9 | | |
| T6 (field coil) | 135.9 | 120 | 120 |
| T7 (frame) | 113.9 | | |
| T8 (frame) | 117.1 | 100* | 115* |
| TG (Tooth surface at air gap) | 142.0 | | |
| T9 (average coolant) | 104.2** | 94.5*** | 94.5*** |
| Coolant Rise | 8.4 | 3 | 3 |

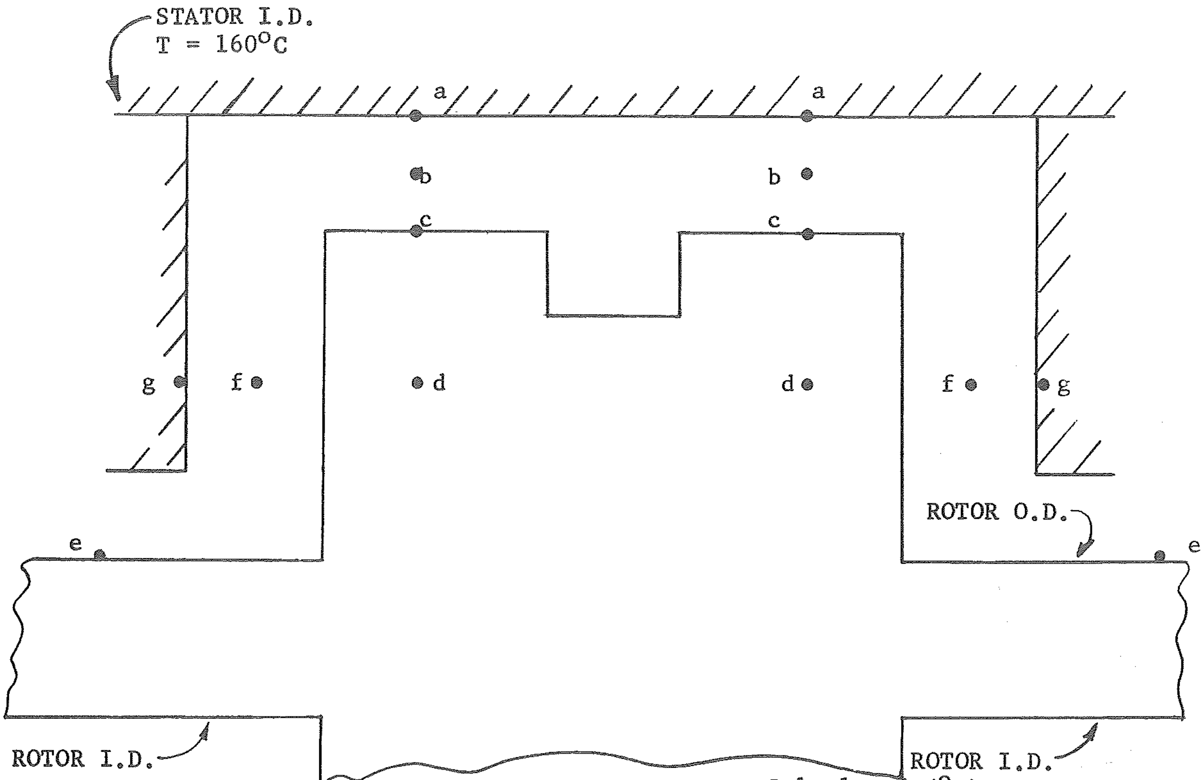
*Located on inside diameter **$100^{o}C$ Coolant assumed

***$93^{o}C$ Coolant

FIGURE 42

STATOR AND FIELD TEMPERATURES

15 KVA 0.8 P.F.



| | Calculated (°C) |
|---|---|
| Ta (Stator inside diameter) | 160.0* |
| Tb (Air gap) | 219.0 |
| Tc (Pole face) | 222.7 |
| Td (Rotor pole) | 219.5 |
| Te (Shaft) | 175.0* |
| Tf (Baffle gap) | 354.8 |
| Tg (Stationary baffle) | 160.0* |

FIGURE 43

AIR GAP AND ROTOR TEMPERATURES

15 KVA 0.8 P.F.

* Assumed Boundary Points

## DESIGN CALCULATIONS AND ANALYSIS

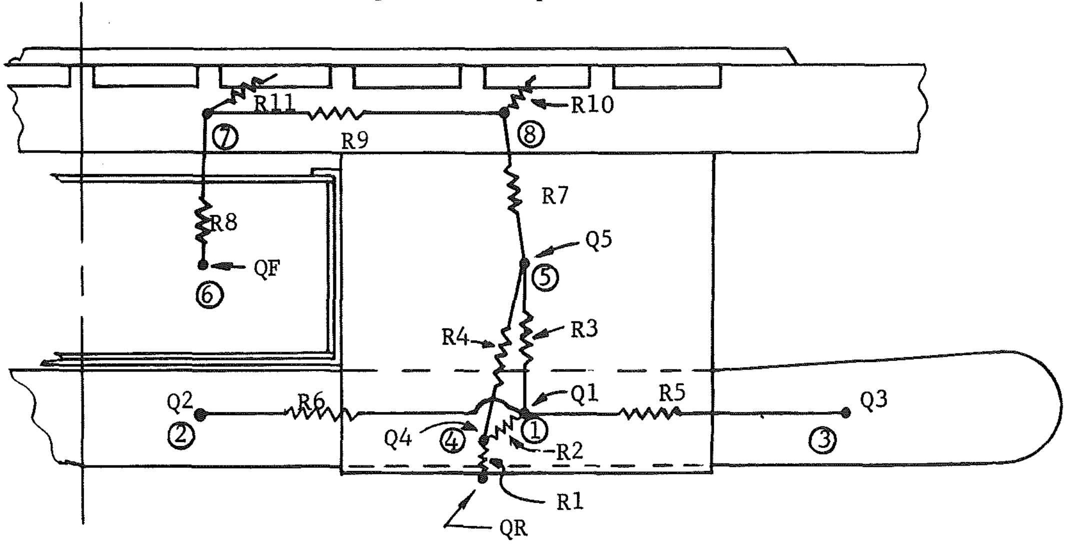
### A. Alternator

#### 1. Electrical Design Parameters

The alternator design parameters are shown in Table IV where the resistances, reactances, and flux densities have been calculated by computer.

#### 2. Stator Thermal Analysis

Consider the following thermal equivalent circuit for the stator.



COIL MEAN LENGTH OF TURN = 1.74 FT = 20.9 IN.

Total copper loss = 276 watts or $\frac{276}{2}$ = 138 watts/end

portion under exciting coil = $\frac{44}{20.9}$ X 138 = 29.1 watts (Q2)

portion in slots = $\frac{8}{20.9}$ X 138 = 52.8 watts (Q1)

portion in end turns = 138 - (52.8 + 29.1) = 56.1 watts (Q3)

Losses in teeth

From stray load loss $\frac{2}{3}$ X 150 = 100 watts = 50 watts/end

From core loss 45/2 = 22.5 watts/end

Total tooth loss/end = 72.5 watts (Q4)

## TABLE IV

## FINAL ALTERNATOR DESIGN PARAMETERS

### A. STATOR

| | | | |
|---|---|---|---|
| Turns per Coil | 4 | Slot Pitch | .346" |
| Effective Turns | 26.55 | O.D. | 8.68" |
| Strands per Turns | 2 | I.D. | 5.28" |
| Circuits | 2 | Slots Skewed | 0 |
| Coil Pitch | .667 | Yoke Thickness | 1.1" |
| Resistance at 160°C | .0183 per unit | Slot Width | .171" |
| | | Stack Separation | 2.2" |
| Height of Iron | 4.0" | Slots | 48 |

### B. ROTOR

| | | | |
|---|---|---|---|
| O.D. | 5.2" | Tooth Axial Length | 1.95" |
| Hub Diameter | 3.6" | Tooth Axial Separation | 2.2" |
| Tooth Thickness | 2.1" | Pole Arc | 2.86" |
| Weight (ARP) | 20 lbs. | | |
| Height of Iron | 3.9" | | |

### C. FIELD

| | |
|---|---|
| O.D. | 8.68" |
| I.D. | 6.48" |
| Turns | 520 |
| Resistance at 160°C | 4.97 ohms |

### D. REACTANCES (PER UNIT)

| | | | |
|---|---|---|---|
| $X_a$ | .1028 | $X_f$ | .577 |
| $X_{ad}$ | 1.00 | $X'_d$ | .456 |
| $X_{aq}$ | .623 | $X_2$ | .167 |
| $X_o$ | .018 | $X''_d$ | .156 |
| | | $X''_q$ | .177 |

### E. FLUX DENSITY AT RATED LOAD (KILOLINES/IN$^2$)

| | |
|---|---|
| Air Gap | 48.4 |
| Frame | 75 |
| Rotor Hub | 77 |
| Rotor Teeth | 82 |
| Stator Teeth | 89.7 |
| Stator Yoke | 43 |

### F. EFFICIENCY (LOSSES IN WATTS)

| LOSSES | 11.25 KVA | 15 KVA |
|---|---|---|
| Stator Copper | 154 | 276 |
| Field Copper | 157 | 206 |
| Core Loss | 190 | 200 |
| Windage (Argon at 6 psia) | 150 | 150 |
| Stray Load | 113 | 150 |
| Pole Face | 24.5 | 40 |
| Exciter Regulator | 85 | 94 |
| Total | 873.5 | 1116 |
| Efficiency | 91.15% | 91.49% |

### G. WEIGHT

| | |
|---|---|
| Electromagnetic | 82 pounds |

Losses in Yoke

From stray load loss $\frac{1}{3} \times 150 = 50 = 25$ watts/end

From core loss = 158 = 79/end

Q5 Total loss in yoke = 104 watts/end

Total field watts = 213 = 106.5 watt/end (QF)

Windage = 150 watts total (QR) = 40 watts/end

Pole face = 40 watts total

Assume all losses absorbed by cooling fluid

Total losses = 1032 watts

Coolant used is GE silicone oil Versilube F-50, 10 lb/min

Properties from GE Technical Data Book S-10A

Oil-in temperature = 100°C

$C_p$ = specific heat at 100°C - 120°C ≈ .39 Btu/lb°F

$$C_p = .39 \text{ Btu/lb}^\circ\text{F} \times .293 \frac{\text{watt hr.}}{\text{Btu}} \times \frac{60 \text{ min.}}{\text{hr.}} \times \frac{1.8^\circ\text{F}}{^\circ\text{C}}$$

$$= 12.32 \frac{\text{watt min.}}{\text{lb}^\circ\text{C}}$$

$$\text{Temperature rise of coolant} = \frac{1032 \text{ watts}}{12.32 \frac{\text{watt min}}{\text{lb}^\circ\text{C}} \times 10 \frac{\text{lb}}{\text{min}}} = 8.37^\circ\text{C}$$

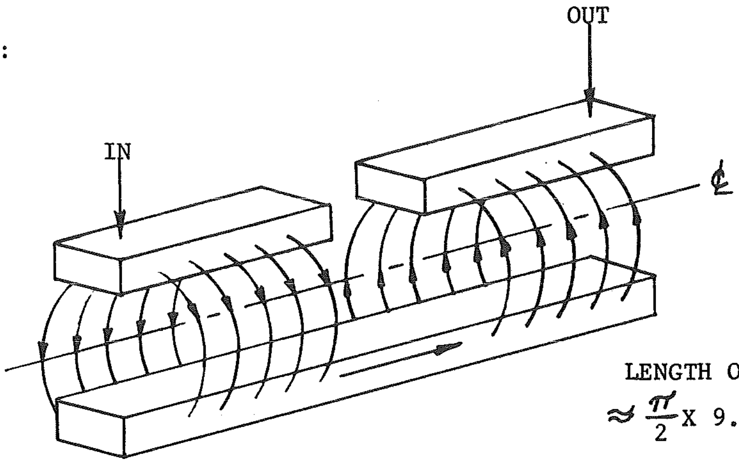
$$\text{Bulk temperature of fluid} = 100 + \frac{8.37}{2} = 104.2^\circ\text{C} = 219.8^\circ\text{F, say } 220^\circ\text{F}$$

Assume watt temperature ≈ 220°F + 20°F = 240°F

| Properties | at 220°F ($t_b$) | at 240°F ($t_w$) |
|---|---|---|
| K | .083 Btu/ft/hr/°F | .082 |
| Cp | .39 Btu/lb°F | .40 |
| $\nu$ | .581 ft$^2$/hr | 504 ft$^2$/hr |
| $\mu$ | 34.8 lb/ft hr | 30.2 lb/ft hr |
| $\rho$ | 60.6 lb/ft$^3$ | 60.0 lb/ft$^3$ |

Calculate $R_e$ at bulk temperature $R_e = \frac{\rho_b VD}{\mu_b}$

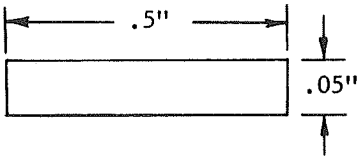
FLUID PATH:



LENGTH OF PASSAGE

$\approx \frac{\pi}{2} X\ 9.6 = 15.2 = 1.26$ ft.

Flow of 10 lb/min passes through 10 passages in parallel



$$D = \text{equivalent diameter} = \frac{4A}{P} = \frac{4(.5)(.05)}{2(.05)+2(.5)} = .091 \text{ in.} = .0076 \text{ ft.}$$

$$\text{Velocity} = \frac{10 \text{ lb/min X } \frac{1 \text{ ft}^3}{60.6 \text{ lb}} \text{ X } 60 \frac{\text{min}}{\text{hr}}}{10 \text{ X } (.5 \text{ X } .05)/144} = 5160 \text{ ft/hr}$$

$$R_e = \frac{60.6 \text{ lb/ft}^3 \text{ X } 5760 \text{ ft/hr X } .0076 \text{ ft.}}{34.8 \text{ lb/ft hr.}} = 76.4$$

from GE Heat Transfer Design Data Book, Sec G503.3, Fig. 8 and L/D = 1.26/.0076 = 166

$$\left(\frac{h}{C_bG}\right) \left(\frac{c\mu}{K}\right)_b^{2/3} \left(\frac{\mu_w}{\mu_b}\right)^n = .0172 \qquad n = .12 \text{ heating of oil}$$

$$G = \rho_b V$$

$$h = \frac{.0172\ (C_b\, \rho_b V)}{\left(\frac{C\mu}{K}\right)_b^{2/3} \left(\frac{\mu_w}{\mu_b}\right)^{.12}}$$

$$h = \frac{.0172\ (.39 \text{ X } 60.6 \text{ X } 5760)}{\left(\frac{.39 \text{ X } 34.8}{.083}\right)^{2/3} \left(\frac{34.8}{30.2}\right)^{.12}}$$

$$h = 77.4 \frac{\text{Btu}}{\text{hr ft}^2\ {}^{o}\text{F}} = .284 \frac{\text{watt}}{\text{in}^2\ {}^{o}\text{C}}$$

Temperature rise of frame above oil:

$$\text{Area} = 10 \text{ X } 9.6\pi \text{ X } (2 \text{ X } .05 + .5) = 181.0 \text{ in}^2$$

(Assumes no heat transfer from duct cover)

$$\Delta t = \frac{1032 \text{ watts}}{.284 \frac{\text{watt}}{\text{in}^2\ {}^{o}\text{C}} \text{ X } 181 \text{ in}^2} = 19.9^{o}\text{C}$$

If duct cover were at frame temperature

Correction factor for flat ducts with both walls heated from G503-3, p3, fig. 6C

$$\left(\frac{C\mu}{K}\right)_b \left(\frac{GDe}{\mu_b}\right) \left(\frac{De}{L}\right) =$$

$$(163.5)(76.4)\left(\frac{1}{132}\right) = 94.7$$

Correction factor = 1.3

$$h = 1.3 \text{ X } .284 = .369 \frac{\text{watts}}{{}^{o}\text{C in}^2}$$

$$\text{Area} = 10 \text{ X } 9.6\pi\ (2 \text{ X } .05 + .5 + 1/2(.5)) = 256 \text{ in}^2$$

(Assumes 1/2 cover area effective)

$$\Delta t = \frac{1032}{.369 \text{ X } 256} = 10.85^{o}\text{C}$$

The actual case probably lies somewhere inbetween these two. Use average:

$$h = \frac{.369 + .284}{2} = .326 \frac{\text{watts}}{{}^{o}\text{C in}^2}$$

## Calculation of Resistances:

$R_1$ Tooth portion

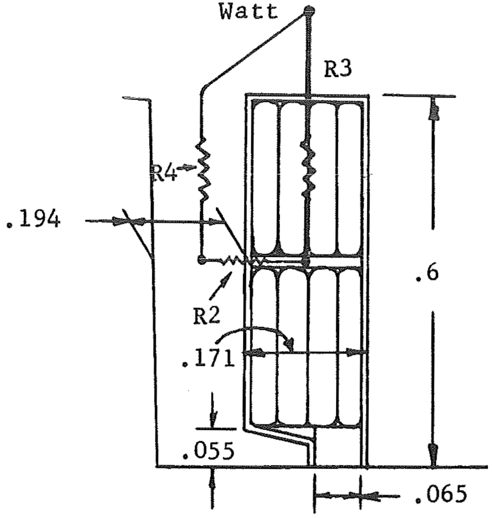
$$\text{average tooth width} = \left[\frac{(5.28 + .3)\pi}{48} - .171\right] = .194$$

$$\text{area} = .194 \text{ X } 48 \text{ X } 2 \text{ X } .97 = 18.1 \text{ in}^2$$

$$3\% \text{ Si stl, typical } K = .55 \frac{\text{watt}}{\text{in}\ {}^{o}\text{C}}$$

$$\frac{1}{KA} = \frac{.3}{.55 \text{ X } 18.1} = .0302 \frac{{}^{o}\text{C}}{\text{Watt}}$$

R1 = .0302 = $.0302 \frac{^\circ C}{Watt}$



Slot resistances are calculated using diagram shown to the left: (wire configuration changed in final design to reduce deep bar losses.)

(R2) Conductor insulation $\ell$ = .0045

K = .00765

A = 2 in X .224 X 2 X 2 X 48 = 86 $in^2$

$$R = \frac{1}{KA} = \frac{.0045}{.00765 \times 86} = .00685 \frac{^\circ C}{Watt}$$

Slot liner K = $.0217 \frac{watt}{in^\circ C}$

A = 86 $in^2$ 1 = .0105

$$R = \frac{\ell}{AK} = \frac{.0105}{86 \times .0217} = .00564 \frac{^\circ C}{Watt}$$

Tooth K = $.55 \frac{watt}{in^\circ C}$

A = (.6-.055) 2 X 2 X 48 = 104.5

$\ell$ = .194/2 = .097

$$R = \frac{.097}{.55 \times 104.5} = .00169 \frac{watt}{^\circ C}$$

(R2) = .00685 + .00564 + .00169 = .0142 $\frac{^\circ C}{\cancel{watt}}$

(R3) 1/2 thickness of separator

A = (.171 - (2 X .0105)) 2 X 48 = 14.4 $in^2$

$$R = \frac{.010}{.0217 \times 14.4} = .032 \frac{^\circ C}{Watt}$$

Conductor insulation

$$A = 2 \times 4 \times (.0315) \times 48 = 12.1 \text{ in}^2$$

$$R = \frac{.0045}{.00765 \times 12.1} = .0486 \frac{^\circ C}{\text{Watt}}$$

Yoke

$$\ell = 1.1/2 = .55$$

$$\text{Area} = .171 \times 2 \times 48 = 16.4 \text{ in}^2$$

$$R = \frac{.55}{16.4 \times .55} = .061 \frac{^\circ C}{\text{Watt}}$$

R3 $= .032 + .0486 + .061 = .1416 \frac{^\circ C}{\text{watt}}$

R4 1/2 tooth, $\ell = .3$

$$A = .194 \times 2 \times 48 \times .97 = 18.1 \text{ in}^2$$

$$R = \frac{.3}{18.1 \times .55} = .0302 \frac{^\circ C}{\text{watt}}$$

yoke

$$\text{Area at OD of slot} = \left(\frac{6.48\pi}{48} - .171\right) 48 \times 2 = 24.3$$

area at mid radius of yoke

$$= \left[\frac{(6.48 + 1.1)\pi}{48} - .171\right] 48 \times .2 = 31.2 \text{ in}^2$$

$$A = \frac{24.3 + 31.2}{2} = 27.7 \text{ in}^2$$

$$R = \frac{1.1/2}{.55 \times 27.7} = .0361 \frac{^\circ C}{\text{Watt}}$$

R4 $= .0361 + .0302 = .0663 \frac{^\circ C}{\text{watt}}$

R5 $\ell = 1/2 \left[2 + 1/2 \quad (4.25)\right] = 2.125 \text{ in}$

$$\text{Area} = 16 \times (.224 \times .0315) \times 48 = 5.43 \text{ in}^2$$

R5 $= \frac{2.125}{5.43 \times 9.65} = .0406 \frac{^\circ C}{\text{watt}}$

R6 $\ell = 1/2 \left[2 + 1.1\right] = 1.55''$

$\text{Area} = 5.43 \text{ in}^2$

R6 $= \dfrac{1.55}{5.43 \times 9.65} = .0296 \dfrac{^{o}C}{\text{watt}}$

R7 $R_{\text{yoke}} = \dfrac{\text{Ln}\ (r_2/r_1)}{2\pi LK}$ $\quad r_2 = 8.68/2 = 4.34,\ r_1 = 7.68/2 = 3.84$

$$= \frac{\text{Ln}\ (4.34/3.84)}{2\pi\ (2)\ .55} = \frac{.122}{6.92} = .0176 \frac{^{o}C}{\text{watt}}$$

contact drop between yoke and frame

$$\frac{1}{hc} = 1 \frac{in^{2\,o}C}{\text{watt}}$$

$A = (6.48 + 2.2 + .90)\pi \times 2 = 60.2\ in^2$

$$R = \frac{1}{60.2} = .0166 \frac{^{o}C}{\text{watt}}$$

path through 1/2 of frame thickness

$\ell = .45 \times 1/2 = .225$ in.

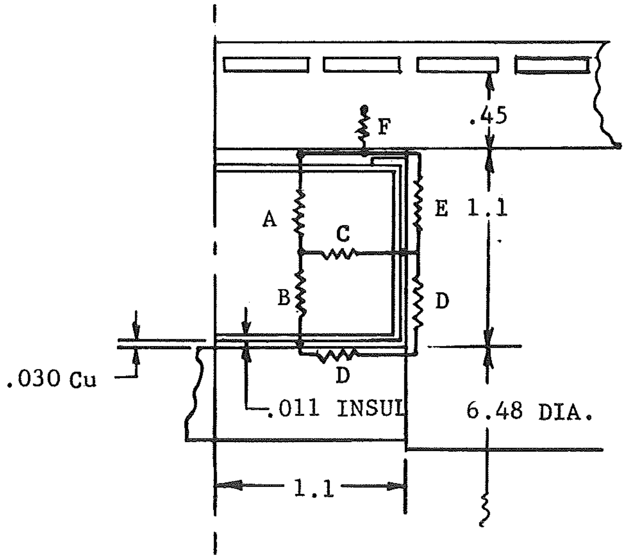
$A = 9.13\ \pi \times 2 = 57.4\ in^2$

$K$ ingot iron $= 1.67 \dfrac{\text{watt}}{in\,^{o}C}$

$$R = \frac{.225}{1.67 \times 57.4} = .00235 \frac{^{o}C}{\text{watt}}$$

$R7 = .0176 + .0166 + .00235 = .0366 \dfrac{^{o}C}{\text{watt}}$

R8 Field coil to frame



Equivalent thermal conductivity of conductor matrix

GE heat transfer data book, Sec. G502.2, p2

conductor diameter = .0856"
insulated dia = .0856 + .0045 = .0901

diameter ratio = $\frac{.0856}{.0901} = .95$

"F" = 11 varnish, K = $.00765 \frac{\text{watt}}{\text{in}^\circ\text{C}}$

Equivalent K = (11)(.00765) = $.084 \frac{\text{watt}}{\text{in}^\circ\text{C}}$

RA

Portion through coil
effective $\ell = \frac{1.1}{4} = .275$ in

area = $(1.1 - .030 - .011)(6.48 + 3/4 \times 2.2)\pi \doteq 26.9 \text{ in}^2$

$R = \frac{.275}{26.9 \times .084} = .122 \frac{^\circ\text{C}}{\text{watt}}$

portion through .011 insulation + extra .030 varnish

l = .011", .030"

$A = (6.48 + 2)\pi \times (1.1 - .030 - .011) = 28.2 \text{ in}^2$

K = .0217, .0069

$R = \frac{1}{28.2}\left[\frac{.011}{.0217} + \frac{.030}{.0069}\right] = .1725 \frac{^\circ\text{C}}{\text{Watt}}$

assume no drop in copper wire band

Ⓡ(RA) = $.122 + .1725 = .2945 \frac{^\circ\text{C}}{\text{watt}}$

RB

coil portion

$\ell = .275$

$A = (1.1 - .03 - .011)(6.48 + 1/4 \times 22)\pi = 23.4$

$R = \frac{.275}{23.4 \times .084} = .140 \frac{^\circ\text{C}}{\text{watt}}$

.011 insulation strip + .03 varnish

$\ell$ = .011", .03"

$$A = (6.48 + .082)\pi \times (1.1 - .03 - .011) = 21.8$$

$$R = \frac{1}{21.8}\left[\frac{.011}{.0217} + \frac{.030}{.0069}\right] = .223\ \frac{^{o}C}{Watt}$$

$$\text{RB} = .140 + .223 = .363\ \frac{^{o}C}{watt}$$

**RC**

coil portion + .030 varnish + .011 insulation

$$1 = \frac{1.1}{2} = .55''$$

$$A = \left[(6.48 + 1.0)^2 - (6.48)^2\right]\frac{\pi}{4} = 11.9\ in^2$$

$$R = \frac{1}{11.9}\left[\frac{.55}{.084} + \frac{.030}{.0069} + \frac{.011}{.0217}\right] = .926\ \frac{^{o}C}{Watt}$$

$$RC = .926\ \frac{^{o}C}{watt}$$

**RD**

cylindrical portion

$$1 = .55''$$

$$A = (6.48 + .03)\pi \times .03 = .613\ in^2$$

radial portion

$$1 = .55''$$

$$A = (6.48 + 1/4(2.2))\pi \times .03 = .652$$

$$\text{RD} = \frac{.55}{9.95 \times .613} + \frac{.55}{9.95 \times .652} = .1854\ \frac{^{o}C}{watt}$$

**RE**

radial portion

$$1 = .55''$$

$$A = (6.48 + 3/4(2.2))\pi \times .03 = .766$$

$$R = \frac{.55}{9.95 \times .766} = .0722\ \frac{^{o}C}{watt}$$

$$\text{RE} = .0722\ \frac{^{o}C}{watt}$$

**RF**

contact drop

$$\frac{1}{hc} \approx 1.0 \, \frac{in^2 \, {}^\circ C}{watt}$$

$$\text{Area} = (6.48 + 2.2)\pi \times 1.1 = 30 \; in^2$$

$$R = \frac{1}{30} = .0333 \; \frac{{}^\circ C}{watt}$$

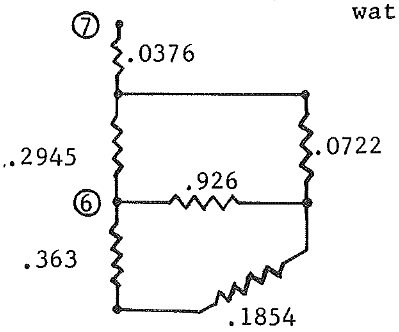
path through 1/2 frame thickness

$$l = .45/2 = .225$$

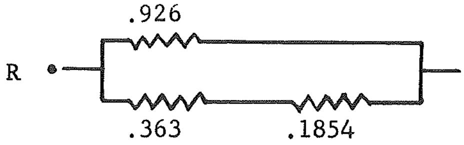
$$A = 9.13\pi \times 1.1 = 31.5 \; in^2$$

$$R = \frac{.225}{31.5 \times 1.67} = .00428 \; \frac{{}^\circ C}{watt}$$

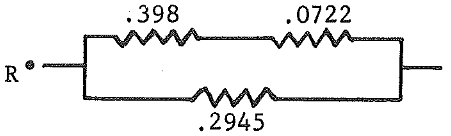
**RF** $= .0333 + .00428 = .0376 \; \frac{{}^\circ C}{watt}$



Equivalent resistance from ⑥ to ⑦



$$R = \frac{(.5484)(.926)}{(.5484) + (.926)} = .398 \; \frac{{}^\circ C}{Watt}$$



$$R = \frac{(.398)(.2945)}{(.398) + (.2945)} = .1695 \; \frac{{}^\circ C}{Watt}$$

**R8** $= .0376 + .1695 = .207 \; \frac{{}^\circ C}{watt}$

**R9**

axial path through frame

$$l = \frac{1.1}{2} + \frac{2}{2} = 1.55 \; in$$

$$A = (6.48 + 2.2 + .45)\pi \times .45 = 12.9 \; in^2$$

$$\text{(R9)} = \frac{1.55}{12.9 \times 1.67} = .072\ \frac{^{\circ}\mathrm{C}}{\mathrm{watt}}$$

(R10)

path through 1/2 frame thickness

$$l = .45/2 = .225''$$

$$A = (9.13 + .225)\pi \times 2 = 58.8\ \mathrm{in}^2$$

$$R = \frac{.225}{58.8 \times 1.67} = .00229\ \frac{^{\circ}\mathrm{C}}{\mathrm{Watt}}$$

oil film drop

$$h = .326\ \frac{\mathrm{watt}}{^{\circ}\mathrm{C\,in}^2}$$

$$A/\mathrm{duct} = 9.68\,\pi\,(.5 + 2 \times .05 + .25) = 25.8\ \mathrm{in}^2$$

$$3\ \mathrm{ducts},\ A = 3 \times 25.8 = 77.4\ \mathrm{in}^2$$

$$\frac{1}{hA} = \frac{1}{.326 \times 77.4} = .0397\ \frac{^{\circ}\mathrm{C}}{\mathrm{watt}}$$

$$\text{(R10)} = \overset{\text{frame}}{.00229} + \overset{\text{oil}}{.0397} = .0420\ \frac{^{\circ}\mathrm{C}}{\mathrm{watt}}$$

(R11)

path through 1/2 frame thickness

$$l = .225''$$

$$A = (9.13 + .225)\pi \times 1.1 = 32.4\ \mathrm{in}^2$$

$$R = \frac{.225}{32.4 \times 1.67} = .00416\ \frac{^{\circ}\mathrm{C}}{\mathrm{Watt}}$$

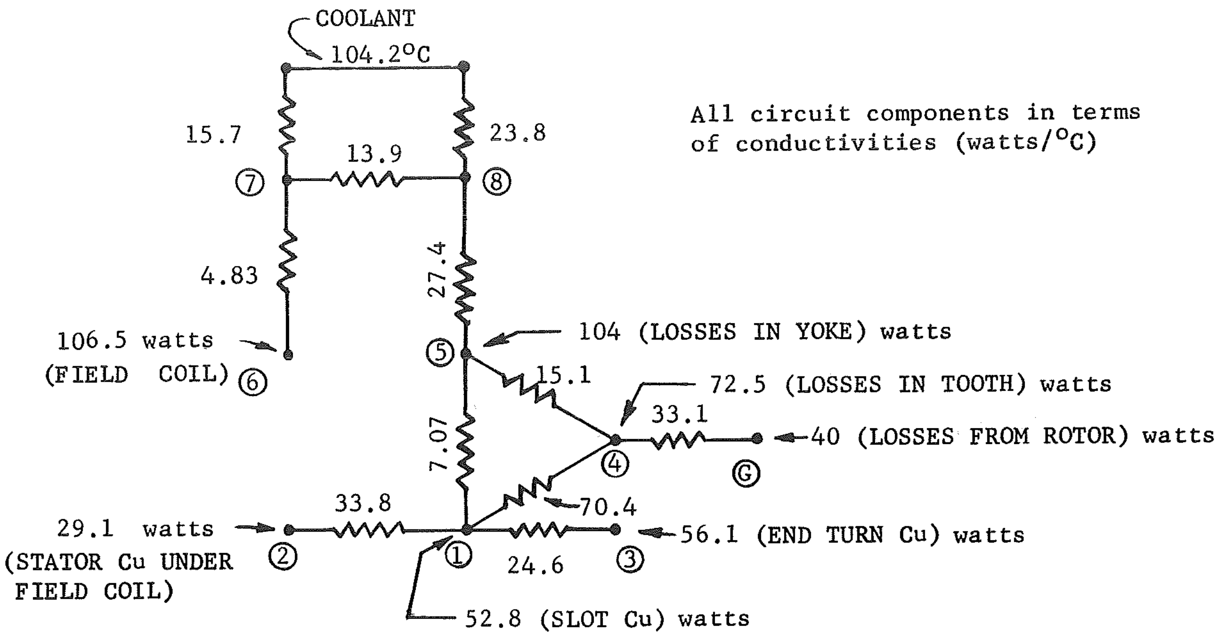
oil film drop

$$2\ \mathrm{ducts} \times 25.8\ \mathrm{in}^2/\ \mathrm{duct} = 51.6\ \mathrm{in}^2$$

$$R = \frac{1}{.326 \times 51.6} = .0594\ \frac{^{\circ}\mathrm{C}}{\mathrm{Watt}}$$

$$\text{(R11)} = \overset{\text{frame}}{.00416} + \overset{\text{oil}}{.0594} = .0636\ \frac{^{\circ}\mathrm{C}}{\mathrm{watt}}$$

Equivalent Thermal Circuit in Terms of Conductivities



All circuit components in terms of conductivities (watts/°C)

Write equations based on $\Sigma Q = 0$

1. $52.8 + 33.8 (T2 - T1) + 7.07 (T5 - T1) + 70.4 (T4 - T1) + 24.6 (T3-T1) = 0$
2. $29.1 + 33.8 (T1 - T2) = 0$
3. $56.1 + 24.6 (T1 - T3) = 0$
4. $72.5 + 15.1 (T5 - T4) + 33.1 (TG - T4) + 70.4 (T1 - T4) = 0$
5. $104 + 27.4 (T8 - T5) + 15.1 (T4 - T5) + 70.7 (T1 - T5) = 0$
6. $106.5 + 4.83 (T7 - T6) = 0$
7. $15.7 (104.2 - T7) + 13.9 (T8 - T7) + 4.83 (T6 - T7) = 0$
8. $23.8 (104.2 - T8) + 27.4 (T5 - T8) + 13.9 (T7 - T8) = 0$

G $40 + 33.1 (T4 - TG) = 0$

Temperatures as obtained from computer program:

T1 (slot copper) = 141.5°C

T2 (conductor under coil can) = 142.3°C

T3 (end winding) = 143.7°C

T4 (tooth) = 140.7°C

T5 (yoke) = 129.9°C

T6 (exciting coil) = 135.9°C

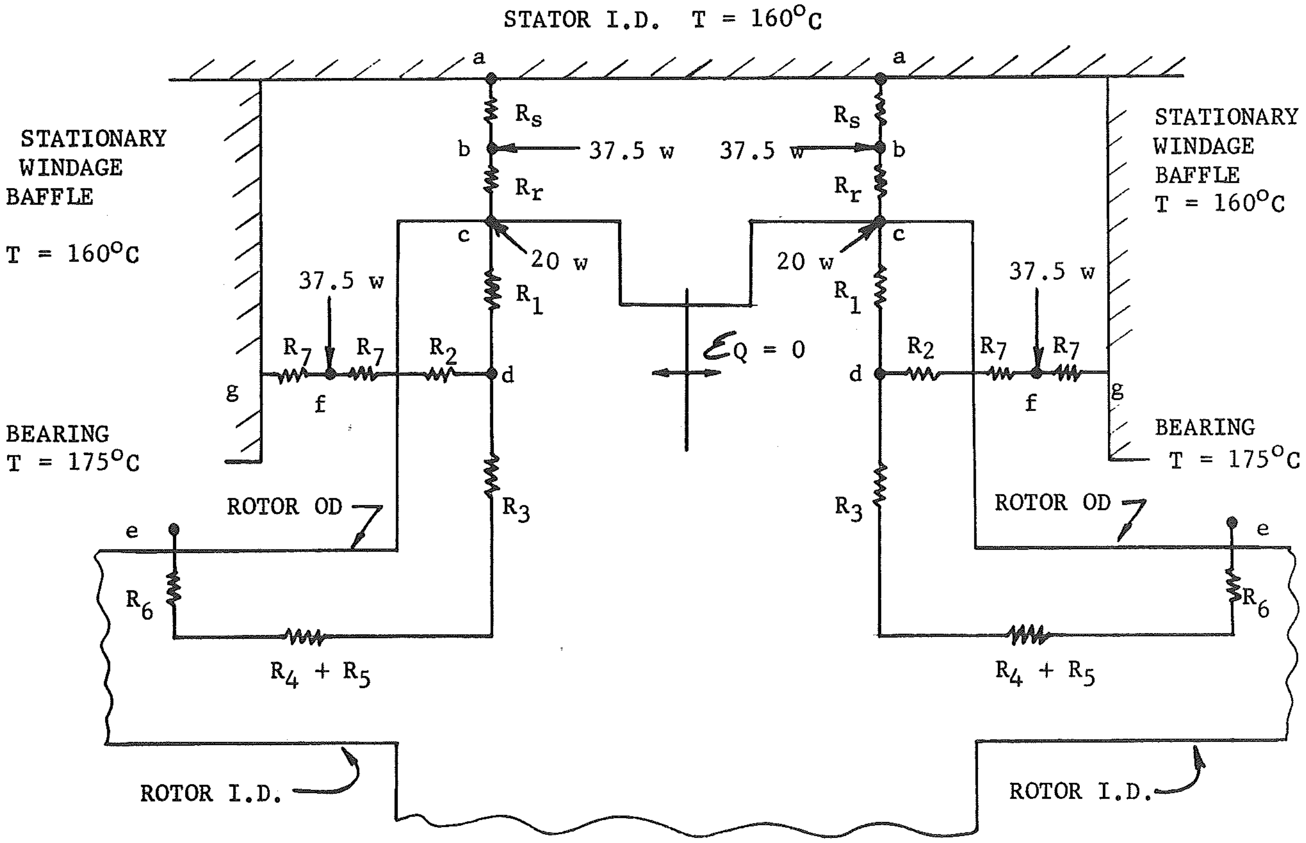
T7 (frame) = 113.9°C

T8 (frame) = 117.1°C

TG (tooth surface at air gap) = 142.0°C

### 3. Turboalternator Rotor Thermal Analysis

Consider the following thermal equivalent circuit for the rotor:



The following assumptions are made for the analysis:

1. The windage losses are located at the center of the air gap.
2. Half of the windage losses are located in the axial air gap and half in the radial air gap.
3. Pole face losses are on the pole surfaces.
4. Temperature of the stator is 160°C (conservative value).
5. No radiation effects are accounted for.

Argon Properties are taken from NASA TR R-132 Report and given below:

Properties evaluated at 200°C = 473°K

$$K = \left[52.8 + .73\ (8.9)\right] 10^{-6} = 59.3\ \text{X}\ 10^{-6}\ \text{g-cal/cm-sec-K}$$

$$K = 59.3\ (6.718\ \text{X}\ 10^{-2})\ 10^{-6} = 3.99\ \text{X}\ 10^{-6}\ \text{Btu/ft-sec-F}$$

$$K = 3.99\ \text{X}\ 10^{-6}\ \text{Btu/ft-sec-F}\ (3600\ \frac{\text{sec}}{\text{hr}}) = .0144\ \text{Btu/hr-ft-F}$$

$$\mu = \left[282.9 + .73\ (47.3)\right]\ 10^{-6} = 317.5\ \text{X}\ 10^{-6}\ \text{poises}$$

$$\mu = 317.5\ \text{X}\ 10^{-6}\ (242) = .0766\ \frac{\#}{\text{ft-hr}}$$

$$R = \frac{1.544\ \text{X}\ 10^{3}\ \text{ft-\#/\#-mole-}^{\circ}\text{R}}{39.94\ \text{g/g-mole}} = 38.7\ \frac{\text{ft-\#}}{\text{\#-R}}$$

$$e = \frac{P}{RT} = \frac{6\#/\text{in}^2 (144\ \text{in}^2/\text{ft}^2)}{38.7\ \text{ft}\ (390 + 460)} = .0263\ \#/\text{ft}^3$$

<u>Heat Transfer from Rotor to Stator and from Rotor to Bearing</u>.

Assume temperature at stator ID, $T_2$ = 160°C
Assume temperature at bearing face, $T_b$ = 175°C

Windage losses:

$$q_1 + q_3 = \frac{150}{2}\ \text{watts}, \qquad q_1 = q_3 = \frac{75}{2}\ \text{watts}$$

Pole face losses:

$$q_2 = \frac{40}{2}\ \text{watts}$$

The film coefficient, h, will be determined by two methods, with the lowest value being used.

Gazley's Method (Reference 1)

Using figs. 12 and 14 of Reference 1

$$V_e = \frac{1}{2}\ U_r = \frac{1\ (\pi)(5.2\ \text{in})(12{,}000\ \text{rev/min})(60\ \text{min/hr})}{2\ (12\ \text{in/ft})} = 4.9 \text{ X } 10^5\ \text{ft/hr}$$

$$R_e = \frac{2(.04\ \text{in})(4.9 \text{ X } 10^5\ \text{ft/hr})(.0263\#/\text{ft}^3)}{.0766\ \#/\text{ft hr}\ (12\ \text{in/ft})} = 1.12 \text{ X } 10^3$$

Heat transfer between stator and air, Curve 12 of Reference 1,

$$\frac{2\ h_s\ l_g}{K} = 7.5$$

$$\therefore\ h_s = \frac{7.5\ (.0144\ \text{Btu/hr-ft-F})(12\ \text{in/ft})}{2(.040\ \text{in})} = 16.25\ \text{Btu/hr-ft}^2\text{-F}$$

Heat transfer between rotor and air, Curve 14 of Reference 1,

$$\frac{2\ h_r\ l_g}{K} = 7.5,\ \therefore\ h_s = 16.25\ \text{Btu/hr-ft}^2\text{-F}$$

Becker & Kaye's Method (Reference 2)

Using Fig. 3

$$b/r_m = \frac{.040}{2.6} = 1.54 \text{ X } 10^{-2},\ \frac{b}{2\ r_m} = .77 \text{ X } 10^{-2} = .0077$$

$$P = .0571\left[1 - .652\ \left(\frac{.0154}{1-.0077}\right)\right] + \frac{.00056}{\left[1-.652\ \left(\frac{.0154}{1-.0077}\right)\right]}$$

$$P = .0565 + .00057 = .05707$$

$$F_g = \frac{(3.14)^4}{1697\ (1 - .0077)^2(.05707)} \approx 1$$

$$T_a = \left(\frac{W^2 rmb^3}{r^2}\right)\ \frac{1}{Fg}$$

$$W = (2)(3.14)(12{,}000\ \text{rev/min})(60\ \text{min/hr}) = 4.52 \text{ X } 10^6\ \text{rad/hr}$$

$$r_m = \frac{2.6\ \text{in}}{12\ \text{in/ft.}} = .217\ \text{ft} = 2.17 \text{ X } 10^{-1}\text{ft}$$

$$b = \frac{.040\ \text{in}}{12\ \text{in/ft}} = 3.34 \text{ X } 10^{-3}\text{ft.}$$

$$r = \frac{.0765\ \#/\text{ft-hr}}{.0246\ \#/\text{ft}^3} = 3.11\ \text{ft}^2/\text{hr}$$

$$\therefore\ T_a = \left[\frac{(4.52 \text{ X } 10^6)^2/\text{hr}^2(2.17 \text{ X } 10^{-1}\text{ft})(3.34 \text{ X } 10^{-3})^3\ \text{ft}^3}{(3.11)^2\ \text{ft}^4/\text{hr}^2}\right]\ \frac{1}{1}$$

$T_a = 1.68 \times 10^4$

$$\therefore \frac{2\ Ub}{K} = 4.2$$

$$U = \frac{4.2\ (.0154\ \text{Btu/hr-ft-F})(12\ \text{in/ft})}{2\ (.040\ \text{in})} = 9.72\ \text{Btu/hr-ft}^2\text{-F}$$

Since this is the value from rotor to stator then:

$U_r = U_s = 2\ (9.72) = 19.44\ \text{Btu/hr-ft}^2\text{-F}$ for transfer from stator to air and from rotor to air.

Thermal Resistances

Since Gazley's Method produces the lowest heat transfer coefficient from iron to air, it will be used in the calculation of $R_s$ and $R_r$.

$R_s = R_r = \frac{1}{hA}$ where A is the area per two poles
$A = .35\ (3.14)(5.2)(2) = 11.4\ \text{in}^2$

$$R_s = R_r = \frac{1\ (273\ \text{Btu/hr ft}^2\text{-F/watt/in}^2\text{-C})}{(16.25\ \text{Btu/hr ft}^2\text{-F})(11.4\ \text{in}^2)} = 1.47\ \frac{\text{C}}{\text{watt}}$$

For B3E20L, $K = .53$ watt/in-C @ 25°C

For 4620 $K = 30\ \text{Btu/hr-ft}^2\text{-F}$ @212°F

$$\text{or } K = \frac{30}{22.75} = 1.32\ \text{watt/in-C}$$

$$R_1 = \frac{.8\ \text{in}}{(.53\ \text{watt/in-C})(2.22)(2)\ \text{in}^2\ (.94)(2)} = .183\ \text{C/watt}$$

$$R_2 = \frac{1\ \text{in}}{(1.32\ \text{watt/in-C})(3.14)\left[(1.8)^2 - (1.4)^2\right]\ \text{in}^2} = .187\ \text{C/watt}$$

$$R_3 = \frac{1.1\ \text{in}}{(1.32\ \text{watt/in-C})(2.2)(2)\ \text{in}^2(2)} = .095\ \text{C/watt}$$

$$R_4 = \frac{.5\ \text{in}}{(1.37\ \text{watt/in-C})(3.14)\left[(1)^2 - (.3)^2\right]} = .133\ \text{C/watt}$$

Assume bearing support and shaft are of H-11

$$\therefore K = \frac{16.6}{22.75} = .73\ \text{watt/in-C}$$

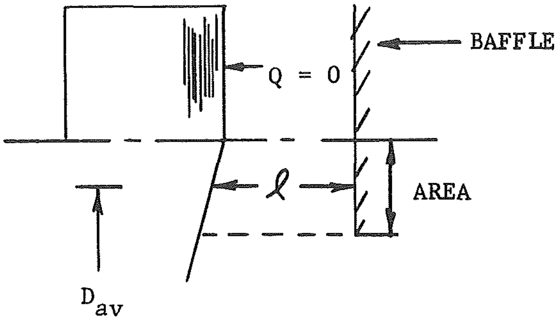
$$R_5 = \frac{1\ \text{in}}{(.73\ \text{watt/in-C})(3.14)\left[(.75)^2 - (.3)^2\right]} = .925\ \text{C/watt}$$

$$R_6 = \frac{.5\ \text{in}}{(.73\ \text{watt/in-C})(.8\ \text{in})(2)(3.14)(1\ \text{in})} = .136\ \text{C/watt}$$

$$R_T = R_3 + R_4 + R_5 + R_6$$

$$R_T = .095 + .133 + .925 + .136 = 1.289 \text{ C/watt}$$

The air gap resistance between baffles and rotor will be analyzed by Gazley's method.



The heat flow into the punchings from the baffle is negligible because of the high resistance through this path.

$\ell$ = .33 - The average gap length at the area of heat flow

$A = 3.14 \quad (1.9)^2 - (1.5)^2 \quad = 4.25 \text{ in}^2\text{/end}$

$D_{AV}$ = 3.2 in - average diameter

The average velocity of the rotor at this point is:

$$U = 3.14\ (3.2) \text{ in}(12{,}000 \text{ rpm}) = 1.21 \times 10^5 \text{ in/min.}$$

Now the average tangential velocity of argon in the gap is:

$$V_e = \frac{1}{2}\ \frac{(1.2 \times 10^5 \text{ in/min})(60 \text{ min/hr})}{12 \text{ in/ft}} = 3 \times 10^5 \text{ ft/hr}$$

$$R_e = \frac{2\ (.33 \text{ in})(3 \times 10^5 \text{ ft/hr})(.0263\ \#/\text{ft}^3)}{.0766\ \#/\text{ft-hr} \quad (12 \text{ in/ft})} = 5.65 \times 10^3$$

From Fig. 12 of Reference 1

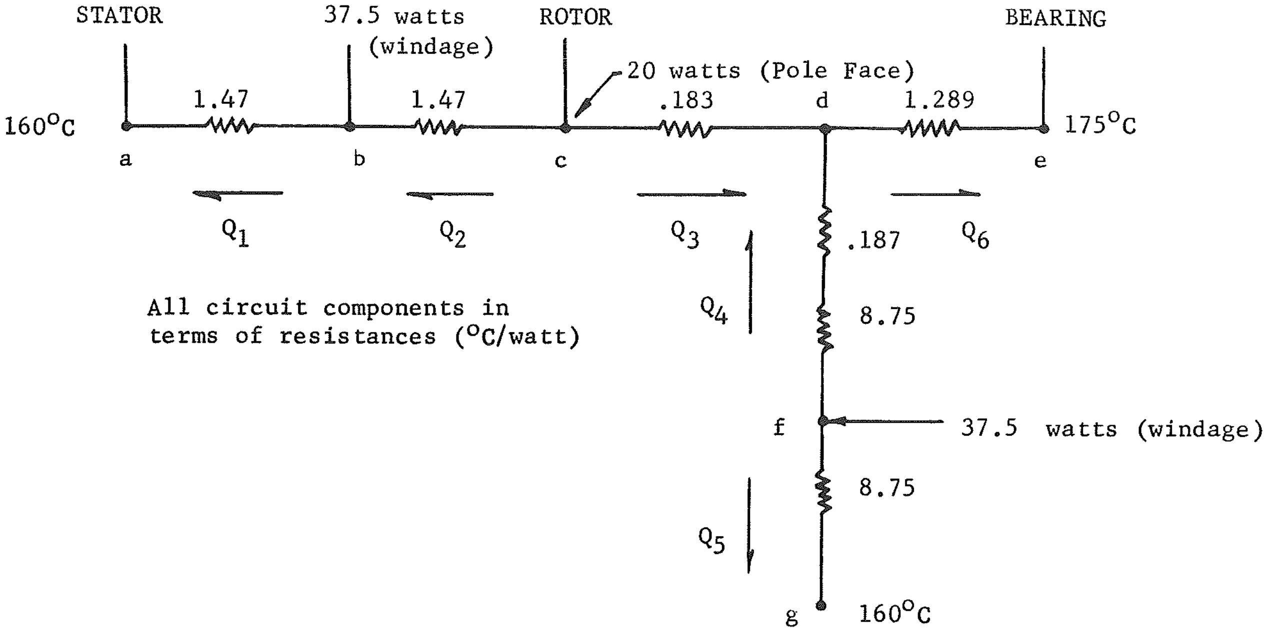
$$N_\mu = 28$$

$$h = \frac{28\ (.0144 \text{ Btu/\#-ft-F})(12 \text{ in/ft})}{2\ (.33 \text{ in})} = 7.34 \text{ Btu/hr-ft}^2\text{-F}$$

$$R_7 = \frac{273 \text{ Btu/hr-ft}^2\text{-F/watt/in}^2\text{-C}}{7.34 \text{ Btu/hr-ft}^2\text{-F}(4.25 \text{ in}^2)} = 8.75 \text{ C/watt}$$

Thermal Circuit Solution

Placing the resistance values in the thermal circuit gives the following:



Solution of the circuit yields the following results:

| | | |
|---|---|---|
| $Q_1 = 40$ | $\Delta t_{ab} = 40\ (1.47) = 59^{\circ}C$ | $T_b = 219.0^{\circ}C$ |
| $Q_2 = 2.5$ | $\Delta t_{bc} = 2.5\ (1.47) = 3.7$ | $T_c = 222.7^{\circ}C$ |
| $Q_3 = 17.5$ | $\Delta t_{cd} = 17.5\ (.183) = 3.2^{\circ}C$ | $T_d = 219.5^{\circ}C$ |
| $Q_4 = 16$ | $\Delta t_{fd} = 16\ (8.927) = 143^{\circ}C$ | $T_f = 354.8^{\circ}C$ |
| $Q_5 = 21.5$ | $\Delta t_{fg} = 21.5\ (8.927) = 193$ | $T_f = 353^{\circ}C$ |
| $Q_6 = 33.5$ | $\Delta t_{de} = 33.5\ (1.289) = 43.2$ | $T_d = 217.5^{\circ}C$ |

The small differences in the temperatures $T_d$ (219.5 versus 217.5) and $T_f$ (354.8 versus 353) reflect the accuracy of the iterative procedure that was used to solve the circuit. The highest temperature occurs in the air gap between the rotating and stationary windage baffles and is due to the high thermal resistance of this gap. Other temperatures, such as pole tip, $T_c$, are very reasonable and are conservative since a stator ID temperature of 160°C was used as a boundary temperature; whereas, the stator analysis gave 142.0°C.

4. Coolant Analysis

Assume that coolant is GE Silicone oil, Versilube F-50 which, at operating temperature, has a viscosity of 34.8 lb/ft hr and a weight density of 60.6 $lb/ft^3$.

Calculate Reynolds number of oil in coolant passageway:

$$R_e = \frac{VD_e \rho}{\mu}$$

$$D_e = \text{hydraulic diameter} = \frac{4A}{P}$$

$$D_e = \frac{4(.5)(.05)}{2(.5 + .05)} \text{ X } \frac{1 \text{ ft}}{12 \text{ in}} = .0076 \text{ ft.}$$

$$V = \frac{10 \text{ lb/min X } \frac{ft^3}{60.6 \text{ lb}} \text{ X } \frac{1 \text{ min}}{60 \text{ sec}}}{10\ (.5)(.05)\ \frac{1 \text{ ft}^2}{144 \text{ in}^2}} = 1.588 \text{ ft/sec}$$

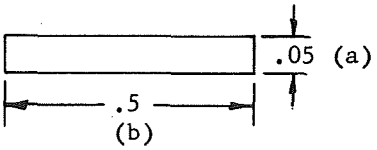
$$R_e = \frac{1.588 \text{ ft/sec X } .0076 \text{ ft X } 60.6 \text{ lb/ft}^3}{34.8 \text{ lb/ft hr X } \frac{1 \text{ hr}}{3600 \text{ sec}}} = 75.7$$

Calculate viscous losses:

$$\Delta p = 4 f \frac{L}{D} \rho \frac{V^2}{2g}$$

Use method shown on page 1, Section G402.2 of GE Fluid Flow Data Book

From Fig. 2



$$a/b = \frac{.05}{.5} = .1, \ K_2 = 21.1 = f \bullet R_e$$

$$f = \frac{21.1}{R_e} = \frac{21.1}{75.7} = .279$$

L: effective length of passages
mean radius = 48 in
length $L = \frac{4.8}{12} \text{ X } \pi = 1.26$ ft.

$$\Delta p = 4f\frac{L}{D} \rho \frac{V^2}{2g}$$

$$= 4(.279) \frac{1.26}{.0076} \frac{60.6\ (1.588)^2}{2(32.2)}$$

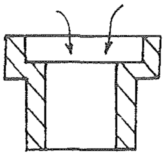
$\Delta p$ = 438 $lb/ft^2$ = 3.04 $lb/in^2$ per half circumference

There are two sets of these passages in series

2 X 3.04 $lb/in^2$ = 6.08 psi viscous drop

(ignore viscous drop in headers - velocity extremely low)

Calculate dynamic drop



entering header   1 1/2 velocity heads

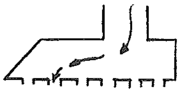
$$\text{area} = (.42)^2 \frac{\pi}{4} \frac{1}{144} = 9.62 \text{ X } 10^{-4} \text{ft}^2$$

$$V = \frac{10 \text{ lb/min X } \frac{1 \text{ ft}^3}{60.6 \text{ lb}} \text{ X } \frac{1 \text{ min}}{60 \text{ sec}}}{9.62 \text{ X } 10^{-4} \text{ ft}^2} = 2.75 \text{ ft/sec}$$

$$\Delta p = 1.5 \left(\frac{\rho V^2}{2g}\right) \text{ X } \frac{1}{144} \qquad \left(\frac{\rho}{2g} \text{ X } \frac{1}{144}\right) = .654 \text{ X } 10^{-2} \frac{\text{lb sec}^2}{\text{ft}^2 \text{in}^2}$$

$$\Delta p = 1.5 (2.75)^2 (.654 \text{ X } 10^{-2}) = .075 \text{ lb/in}^2$$

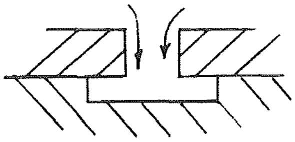
Turns in header



neglect - area relatively large

$$\left(V = \frac{10}{60 \text{ X } 60.6 \text{ X } .01 \text{ ft}^2} = .275 \text{ ft/sec}\right)$$

Entrance to 1/4" diameter holes



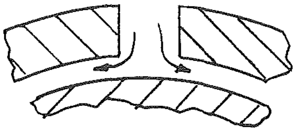
1 1/2 velocity heads

$$\text{area} = (.25)^2 \frac{\pi}{4} \text{ X } \frac{1}{144} \text{ X } 5 = .00170 \text{ ft}^2$$

$$V = \frac{10 \text{ lb/min X } \frac{1}{60.6} \text{ X } \frac{1}{60}}{.00170 \text{ ft}^2} = 1.61 \text{ ft/sec}$$

$$\Delta p = 1.5(1.61)^2 (.654 \text{ X } 10^{-2}) = .0254 \text{ lb/in}^2$$

Turn into smaller area of cooling passage



1 1/2 velocity heads for decrease in area

1 1/2 velocity heads for turn

$$\text{area} = \frac{.05 \text{ X } .5 \text{ X } 10}{144} = .001735 \text{ ft}^2$$

$$V = \frac{10}{60 \text{ X } 60.6 \text{ X } .001735} = 1.57 \text{ ft/sec}$$

$$\Delta p = 3\text{X}(1.57)^2 (.654 \text{ X } 10^{-2}) = .0484 \text{ lb/in}^2$$

Exit from last header

Same as entrance, $\Delta p = .0744 \text{ lb/in}^2$

Total dynamic drop

| | |
|---|---|
| entrance to first header | .0750 psi |
| 1/4" diameter holes (X2 for 2 sets) | .0508 |
| entrance and turn-cooling passage (X2 for 2 sets) | .0968 |
| exit from last header | .0744 |
| | .2970 |

Total pressure drop

6.08 psi (viscous) + .2970 psi (dynamic)

= 6.377 psi

Say 6.38 psi

5. Pole Face Losses

a. No Load

No load pole face losses have been calculated from a formula derived by W. J. Gibbs (Reference 3) which after changing to English units appears as follows:

$$P_e = \frac{1.57}{10^3} \quad \frac{(DB_2\ B_m)^3}{\rho\ N_a} \quad \left(\frac{n}{1000}\right)^2$$

where: $P_e$ = eddy current loss (watts/in$^2$)

$D$ = diameter (in)

$B_2$ = flux oscillation factor (Fig. 3 of Reference 1)

$B_m$ = Average flux density in pole face (Kl/in$^2$)

$\rho$ = Resistivity of pole face (microhm - cm)

$N_a$ = number of stator slots

$n$ = Speed (rpm)

Substituting the alternator values:

$$P_e = \frac{1.57}{10^3} \quad \frac{(5.2 \text{ X } .0583 \text{ X } 65)^3}{50 \text{ X } 48} \quad \left(\frac{12,000}{1000}\right)^2 = 0.72 \text{ watts/in}^2$$

No load loss = $P_e$ X Area of poles
No load loss = 0.72 X (2 X 2.86 X 4) = 16.5 watts

b. Load Loss

Load loss was calculated by computer as shown on Figure 56 and the loss amounted to 46 watts.

c. Total Pole Face Loss

Total loss is the sum of no load and load loss. Since the above calculations are for a solid pole face, the values were reduced by a lamination factor of three (3). In addition, tests on a previous alternator (solid pole construction) indicated pole face loss about double the calculated value. Including these factors yields the following for pole face loss:

$$\text{Total loss} = 2(16.5 + 46)/3 \approx 40 \text{ watts}$$

```
HARMONIC MMFS AND LOAD POLE FACE LOSSES   DECK 3013-0-0 PAGE 1
PROBLEM NUMBER 2    ENGINEER LJ YEAGER          DATE 3-12-65
MODEL NUMBER 2CM393A1

STATOR SLOTS  48   PHASES 3   POLES  4   RATED SPEED 12000   N/MAX 99
COIL PITCH  8(SLOTS)   WINDING REPEATS 2 TIMES
CURRENTS IN STATOR COILS
 1   1   1   1   2-  2-  2-  2-  3   3   3   3   1-  1-  1-
 1-  2   2   2   2   3-  3-  3-  3-

ROTOR DIA  5.200   GAP  .040   ROTOR LENGTH  3.950   PUPA  .350
SURFACE RESISTIVITY  50.000
FUNDAMENTAL ARMATURE MMF   746.0,      .0,      .0,      .0,      .0

PROB NUMBER 2       DECK NUMBER 3013-0-0                         PAGE  1
OUTPUT FOR MMF =    746.0
KP  .8660   KD  .9577   KW  .8294    LOAD POLE FACE LOSS    46 WATTS

  N  POLES  FORWARD BACKWARD     KPN      KDN      KWN        TORQUE/N
  1     4   1.0000   0.0000    .8660    .9577    .8294       .0000000
  2     8   0.0000   0.0000    .8660    .0000    .0000       .0000000
  3    12   0.0000   0.0000    .0000    .0000    .0000       .0000000
  4    16   0.0000   0.0000    .8660    .0000    .0000       .0000000
  5    20   0.0000  -0.0429    .8660    .0000    .0000       .0645598
  6    24   0.0000   0.0000    .0000    .0000    .0000       .0000000
  7    28   0.0235   0.0000    .8660    .1576    .1365       .0083407
  8    32   0.0000   0.0000    .8660    .0000    .0000       .0000000
  9    36   0.0000   0.0000    .0000    .0000    .0000       .0000000
 10    40   0.0000   0.0000    .8660    .0000    .0000       .0000000
 11    44   0.0000  -0.0120    .8660    .0000    .0000       .0009924
 12    48   0.0000   0.0000    .0000    .0000    .0000       .0000000
 13    52   0.0101   0.0000    .8660    .1261    .1092       .0004675
 14    56   0.0000   0.0000    .8660    .0000    .0000       .0000000
 15    60   0.0000   0.0000    .0000    .0000    .0000       .0000000
 16    64   0.0000   0.0000    .8660    .0000    .0000       .0000000
 17    68   0.0000  -0.0097    .8660    .0000    .0000       .0003694
 18    72   0.0000   0.0000    .0000    .0000    .0000       .0000000
 19    76   0.0113   0.0000    .8660    .2053    .1778       .0004484
 20    80   0.0000   0.0000    .8660    .0000    .0000       .0000000
 21    84   0.0000   0.0000    .0001    .0000    .0000       .0000000
 22    88   0.0000   0.0000    .8661    .0000    .0000       .0000000
 23    92   0.0000  -0.0435    .8660    .0000    .0000       .0172984
 24    96   0.0000   0.0000    .0001    .0001    .0000       .0000000
 25   100   0.0400   0.0000    .8661    .9577    .8294       .0116901
 26   104   0.0000   0.0000    .8660    .0001    .0000       .0000000
 27   108   0.0000   0.0000    .0001    .0000    .0000       .0000000
 28   112   0.0000   0.0000    .8661    .0000    .0000       .0000000
 29   116   0.0000  -0.0074    .8660    .0000    .0000       .0000748
 30   120   0.0000   0.0000    .0001    .0000    .0000       .0000000
 31   124   0.0053   0.0000    .8661    .1576    .1365       .0000235
 32   128   0.0000   0.0000    .8660    .0000    .0000       .0000000
 33   132   0.0000   0.0000    .0001    .0000    .0000       .0000000
 34   136   0.0000   0.0000    .8661    .0000    .0000       .0000000
 35   140   0.0000  -0.0038    .8660    .0000    .0000       .0000072
```

FIGURE 56

## SECTION V

## Voltage Regulator-Exciter Design

### A. Voltage Regulator Design Objectives

Reliability was the primary objective in the design of the VRE. Although not stated explicitly in the specification, it was recognized that the mission of the Brayton Cycle System was similar to others, whose specifications called for a reliability goal of 99.90% for a 10,000 hour mission.

This requirement for high reliability, combined with the need to operate in a space environment, led to the following design decisions:

1. Eliminate materials known to degrade rapidly in space and radiation environments.
2. Use as few different materials and components as possible. Use materials and parts proven radiation-resistant on other NASA programs.
3. Derate all components drastically.
4. Use redundancy wherever possible.
5. Weld all connections.

To approach this reliability, the problem was attacked both theoretically and practically. The theoretical approach involved investigation of established or predicted failure rates for various components plus a study of the benefits of redundancy.

The practical approach considered the advantages of circuit simplicity, elimination of known component failure modes or weaknesses, quality control, derating, burn-in, and restrictive purchase part specifications.

The reliability program is discussed in detail in "B" of this section. From Table VI the predicted reliability is 99.78 percent.

### 1.0 Voltage Regulator

The voltage regulator consists of the following circuits:

a. Sensing Circuit
b. Reference circuit
c. Comparison Circuit and Transistor Preamplifier
d. Magnetic Amplifier Circuit
e. Stabilizing Circuit
f. High Phase Takeover Circuit

#### Sensing Circuit

The sensing circuit shown in Figure 44 measures the average of three RMS line-to-neutral voltages and produces a DC voltage proportional to this average.

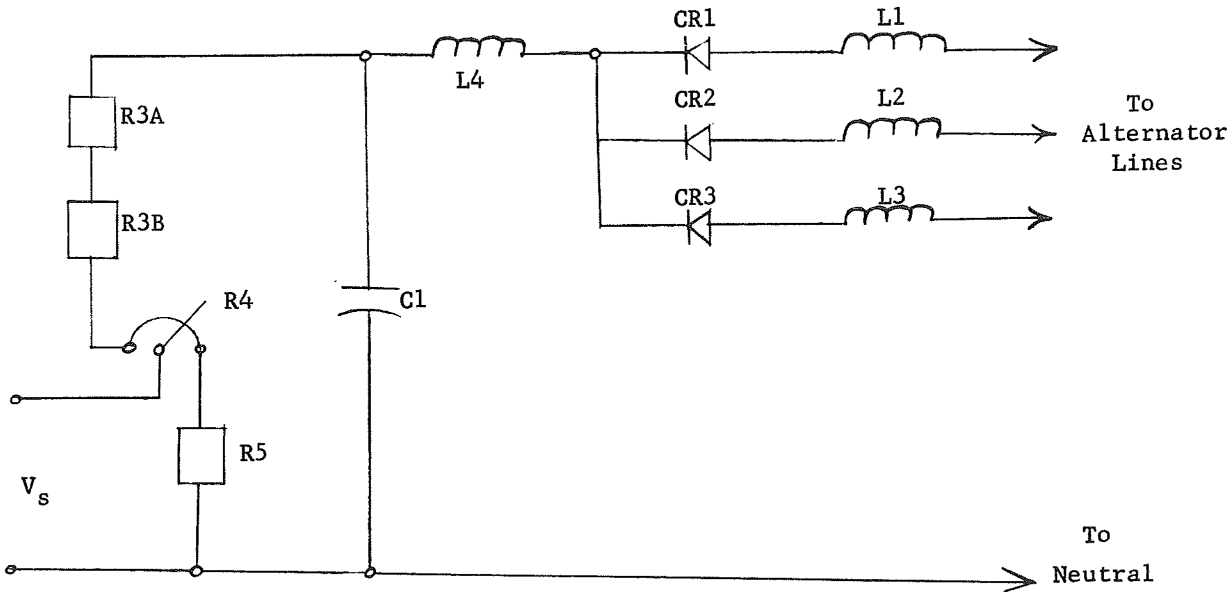


FIG. 44 SENSING CIRCUIT

Rectifiers CR1-3 produce a DC voltage which is filtered by L4 and C1. The filtered DC voltage across C1 is applied to a voltage divider consisting of resistors R3A, R3B, R4 and R5. The sensing voltage, $V_s$, is applied to the comparison circuit.

L1, L2 and L3 are RF chokes designed to prevent electromagnetic interference generated by the rectifiers from reaching the lines.

## Reference Circuit

The reference circuit, shown in Figure 45, provides an essentially constant reference voltage.

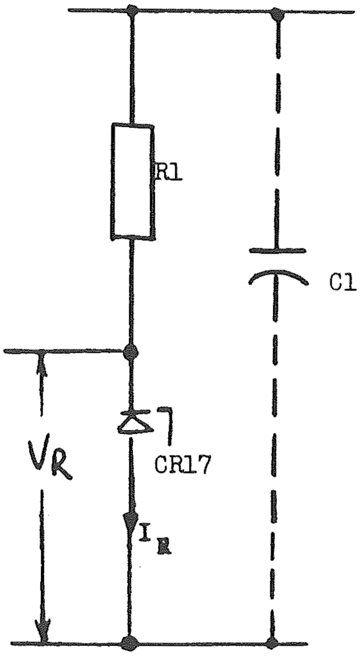


FIG. 45 REFERENCE CIRCUIT

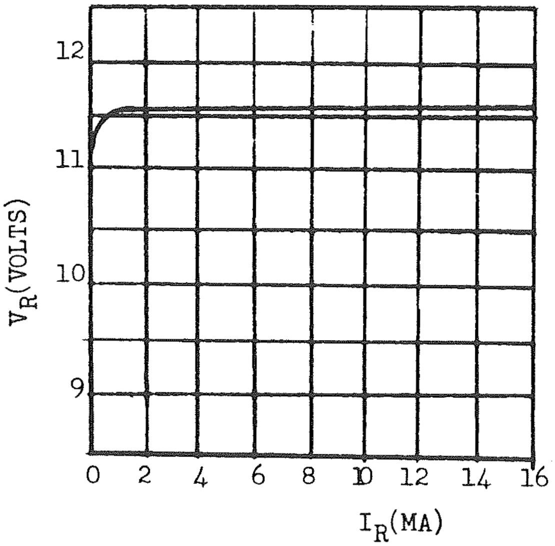


FIG. 46 ZENER DIODE CHARACTERISTICS

The filtered DC voltage across C1 in the sensing circuit is also applied across R1 in series with zener diode CR17. CR17 has a nearly constant 11.7 volt drop for a large range of current as shown in Figure 46. Resistor R1 limits the current thru CR17 to a safe value. If the voltage applied across R1 and CR17 increases, the current increases, and the increase in voltage is absorbed as IR drop across R1. The voltage across CR17 remains almost constant because of its flat characteristic.

## Comparison Circuit & Transistor Preamplifier

The comparison circuit shown in Figure 47 compares the sensing voltage to the reference voltage and delivers an error current, $I_B$, to the transistor base emitter circuit.

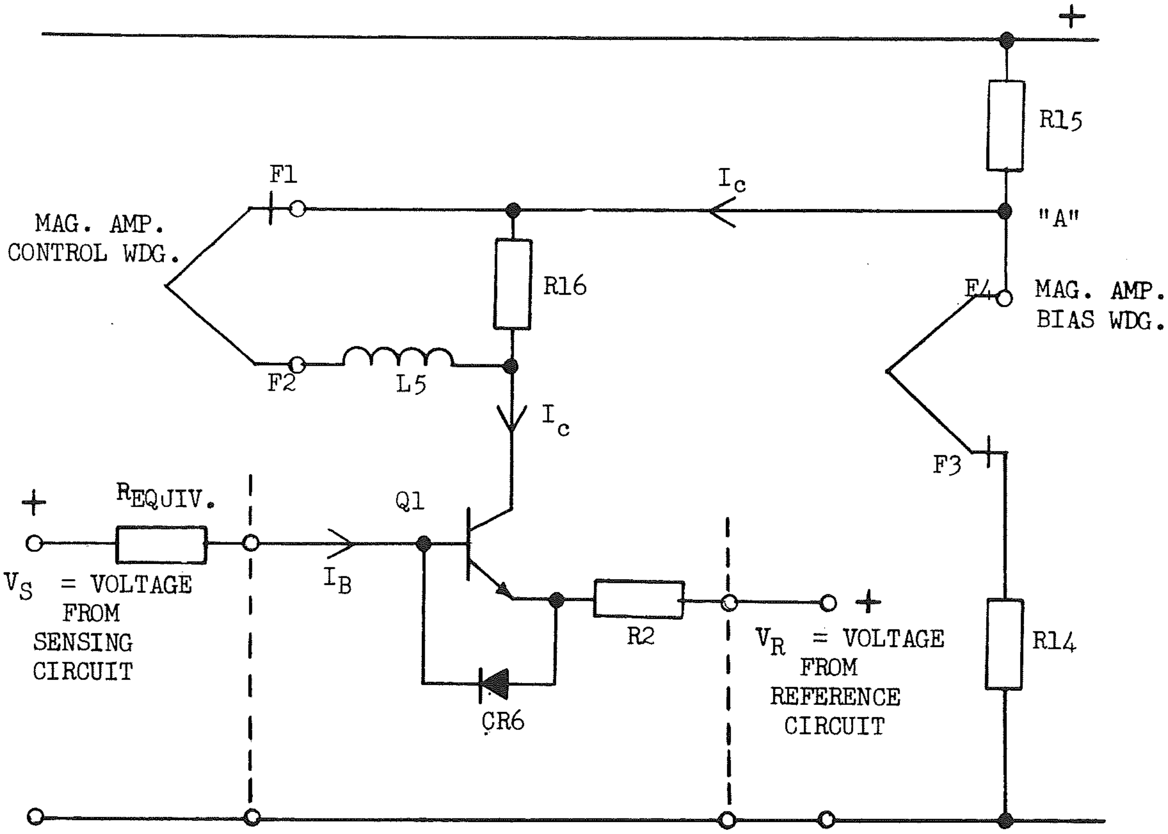


FIG. 47 COMPARISON CIRCUIT AND TRANSISTOR PREAMPLIFIER

The reference and comparison circuits have a common negative as shown in Figure 47, while the positive sides are connected through the base-emitter circuit of transistor Q1 and resistor R2. When $V_S$ exceeds $V_R$, current $I_B$ flows in the direction shown.

The transistor amplifies the small error current to the level required to control the magnetic amplifier. The small signal current $I_B$ flowing in the base-emitter circuit controls the much larger current $I_C$ flowing in the collector-emitter circuit.

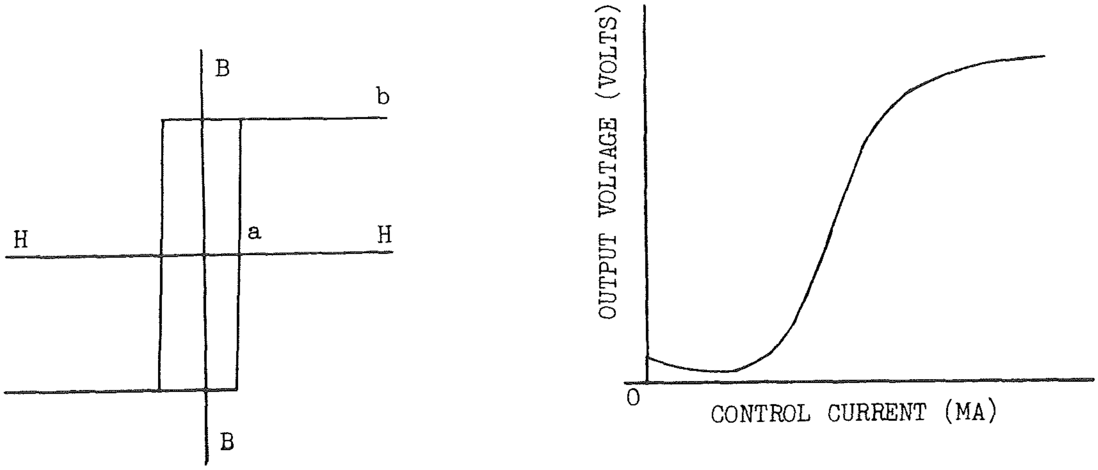
Resistors R15 and R14 form a voltage divider which reduces the voltage level at "A" to a value well with the rating of Q1. R15 and R14 also set the current to bias winding F3-F4 of the magnetic amplifier. Transistor collector current $I_C$ flows from point "A" through winding F1-F2 of the magnetic amplifier to regulate its output.

Resistor R16 and reactor L5 provide for smooth magnetic amplifier control. Resistor R2 stabilizes the gain of the transistor and CR6 protects against reverse voltage across the base-emitter circuit.

### Magnetic Amplifier

The exciter control winding requires changes in the order of amperes. The milliampere collector current is changed to ampere error current by the magnetic amplifier shown in Figure 49.

The magnetic amplifier gate windings act as switches (or gates) between the supply voltage and the load. If the core flux is on the steep slope (a) of the saturation curve, Figure 48, the gate winding has a very high inductance and the load current is limited to a very low value. If the core flux is on the flat portion (b) of the saturation curve, the gate winding has a low inductance and the load current is limited mainly by the load resistance.



(a) B-H LOOP

(b) **MAGNETIC AMPLIFIER CONTROL CHARACTERISTIC**

FIG. 48 CHARACTERISTIC CURVES OF A MAGNETIC AMPLIFIER

The flux in the core is determined by the current in the gate, bias and control windings. With the control and bias windings open, the core flux is determined solely by the current in the gate windings.

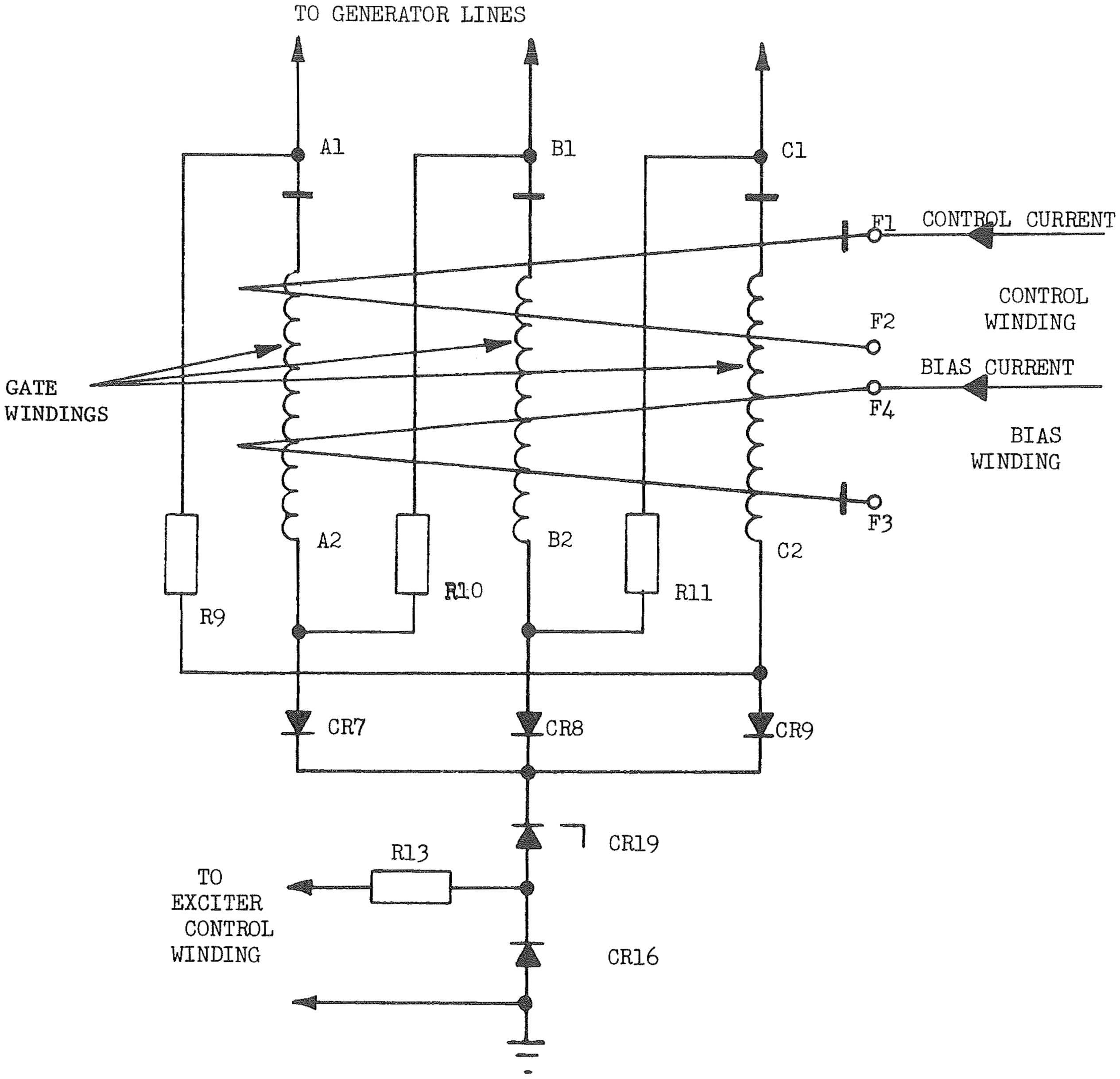


FIG. 49 MAGNETIC AMPLIFIER

The supply voltage is applied to the gate windings in series with the load. After the supply voltage wave passes through zero and becomes positive, a small magnetizing current proportional to supply voltage flows in the gate windings. This small current is rectified and quickly saturates the core. With the core saturated, the gate winding inductance drops to a low value and gate (or load) current is determined only by the load resistance and supply voltage. Thus with no bias or control current, the cores are saturated for all but the first few degrees of the supply voltage wave and the output is a maximum.

The bars on A1, B1, C1, F1 and F3 indicate that these terminals have the same polarity, or that current into any of these terminals produces flux in the core in the same direction. In Figure 47 , bias current flows into F4 and out of F3 of the bias winding and therefore produces flux which opposes the flux due to the magnetizing or load current. The magnetizing current must, therefore, increase to a larger value before the core saturates, so saturation occurs later in the cycle. If the bias current is increased sufficiently, it will not allow the magnetizing current to saturate the core at all, so the gates will remain "closed" to load current for the entire half cycle.

In Figure 47, control current (transistor collector current) flows into F1 and out of F2 of the control winding and therefore produces flux which aids the magnetizing current and opposes the bias current. An increase in control current therefore advances the angle at which saturation occurs (the firing angle) and permits a larger average load current. By varying the control current, the magnetic amplifier can be made to fire from approximately 0 to 180 degrees of the applied voltage. In this way, the control winding current controls the output current of the magnetic amplifier.

In Figure 49, rectifiers CR7, 8, 9 rectify the gate current to provide the required DC output and resistors R9, R10 and R11 reset the cores. R13 sets the proper output current level and improves the power factor of the exciter control winding. CR16 is a free wheeler which provides a discharge path for the inductance in the exciter control winding and CR19 is a zener diode which increases the load impedance at low current to improve the magnetic amplifier performance.

The complete operation of the voltage regulator can now be traced. If the alternator voltage increases, the error current increases in a direction to turn on the transistor and magnetic amplifier. The magnetic amplifier output current increases, decreasing the output of the exciter. The exciter output current is the alternator field current. With reduced field current, the alternator line voltage returns to normal.

## Stabilizing Circuit

In any closed-loop regulating system containing more than two significant time constants and having relatively high gain, there is a possibility of sustained oscillation, or "hunting". To prevent this condition, a stabilizing circuit is connected between the exciter output and the transistor input as shown in Figure 50.

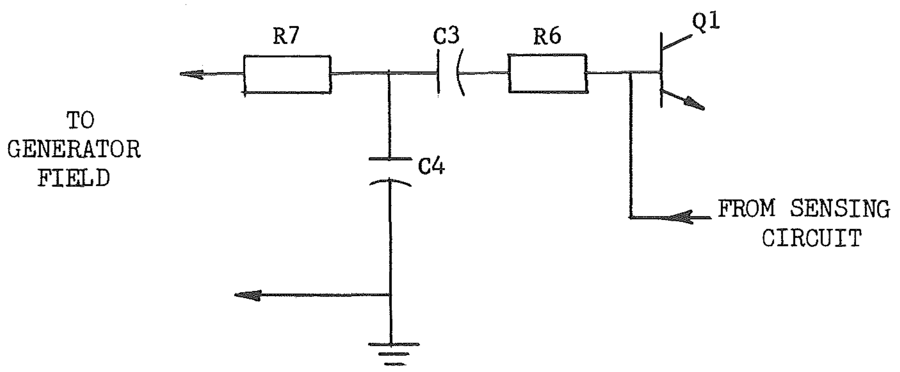


FIG. 50 STABILIZING CIRCUIT

A momentary increase in line voltage causes a corresponding increase in the sensing voltage applied to the transistor base. This increase in base voltage increases transistor current and magnetic amplifier output current which in turn decreases the exciter output, which is the generator field voltage.

A decrease in alternator field voltage is equivalent to the addition of a negative voltage at the field. This negative voltage is applied to the transistor base through C3 and R6 where it transiently opposes the initial increase in base voltage, thereby providing negative feedback to stabilize the system.

## High Phase Takeover Circuit

During normal operation, the voltage across C1 in the sensing circuit is the average value of the three rectified RMS line voltages, due to the filtering action of L4 and C1. The regulator therefore maintains the average of the three RMS line-to-neutral voltages at 120 volts. If one phase voltage decreases, due to a short or open circuit, the regulator acts to increase the other two phase voltages to bring the average back up to normal. Under these abnormal conditions, the high phase takeover circuit takes over control and acts to limit the voltage on the highest phase to 10% above normal. The high phase takeover circuit is shown in Figure 51.

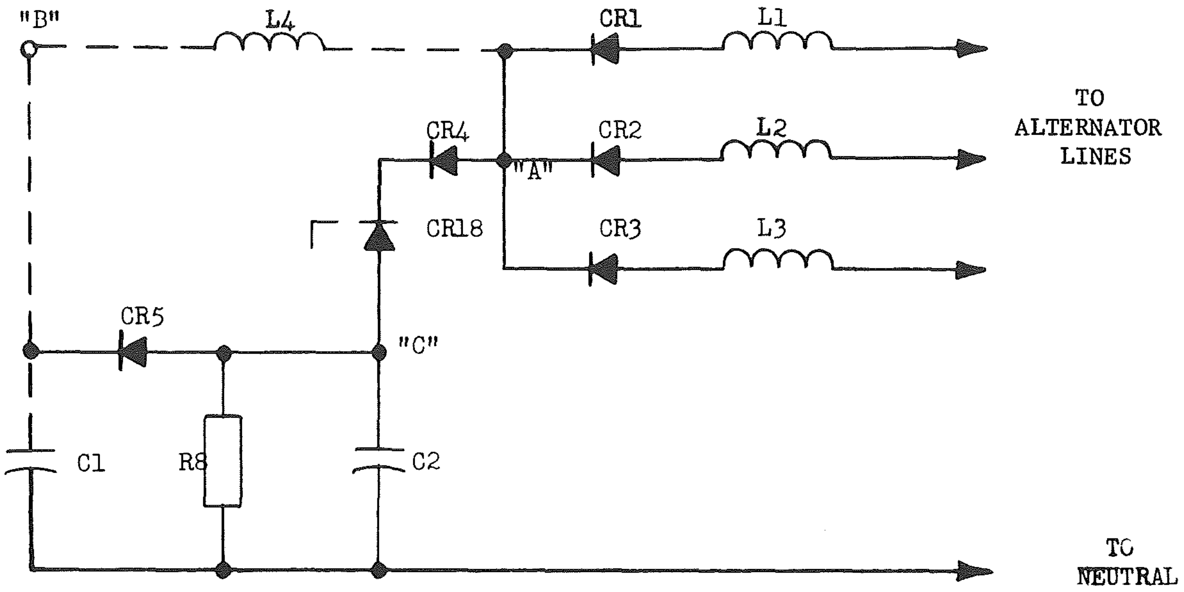


FIG. 51 HIGH PHASE TAKEOVER CIRCUIT

R8 and C2 are selected so that C2 charges up to the peak value of the voltage applied across it. The peak voltage does not change when one of the phase voltages is lost. The voltage at "C" is the peak voltage at "A" less the voltage across zener diode CR18.

During normal conditions, the average value of the three phase voltages, appearing across C1, is larger than the voltage at C2, so diode CR 5 blocks and the high phase takeover circuit has no effect.

When one of the phase voltages goes to zero, the regulator acts to increase the average to the set value. At approximately 110% normal voltage, the voltage across C2 exceeds the voltage across C1, and current flows through CR5 connecting the two. The voltage across C2 then becomes the sensed voltage for the regulator, and the regulator then acts on the alternator to prevent further increase.

2. Static Exciter

The static exciter, Figure 52 supplies field excitation power for the alternator by rectifying a combination of voltage and current signals from the alternator output and feeding the result back to the alternator field. The components of the static exciter are:

a. The saturable current potential transformer (SCPT) in which the voltage and current signals are combined vectorially and into which a control signal from the regulator is introduced.

b. Three-phase bridge rectifier (CR10-15) which rectifies the exciter output.

c. Three-phase linear reactor L7 for shifting each line voltage input signal with reference to the current input signal.

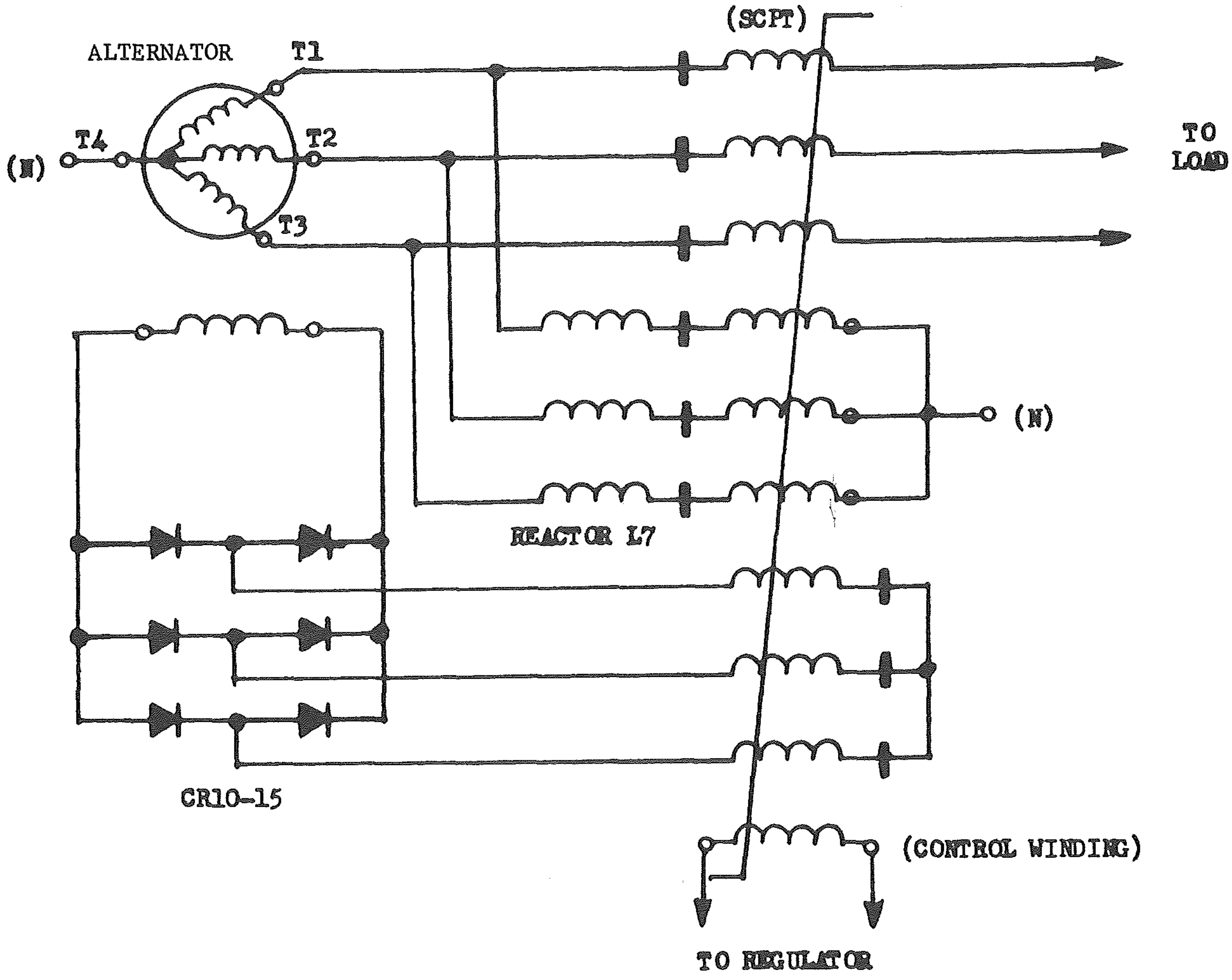


FIG 52 STATIC EXCITER

The SCPT is essentially a three-phase transformer with two primary and one secondary winding per phase and a single control winding which is used to vary the outputs of all three phases. The current and potential (voltage) windings are the two primaries and the secondary winding is the output winding.

A signal which is a function of line voltage is applied to the potential windings through the linear reactors and this input is combined with the current input obtained by running the entire line currents through each of the corresponding windings. The output of the SCPT is fed via the secondary winding to the three-phase rectifier and from there to the alternator field.

The voltage and current signals are proportioned so that for rated loads, at rated 400 hertz frequency, the exciter will supply almost constant voltage. However, a control signal is furnished by the regulator to improve system accuracy, to compensate for field temperature and line drop variations, and to provide transient forcing.

If the alternator output voltage tends to rise:

a. The control signal from the regulator increases.

b. The SCPT becomes more saturated.

c. The exciter output decreases.

d. The field current decreases lowering the alternator output.

If the alternator output voltage tends to fall, the opposite changes take place.

The exciter is also a compensator because it attempts to hold the alternator voltage constant at constant frequency for all loads within the rating of the alternator. It utilizes both the voltage and current output of the alternator in such a manner that the output of the exciter is approximately correct for any load.

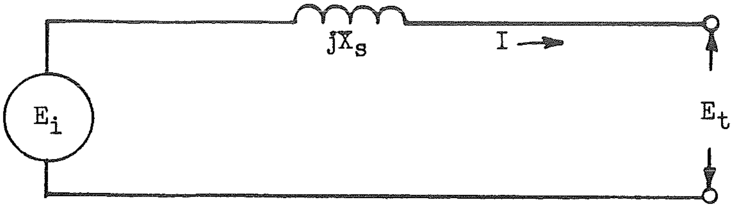
It is well-known that the alternator internal voltage drop $V_x$ can be represented by the equation:

$$V_x = jX_sI$$

where $X_s$ is the synchronous reactance and I is the line current. This equation assumes a cylindrical rotor, no saturation, and no resistance in the armature winding. To compensate for the voltage drop $V_x$, the excitation must provide an internal voltage $E_i$ as shown by the vector diagram in Figure 53

$$E_i = E_t + jX_sI$$

This internal voltage $E_i$ is proportional to the field excitation when no saturation is present.



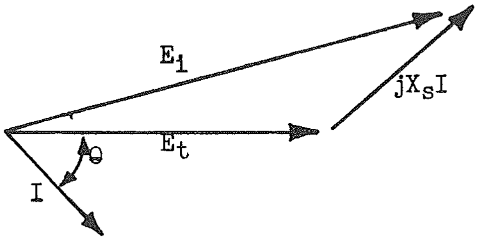


FIG. 53 VECTOR DIAGRAM OF VOLTAGES IN ALTERNATOR

The single phase equivalent circuit for the exciter is shown in Figure 54 This circuit has a voltage source and a current source that represent the excitation obtained from the alternator voltage and alternator current. $X_L$ is the reactance in series with the voltage source, $X_M$ is the magnetizing reactance of the SCPT that is varied by the DC control current, and R is the equivalent AC resistance of the alternator field. With no load on the alternator, the excitation is supplied entirely by the voltage source. When the load is applied, the current source supplies a current that divides between $X_L$, $X_M$, and R. It is easily shown that the current source can be made to supply the synchronous impedance drop by applying Thevenin's Theorem at points X in Figure 54. The revised equivalent circuit, with the current source replaced by the equivalent voltage source, is shown in Figure 55 If $X_M$ is constant, it is evident that the current through R will be proportional to $E_t + jX_LI$. By selecting the proper values for $X_L$ and the turns ratio, $jX_LI$ can be made proportional to $jX_sI$ and the exciter will supply the correct excitation at all loads.

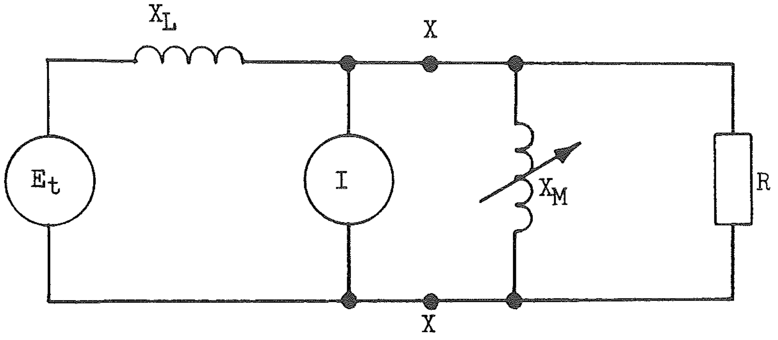


FIG. 54 SINGLE PHASE EQUIVALENT CIRCUIT

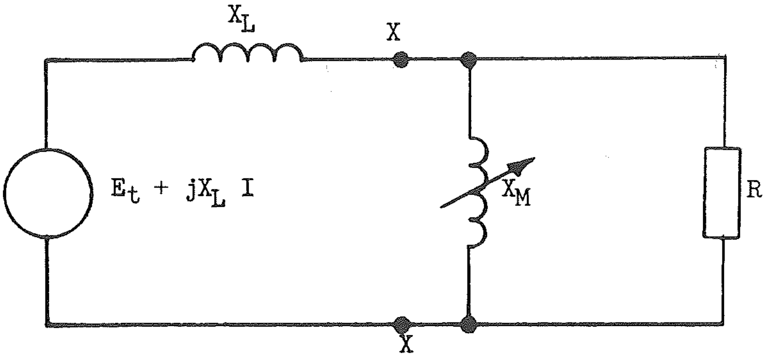


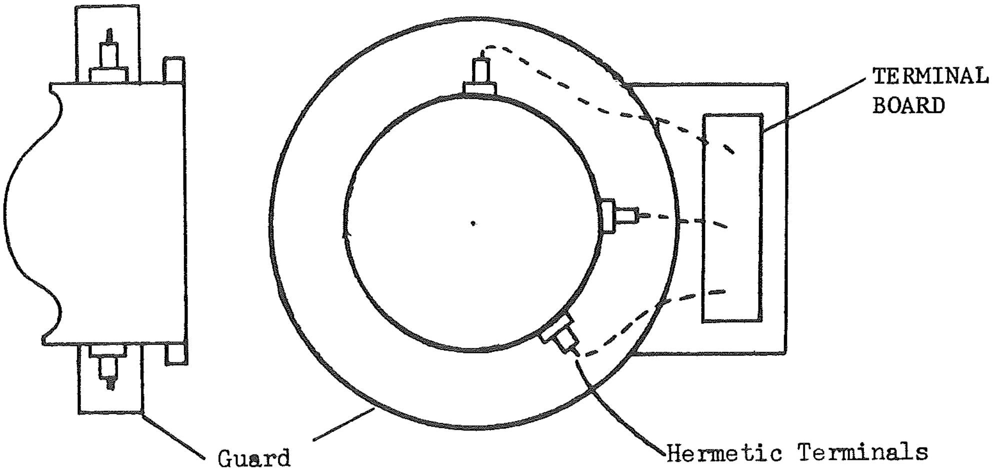
FIG.55 EQUIVALENT THEVENIN CIRCUIT

## 3.0 Special Problem Areas

Special problems developed in several design areas. These problems are discussed below.

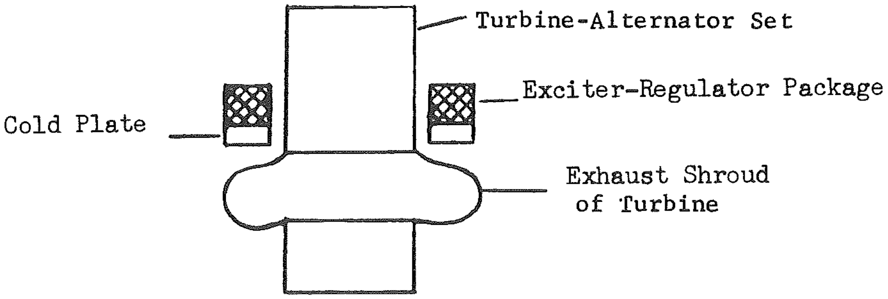
### Excessive Shadow

The original design of both voltage regulator and static exciter called for a sealed enclosure with leads brought out through hermetically sealed terminals. Furthermore, the relatively fragile terminals were to be protected by a guard and jumpers were to be connected to the hermetic terminals and brought out to a terminal board for customer connection. The proposed arrangement is sketched below.



In the proposed overall Brayton Cycle system plan, the voltage regulator would be mounted with its bottom surface perpendicular to a line drawn from the system to the sun and would therefore cast a large shadow on the solar collector.

Several alternate designs were proposed, including a doughnut shaped enclosure which would fit around the turbine-alternator. The enclosure would fit within the outline of the exhaust shroud and therefore would not increase the shadow. The design is sketched below.



In another approach, General Electric proposed that the component modules be built to withstand the space environment, including high vacuum, so the sealed enclosure could be eliminated. This approach was approved by NASA. At the same time, a potentiometer was added so the line voltage could be varied and the potting level was changed to expose test points to permit more flexibility in ground testing. Because of these changes the present "flyable" VRE's should be considered as thermal and electrical breadboards, rather than as flight hardware.

## Amplifier Gain

The amplifier circuit originally proposed for the Brayton Cycle regulator was all magnetic and did not use any transistors. During breadboard tests, it soon became evident that the regulator gain was marginal. The main reason for the gain deficiency was poorer than expected performance from the three phase magnetic amplifier.

Accordingly, a transistor pre-amplifier was added to the circuit. Although all evidence indicates that the transistor will operate satisfactorily in the radiation environment of similar NASA programs, it should be tested before the Brayton Cycle regulator is applied to a nuclear system.

## B. Voltage Regulator-Exciter

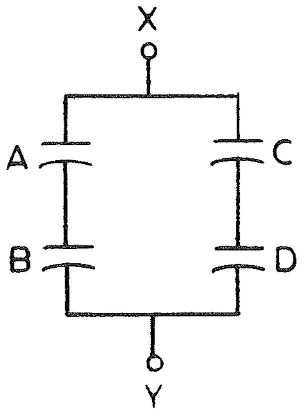
## Design Calculations and Analysis

### 1.0 Stability Analysis

A Bode analysis of the system was made to determine how to stabilize the system and eventually to specify the stabilizing components. The attenuation diagram of the main loop is shown in Figure 57 while the inner (stabilizing) loop is shown in Figure 58 .

Three values are given for stabilizing capacitor C3. In the flyable units, C3 is a redundant quad as shown below, with A, B, C and D each equal to 10 µf.

If redundancy is to improve the reliability, the circuit must be capable of operating when at least one arm of the quad fails. In the table next to the quad, the values of the capacitance measured from x to y are tabulated for various stated failures.



| CONDITION | CXY |
|---|---|
| NO FAILURES | 10 UF |
| A OPEN | 5 UF |
| A SHORT | 15 UF |
| A & C SHORT | 20 UF |
| A OPEN,<br>C SHORT | 10 UF |

In a minimum phase system, if the slope of the attenuation curve is 20 db/decade at crossover, the system will be stable.

The curves in Figure 57 show, and tests confirm, that the system is stable for the values of C shown. The block diagram of the system is shown on Figure 20 in Section III.

BRAYTON CYCLE SYSTEM
ATTENUATION DIAGRAM (MAIN LOOP)

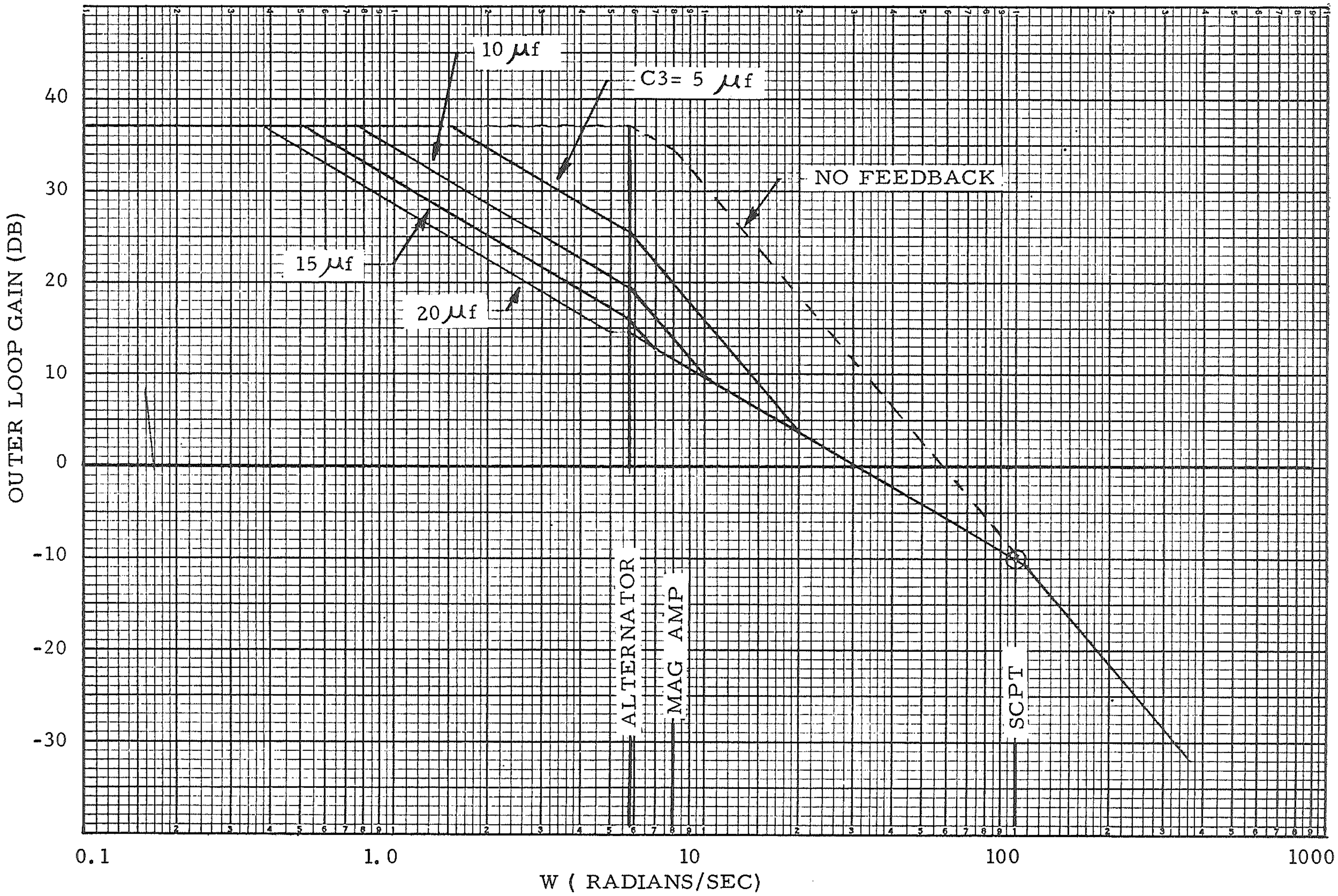


FIGURE 57

## BRAYTON CYCLE SYSTEM

## ATTENUATION DIAGRAM ( INNER LOOP)

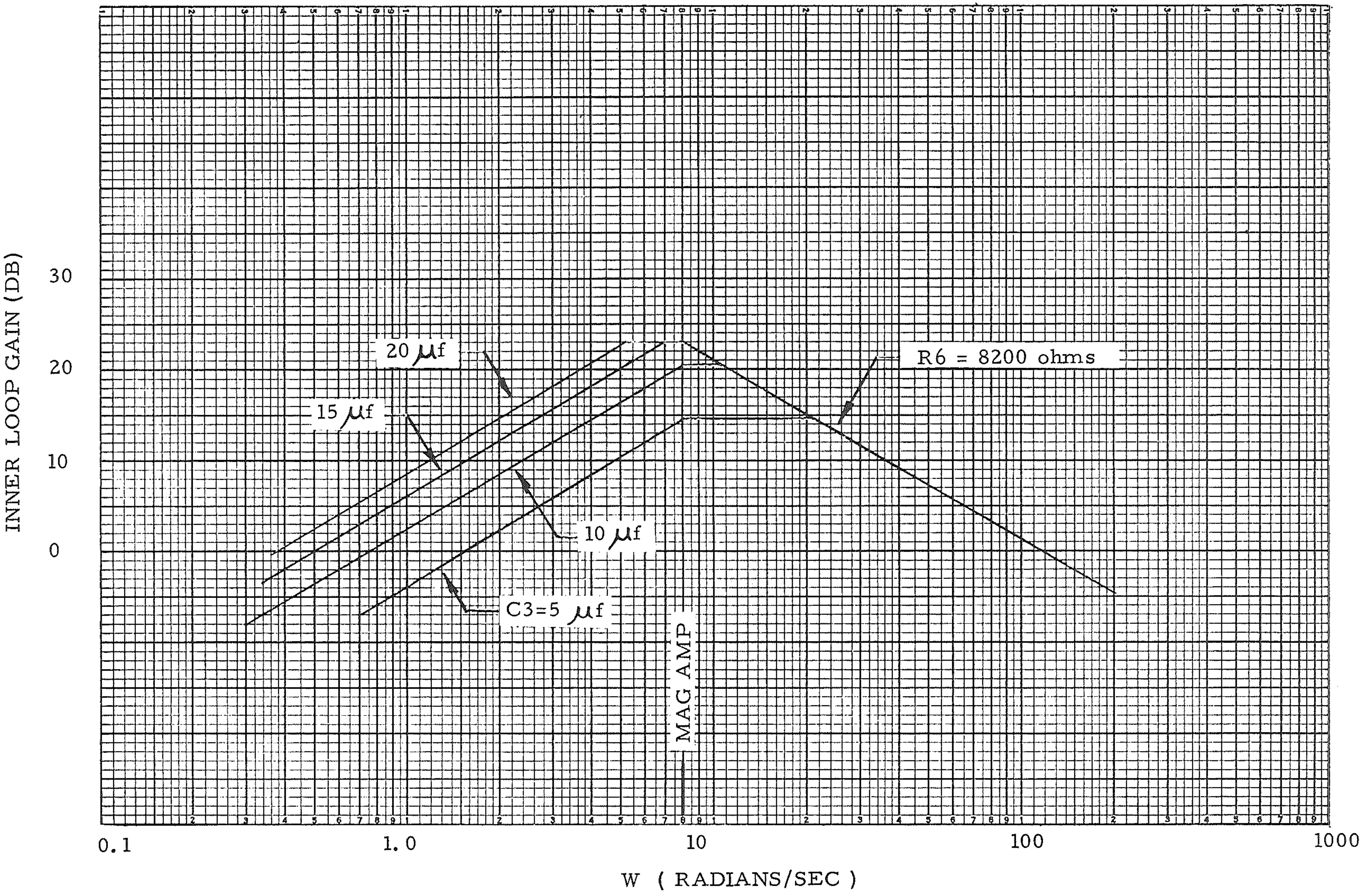


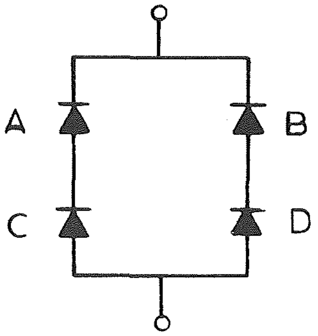
FIGURE 58

A summary of the control component stresses, the application limits for these parameters and the calculated or measured stresses are tabulated in Table V This table confirms that all component stresses are very low.

Reliability estimates were made early in the program and were revised as the design progressed. The results from the final analysis are shown in Table VI. In this table, it is assumed that the voltage adjustment potentiometer has been eliminated.

From the beginning, it was obvious that the extremely high reliability goal could not be approached by standard methods, so redundancy techniques were investigated. Strictly speaking, redundant means superfluous. In the field of reliability, a redundant circuit is one which has extra components so connected that the circuit will operate normally when some components fail.

A typical example is the rectifier quad shown below.



A quad is used for each rectifier in the circuit. If rectifier A opens, rectifiers B and D will still fulfill the rectifier function and allow the circuit to operate. If rectifier A shorts, rectifier C will still allow normal operation. Certain multiple failures such as shorted A plus open B or D, may occur without destroying the component function.

The rectifiers are applied so that any one rectifier in the quad will carry the required current and voltage by itself, so a failure will not overload another component so that it too fails. In the tabulations shown in this report, the stresses shown assume that the total stress is taken by a single component.

Figure 59 illustrates how the failure rate can be reduced by redundancy. If failure rate of an individual rectifier is .02%, the quad will have a failure rate of .00001%.

Most of the regulator circuits are designed so they will tolerate a 20% change in resistance. A parallel combination of ten resistors is used for each resistor, so any two may fail open without exceeding the circuit tolerance. The increase in reliability due to this configuration is shown in Figure 60.

Using a resistor with a failure rate of .02%/1000 hurs., the failure rate of 10 in parallel becomes .00001%, if a 20% increase in resistance is allowable.

Only wirewound or film type resistors are used since it is nearly impossible for them to short.

TABLE V

COMPONENT STRESSES

| COMPONENT | CRITICAL STRESS | APPLICATION LIMIT | CALCULATED OR MEASURED STRESS |
|---|---|---|---|
| R1 | $\frac{\text{Operating Power}}{\text{Rated Power}}$ | 0.2 | .092 |
| R2 | | | .0024 |
| R3, 4 | | | .04 |
| R5 | | | .009 |
| R6 | | | .008 |
| R7 | | | .008 |
| R8 | | | .045 |
| R9, 10, 11 | | | .045 |
| R13 | | | .113 |
| R14 | | | .07 |
| R15 | | | .135 |
| R16 | | | .00016 |
| CR1-3 | $\frac{\text{Operating PRV}}{\text{Rated PRV}}$ | 0.5 | .56 |
| CR4 | | | .22 |
| CR5 | | | .03 |
| CR6 | | | .002 |
| CR7-9 | | | .58 |
| CR10-15 | | | .20 |
| CR16 | | | .30 |
| CR1-3 | Junction Temperature | 90°C | 75°C |
| CR4 | | | 75 |
| CR5 | | | 75(Stud) |
| CR6 | | | 75(Stud) |
| CR7-9 | | | 75(Stud) |
| CR10-15 | | | 90(Stud) |
| CR16 | | | 80(Stud) |

## TABLE V (Continued)

## COMPONENT STRESSES

| COMPONENT | CRITICAL STRESS | APPLICATION LIMIT | CALCULATED OR MEASURED STRESS |
|---|---|---|---|
| CR1-3 | $\frac{\text{Operating Current}}{\text{Rated Current}}$ | 0.5 | .011 |
| CR4 | | | .004 |
| CR5 | | | 0 (Blocked) |
| CR6 | | | 0 (Blocked) |
| CR7-9 | | | .014 |
| CR10-15 | | | .17 |
| CR16 | | | .021 |
| CR17 | $\frac{\text{Operating Power}}{\text{Rated Power}}$ | 0.5 | .18 |
| CR18 | | | .014 |
| CR19 | | | .054 |
| CR17 | Junction Temperature | 90 | 80°C |
| CR18 | | | 75 |
| CR19 | | | 98 |
| Q1 | Junction Temperature | 90 | 75 |
| Q1 | $\frac{\text{Operating Power}}{\text{Rated Power}}$ | 0.5 | .104 |
| Q1 | $\frac{\text{Collector-Emitter Volt}}{\text{Rated Voltage}}$ | 0.5 | 0.5 |
| C1 | $\frac{\text{Operating Voltage}}{\text{Rated Voltage}}$ | .2 | .13 |
| C2 | | .2 | .20 |
| C3 | | .5 | .15 |
| C4 | | .2 | .04 |
| L1-L3 | Operating Temperature (70°C Cold Plate) | Not Specified | 72 |
| L4 | | | 75 |
| L5 | | | 74 |
| L6 | | | 103 |
| L7 | | | 109 |
| SCPT | | | 88 |

## TABLE VI

## PREDICTED RELIABILITY

| Part | Quantity | FAILURE RATE<br>%/1000 Hrs. | TOTAL<br>%/1000 Hrs. |
|---|---|---|---|
| **Magnetics** | | | |
| Inductor | 3 | 0.001 | 0.0030 |
| Filter Choke | 1 | 0.001 | 0.0010 |
| Snap Choke | 1 | 0.001 | 0.0010 |
| Mag. Amp. | 1 | 0.003 | 0.0030 |
| Linear Reactor | 1 | 0.003 | 0.0030 |
| SCPT | 1 | 0.009 | 0.0090 |
| **Resistors** | | | |
| Metal Film 1 Watt | 7 (Redundant) | Neg. | Neg. |
| Metal Film 1/8 Watt | 4 (Redundant) | Neg. | Neg. |
| Wirewound 10 Watt | 3 | 0.0004 | 0.0012 |
| Wirewound 10 Watt | 1 (Redundant) | Neg. | Neg. |
| **Capacitors** | | | |
| Glass (500V) | 1 (Quad) | Neg. | Neg. |
| Mylar Extended Foil | 1 (Double Quad) | Neg. | Neg. |
| Tantalum Etched Foil | 1 (Quad) | Neg. | Neg. |
| Mylar Extended Foil | 1 (Quad) | Neg. | Neg. |
| **Semiconductors** | | | |
| Transistor (Silicon) | 1 | 0.0002 | 0.0002 |
| Diode Rectifier Silicon | 6 (Quad) | Neg. | Neg. |
| Diode Zener Silicon 10W | 1 | 0.0002 | 0.0002 |
| Diode Rectifier Silicon | 10 (Quad) | Neg. | Neg. |
| Diode Zener Silicon | 1 | 0.0002 | 0.0002 |
| Diode T.C. Zener Silicon | 1 (4 in series) | 0.0004 | Neg. |
| TOTAL | | | 0.0218 |

$$\text{MEAN TIME BETWEEN FAILURE} = \frac{1 \times 10^5}{0.0218} = 4{,}590{,}000 \text{ hrs.}$$

Reliability for 10,000 hours

$$R = 1-\lambda t = 1-0.02.8 \times 10^{-5} \times 10^4 = 0.99782$$

"NEG" means negligible

FAILURE RATE FOR REDUNDANT QUAD

(10,000 HR. MISSION)

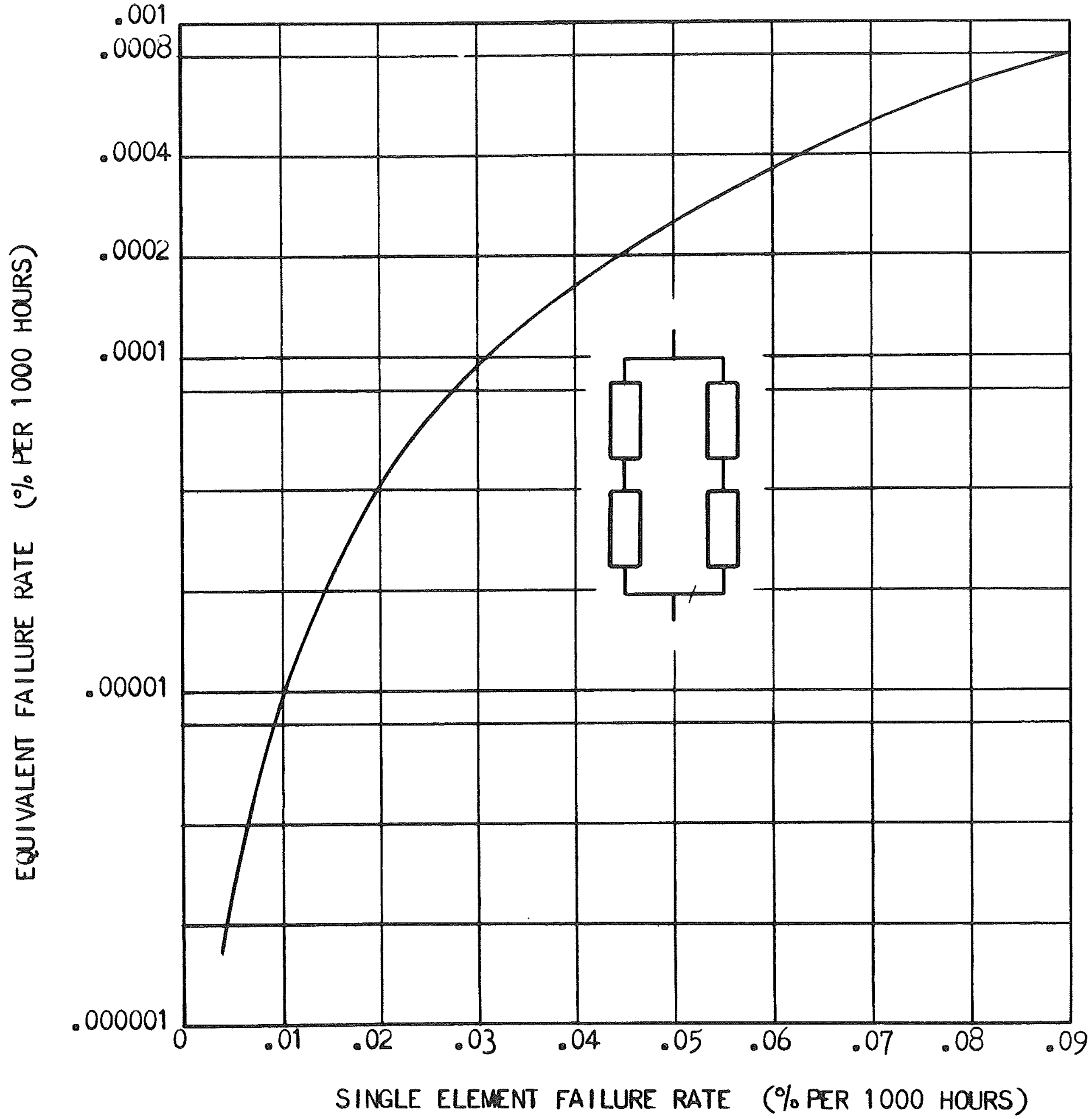


FIGURE 59

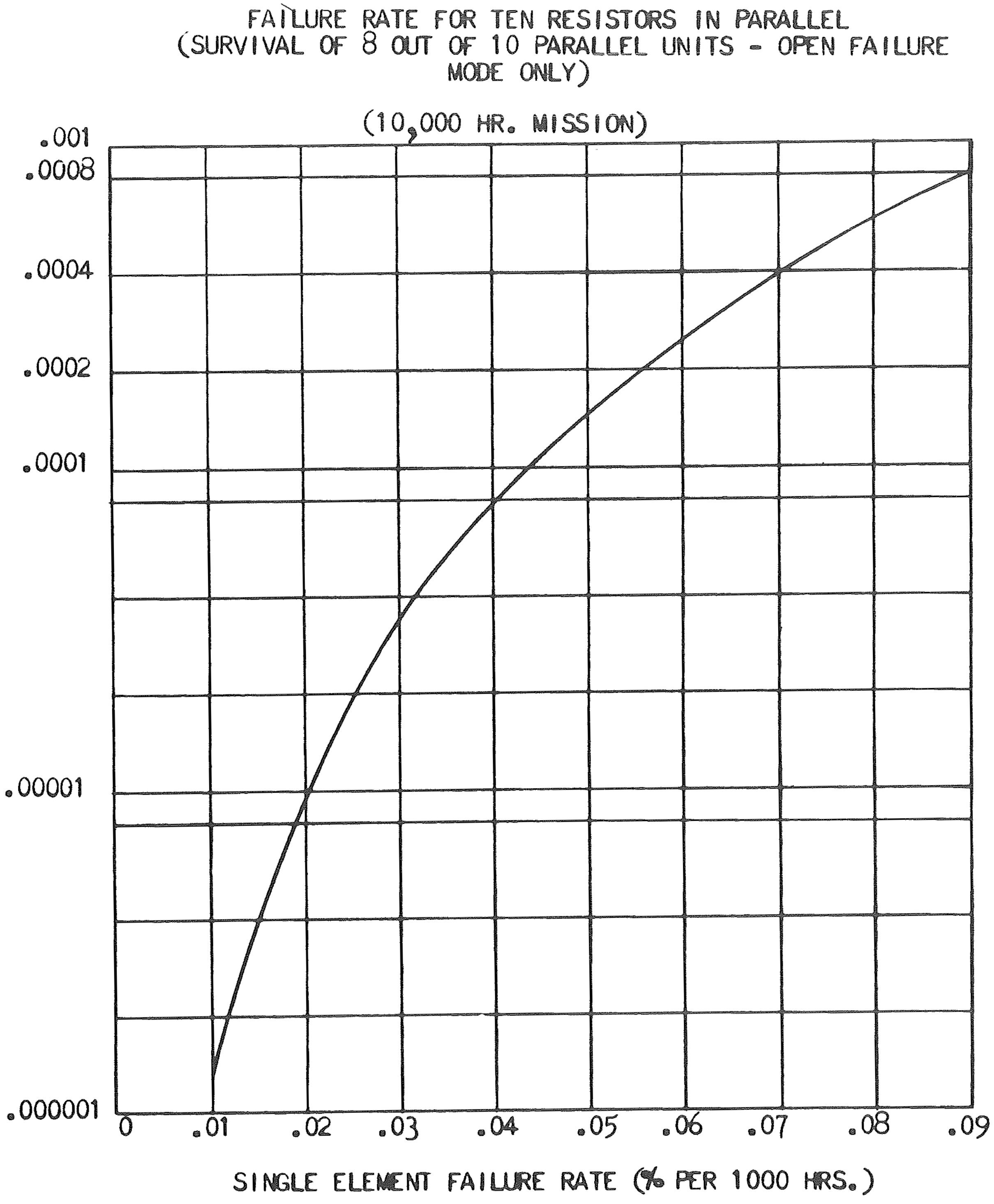

FAILURE RATE FOR TEN RESISTORS IN PARALLEL
(SURVIVAL OF 8 OUT OF 10 PARALLEL UNITS - OPEN FAILURE MODE ONLY)
(10,000 HR. MISSION)
.001
.0008
.0004
.0002
.0001
.00001
.000001
EQUIVALENT FAILURE RATE (% PER 1000 HOURS)
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
SINGLE ELEMENT FAILURE RATE (% PER 1000 HRS.)

FIGURE 60

## 3.0 Static Exciter Design

The single phase equivalent circuit of the static exciter is given in Figure 54. To use this equivalent circuit for design, the alternator excitation characteristics must be converted to their AC equivalent, using the following equations.

$$V_{fac} = .429\ V_{fdc} \qquad (1)$$

$$I_{fac} = .78\ I_{fdc} \qquad (2)$$

$$R = .55\ R_{fdc} \qquad (3)$$

The table below lists the results of these calculations.

Generator Excitation Requirements

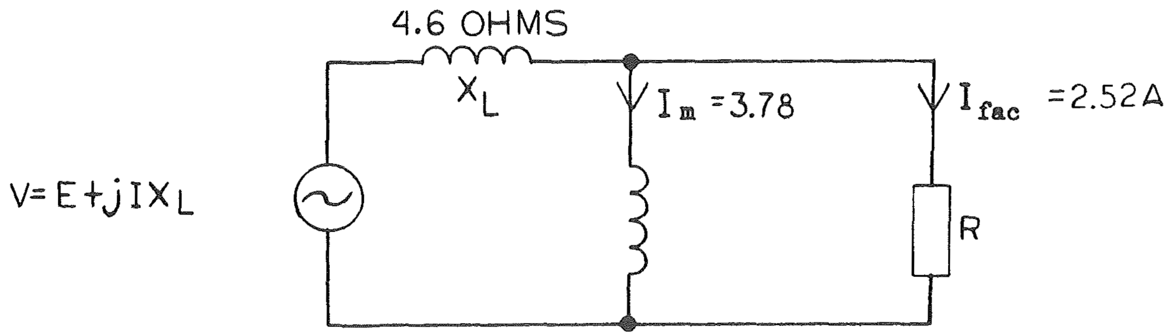
| LOAD | Field Temp. | DC VALUES<br>Field R | <br>Field I | <br>Field V | <br>Corr. Field V | AC VALUES<br>Field V | <br>Field I | <br>Field R |
|---|---|---|---|---|---|---|---|---|
| No Load | Cold | 3.26 | 3.35 | 10.5 | 12.5 | 5.67 | 2.52 | |
| | Hot | 4.97 | 3.35 | 16.1 | 18.1 | 8.17 | 2.52 | 3.24 |
| Rated Load | Cold | 3.26 | 6.38 | 20.1 | 22.1 | 9.95 | 4.8 | |
| | Hot | 4.97 | 6.38 | 30.6 | 32.6 | 14.73 | 4.8 | 3.07 |
| Double Load | Cold | 3.26 | 9.70 | 31.6 | 33.6 | 15.2 | 7.56 | |
| | Hot | 4.97 | 9.70 | 48.2 | 50.2 | 22.8 | 7.56 | 3.01 |
| 3 PU 30 Short | Hot | 4.97 | 9.53 | 47.4 | 49.4 | 22.3 | 7.44 | |
| 4 PU 30 Short | Hot | 4.97 | 12.72 | 63.2 | 65.2 | 20.5 | 9.92 | |

For proper forcing, $X_L$ should be 1.5 to 2.5 x R, and $I_m$ should be 1.0 to 1.5 times $I_{fac}$ at no load. The values chosen were:

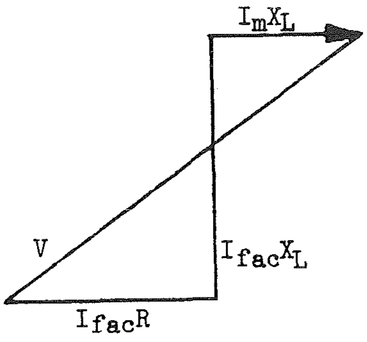
$$X_L = 1.5R = 1.5(3.07) = 4.6 \text{ ohms} \qquad (4)$$

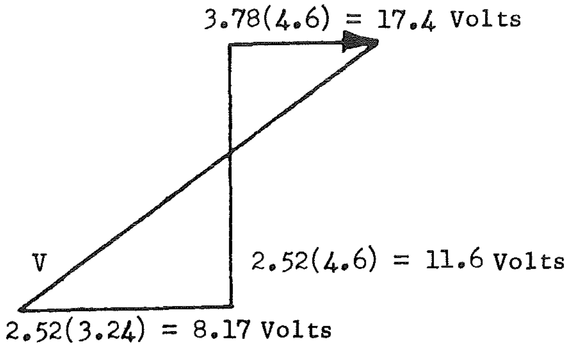
$$I_m = 1.5 \quad I_{fac} = 1.5(2.52 \text{ amps}) = 3.78 \text{ amps} \qquad (5)$$

The equivalent circuit for the no load condition with numerical values inserted is shown below.



At no load, I = 0, and all excitation comes from the primary (voltage) winding. The vector diagram is shown below.





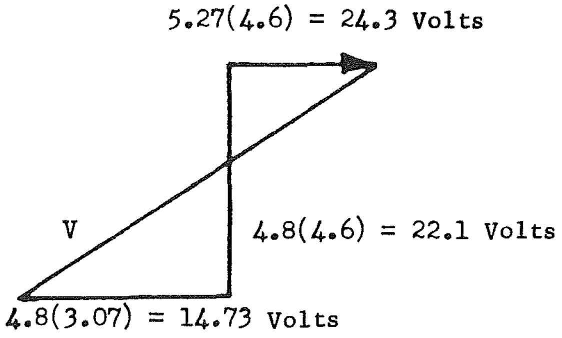
$$V = \sqrt{(8.17 + 17.4)^2 + (11.6)^2} = 28.1 \text{ v} \qquad (6)$$

The exciter, therefore, must supply 28.1 volts at its secondary terminals at no load. Since the primary voltage is 120V,

$$\frac{N_P}{N_S} = \frac{120}{28.1} = 4.27$$

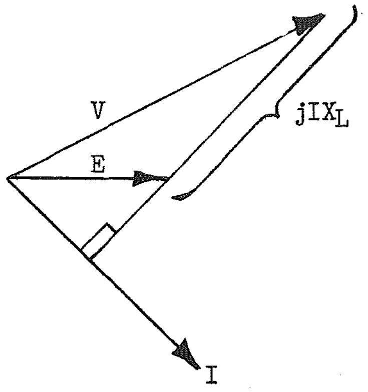
where $N_P$ = primary turns and $N_S$ = secondary turns.

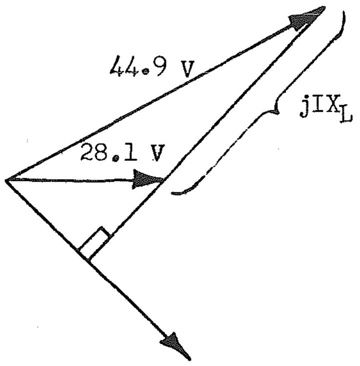
At full load, a higher field current is required, and the excitation is furnished from both primary (voltage) and current windings. Also, $I_m$ will automatically increase since the voltage across it will increase, and some provision should be made for this, if the exciter is to compensate automatically. From experience, $I_m$ at full load is 1 to 2 times $I_m$ at no load. In this design, $I_m$ = 5.27. The excitation requirements at full load are shown below.



$$V = \sqrt{(14.73 + 24.3)^2 + (22.1)^2} = 44.9 \text{ Volts} \quad (8)$$

V, in the secondary, will be supplied by both primary and current windings according to the relation $V = E + jIX_L$. The phase angle $\theta$, by which line current lags line-neutral voltage, is the power factor angle and is specified. The relationships are shown in the diagram below.





By graphical methods, it is determined that $jIX_L = 22.0$ Volts

$$I = \frac{24.0}{X_L} = \frac{24.0}{4.6} = 5.22 \text{ Amps.} \quad (9)$$

For **reliability**, the minimum number of turns should be used on the current windings. For this size exciter, one turn is impractical, so two turns are used.

$$\frac{N_S}{N_I} = \frac{I_I}{I_S} = \frac{41.7}{5.22} = 8.0 \quad (10)$$

where the subscript I refers to the current winding. It was previously shown that $\frac{N_P}{N_S} = 4.27$.

Choosing $N_I = 2$, $N_S = 8.0\ (2) = 16.0$ (Use 16) Turns

$$N_P = 16.0\ (4.27) = 68.3 \text{ (Use 68) Turns} \quad (11)$$

The saturation voltage of the exciter is to be 27V and silicon steel is to be used which has a saturation flux density B = 125 000 lines per square inch.

$$V_{sat} = 4.44\ N_S A f B \times 10^{-8} \tag{12}$$

where:

A = effective iron area (square inches)

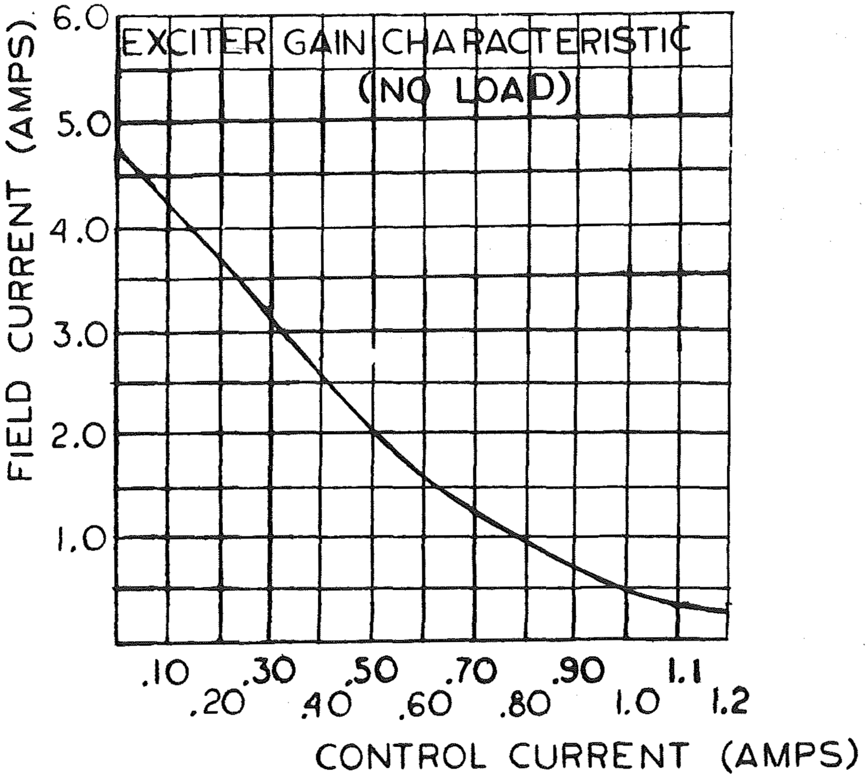
f = frequency hertz

Therefore, $$A = \frac{V \times 10^8}{4.44 N_S f B} = \frac{27 \times 10^8}{4.44(16)\ (400)\ (125\ 000)} = .78\ \text{in}^2 \tag{13}$$

Core AH-19 with a gross area of .844 inches **and a stacking factor** of 0.9, has the correct net iron area.

The difference in control current at no-load and at rated load did not exceed 10%, indicating a very high degree of self-compensation in the static exciter.

The exciter gain characteristic is shown below.



## 4.0 Magnetic Amplifier Design

The magnetic amplifier gate windings must withstand line-neutral voltage and are designed using the same methods outlined for the SCPT. The basic equation for the saturation voltage is repeated below:

$$V = 4.44\ NAfB \times 10^{-8}$$

where B is flux density in gauss and A is iron area in square centimeters, and f is the frequency in Hz. Since the regulator must operate down to 320 Hz, this frequency is used in the calculation. In addition, a saturation flux density of 13900 gauss is used since it is the minimum allowed by the specification.

$$NA = \frac{V \times 10^8}{4.44fB} = \frac{120 \times 10^8}{4.44(320)\ (13\ 900)} = 608 \qquad (15)$$

For reasons that are stated later, it is desirable to use as small a core punching as possible. With a DU-37 industry standard punching, a stack height of 1.4 inches yields a gross cross sectional area of 3.35 square centimeters and a net cross-sectional area of 3.04 square centimeters.

$$N = \frac{608}{3.04} = 200 \text{ turns} \qquad (16)$$

The window of the DU37 punching will accommodate the required 200 gate turns with sufficient space left for the control winding. A further trial and error solution confirms that the DU-37 is the smallest punching that can be used, with losses low enough to maintain a low temperature rise. A small punching has a small magnetic path length, which yields higher gain.

From the stability and gain analysis, a magnetic amplifier gain of 500ma/ma is required. The maximum magnetic amplifier output current will be approximately 1400 ma.

$$G = \text{gain} = \frac{\text{output current}}{\text{control current}} = \frac{I_o}{I_C} \qquad (17)$$

$$I_c = \frac{I_o}{G} = \frac{1400}{500} = 2.8 \text{ ma} \qquad (18)$$

Furthermore,

$$N_c I_c = .8\ Hl \qquad (19)$$

where

$N_c$ = number of control winding turns,

$I_c$ = control current, amperes,

$H$ = Half-width of B-H loop, oersteds, and

$l$ = Length of magnetic path, cm.

For DU-37 orthonol lamination, at 400 cps,

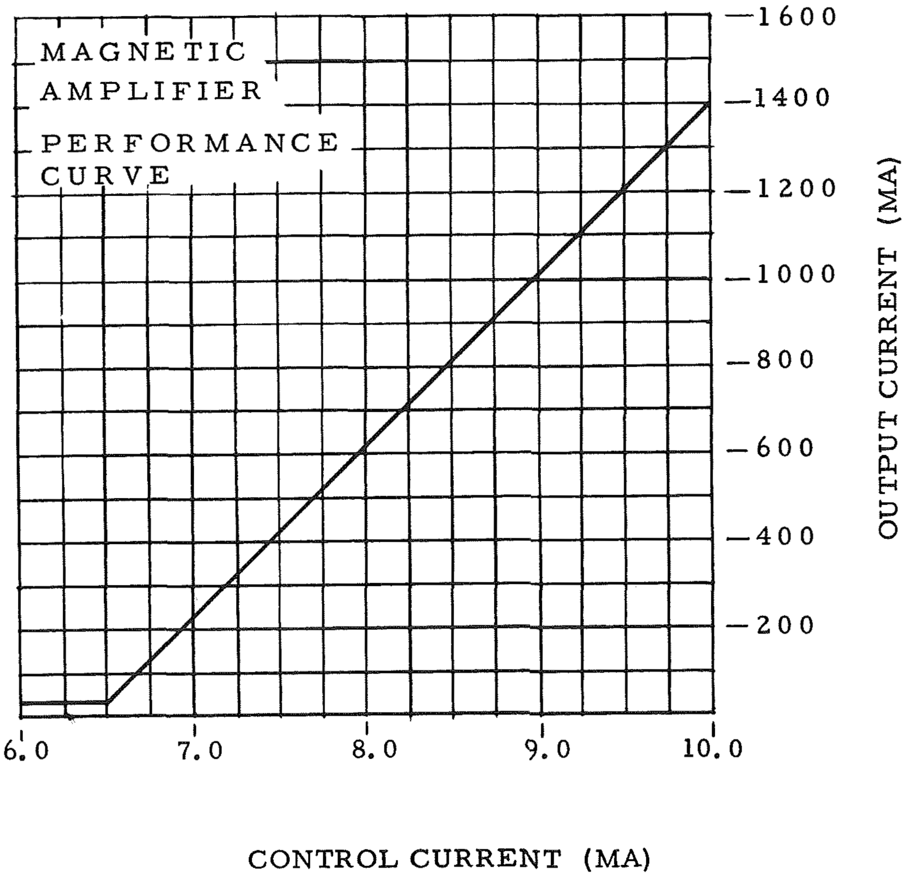
$$N_c I_c = .8(.25) \quad (17.2) = 3.44 \text{ ampere turns} \qquad (20)$$

$$\text{and } N_c = \frac{3.44}{2.8} = 1230 \text{ turns} \qquad (21)$$

An unbiased magnetic amplifier would be fully on with zero control current and negative ampere turns would be required to turn it off. In this application, the opposite sense is required by the system, so a bias winding is added and sufficient current is applied to it to turn the magnetic amplifier off.

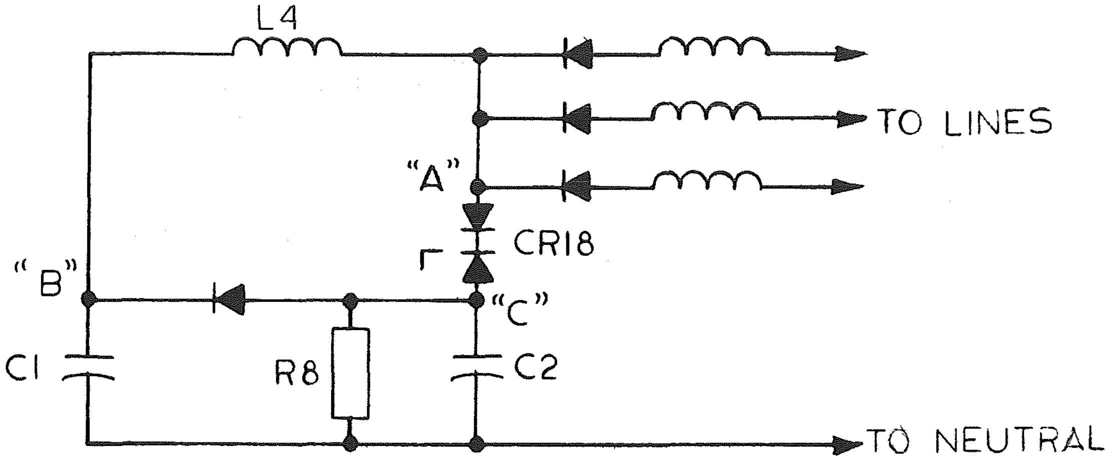
Positive control current then opposes the bias winding ampere turns and turns the magnetic amplifier on. When bias and control winding amperes turns are equal, the magnetic amplifier will be fully on.

The magnetic amplifier gain characteristic is shown below:



## 5.0 High Phase Takeover Circuit

The normal sensing and high phase takeover circuits are shown below.



During normal operation, the voltage at "A" is filtered by L4 and C1, so average voltage appears at "B".

The high phase takeover circuit voltage is the voltage at "C" and is equal to the peak voltage at "A" less the drop in the zener diode CR18.

At the normal 120 volt line voltage, the average voltage at B is 134 volts.

To operate properly the voltage at "C" must be considerably less than 134 volts normally and must be 134 volts at the high phase takeover voltage setting.

During normal conditions, the peak voltage at A is $120\sqrt{2} = 170$ volts, so CR18 must be a minimum of 36 volts to be inactive.

The high phase takeover point was set at 108-110% of normal voltage. At 109% voltage, the peak voltage is 170 (1.09) = 185 volts. A 51 volt zener diode was used to reduce this to the desired 134 volt level.

R8 and C2 are selected so peak voltage is maintained across them even with one phase voltage removed.

# SECTION VI

## TEST RESULTS AND DISCUSSIONS

### 1. Acceptance Tests

The ARP successfully passed the acceptance test specified in Section VIII. In addition, the In-House stator, Engineering Breadboard VRE, and Load Bank also passed the acceptance tests outlined in Section VIII and qualified for use in a gas bearing test rig.

### 2. VRE Development Tests

In general, VRE development tests are made to accomplish the following objectives:

a. Measurement of circuit characteristics for comparison with predicted values.

b. Circuit optimization.

c. Determination of component stresses.

d. Proof that components and construction are adequate for the expected environment.

e. Proof that generated environments (such as Electromagnetic Interference) are within the specification limits.

f. Matching of VRE and alternator for optimum performance.

g. Proof that the complete system meets the requirements of the specification

Development testing has been completed to accomplish objectives a, b, f, g and part of c.

All system gains and time constants were measured. The results are shown on the block diagram, Figure 20. These results are for the final circuit after all changes were made.

The component electrical stresses were measured and the values are recorded in Table V of Section V. The component temperatures given in Table V, however, are calculated and should be proven by a fully instrumented heat run. The calculation method was checked by a single test on one module. Test temperatures were very close to predicted values.

No tests have been run to prove that the flyable VRE will withstand the shock, vibration and accoustical noise environment. It is assumed that these tests will eventually be run as part of the complete system tests. If this system is to be applied to a nuclear source, radiation susceptability tests should be run on all components not previously proved adequate in other NASA programs.

Electromagnetic Interference (EMI) from radiated noise can be reduced by shielding of all interconnections. Conducted noise levels can be reduced by addition of RF chokes in the sensing leads. Chokes have been installed in the sensing leads on the Brayton Cycle system and the enclosures are suitable for connection to shielded cable or conduit. No EMI tests are called for on the contract.

## B. Performance Tests

### a. Alternator

Figure 21 shows the saturation curves obtained on the In-House ARP and indicate that double rated load was achieved with little difficulty. During the rated load test, the maximum thermocouple winding temperature was about 120°C based on a coolant temperature of 93°C (200°F). Such a relatively low temperature indicates the possibility of double rated load continuous rating although the life and efficiency would be reduced. Efficiency over a range of loads is shown in Figure 22 . This data was taken at the Lewis Research Center, NASA, Cleveland, Ohio, and shows at least a 90% efficiency obtained from 5 to 15 KVA, and the maximum efficiency occurring at 11.25 KVA, .8 power factor as called for in the specifications. The alternator met all specifications except the following:

(1) Unbalanced Loads
(2) Maximum Individual Harmonic

Although an amortisseur winding was placed in the machine, it acted primarily in the direct axis due to the location on the rotor poles and did not provide sufficient amortisseur reaction. No attempt was made to place an amortisseur in the quadrature axis due to additional rotor complexity, so early in the program power quality was traded for reliability. A similar situation occurred with harmonic content where skewing of either the rotor or stator was eliminated for reliability reasons. Stator skewing would have complicated the coil insertion procedure for the two stator stacks, and rotor skewing the electron beam welded pole tips. As a result, a strong stator slot harmonic (the 25th) occurred throwing the alternator out of specification at the no load condition (Table III).

b. Voltage Regulator-Exciter

Two types of tests are discussed, the open loop tests on the VRE and the closed loop tests with the VRE controlling the alternator

The open loop tests prove out the wiring of the VRE and assure that performance of the components is normal. The closed loop test is the proof test of the system where the performance can be measured in terms of the specifications.

Both open and closed loop tests were performed on the Breadboard VRE. Open loop test results are included in Section VIII for record purposes and will not be discussed further.

The closed loop tests are detailed on drawing 44A351303 which is included in Section VIII. Briefly, these tests are:

1. Initial Tests
2. Emergency Shutdown
3. High Phase Takeover
4. Range and Steps of Adjustment
5. Frequency Effect
6. Regulation
7. Voltage Modulation
8. Unbalanced load
9. Transient Tests
10. Short Circuit Tests

The results of these tests are shown in the figures which follow and in Table III.

In the initial test, the alternator is brought up to speed and then the field is flashed. The regulator action is checked superficially and the voltage adjustment is checked for proper rotation and operation. In all tests so far, flashing was not required after the first time.

In the emergency shutdown test, the input to the SCPT is shorted by relay contacts provided for this purpose. This reduces the exciter output to zero which reduces the alternator voltage to its residual value and effectively removes voltage from the line. In all tests so far, when the relay was de-energized to remove the short, the alternator voltage returned to normal without flashing.

In the test of the high phase takeover circuit, voltage is first set to normal with all phases intact. One sensing lead is then removed. The breadboard VRE regulated at 131.0 volts or at 109% normal voltage during this test.

The purpose of the Range of Adjustment test is to demonstrate that voltage can be adjusted from 95% to 105% voltage in .25% steps. To reduce test time, tests are made only at the ends and middle of the range. The test results are shown on Figure 23, in which voltage to the next step is plotted as a function of the line voltage. The curve shows that some of the steps are coarser than the specification allows. Nothing was done to correct this condition since the adjustment will eventually be eliminated on truly flyable units and the accuracy of adjustment on the breadboard only exceeded the specification limit by 0.1 volt. During calibration of the recorder chart for transient tests, the line voltage was adjusted over a ±10% range. If the potentiometer is changed to reduce the range to ±5%, the step will also be reduced to one half their present value and will then be within the specification. After the Range of Adjustment test, the line voltage is set to rated and the voltage adjustment is not changed for the balance of the tests.

In the frequency effect test, the line-neutral voltages are recorded, no load, as the alternator frequency is varied from 320 to 480 hertz in 40 hertz steps. The results are shown in Figure 24. During this test, the line-neutral voltage changed a total of 0.3 volts or 0.25%. The specification requires only that operation be without discontinuity.

In the voltage regulation test, the frequency is maintained at 400 hertz and load, at rated power factor, is increased in steps from no load to double load. The results are shown in Figure 25. From no load to full load, the voltage changed only 0.3 volts or ±.13%, compared to the specification limit of ±1%. At 150% load, the voltage regulation was 0.6 volts or ±.25% and at 200% load, the regulation was 0.8 volts or ±.33%. At the overload points, the specification allows a ±3% band. The voltage rise is probably due to a change in alternator waveform, which changes the ratio of RMS to average, which is sensed by the regulator.

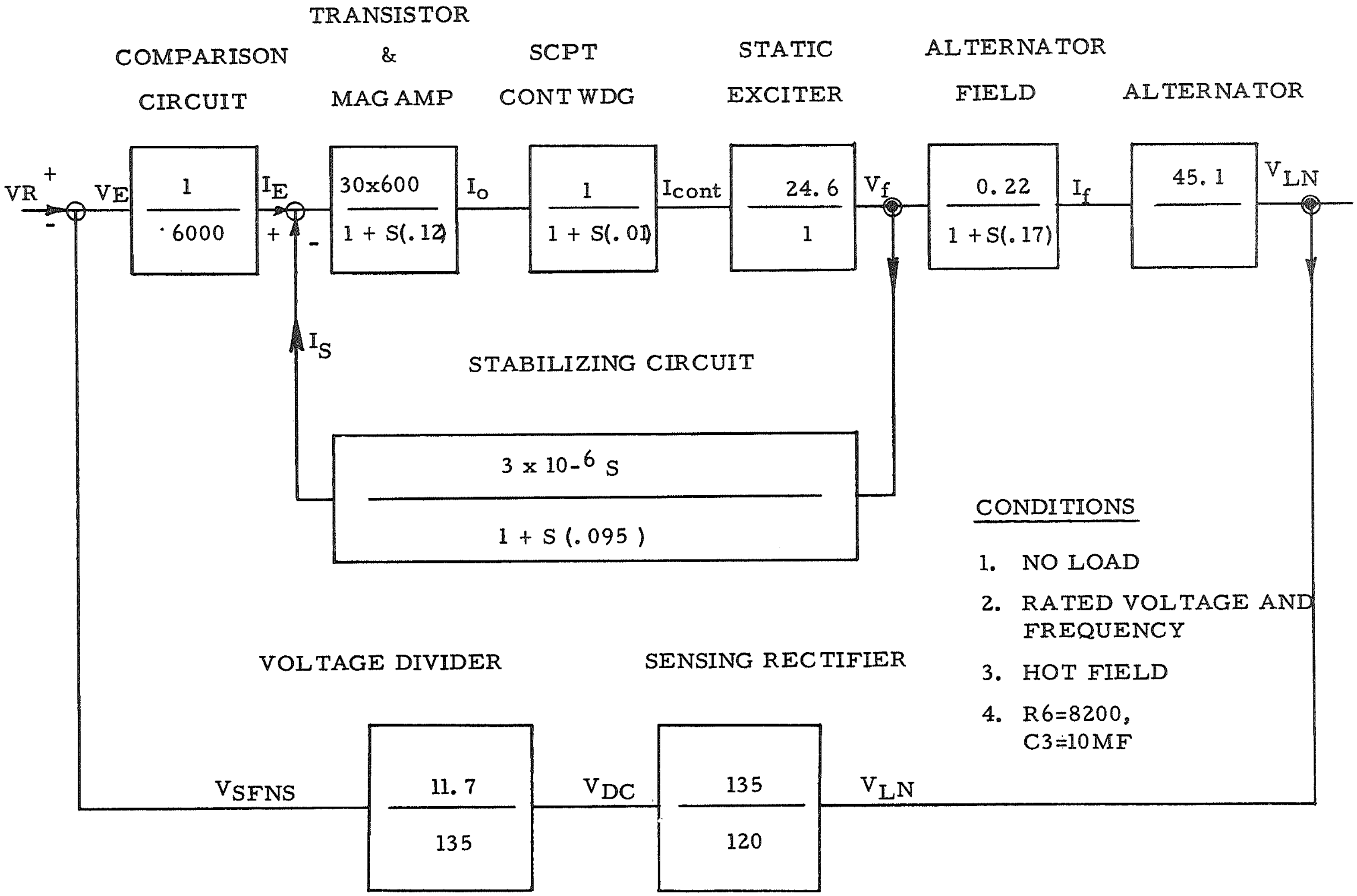
Voltage modulation tests were run at no load and full load. Test values were 0.61% at no load and 0.17% at full load. The specification limit is 1% for 10-100% load.

Unbalanced load tests were run with the required loads as specified in the test instruction. The results, tabulated in Table III, show that the unbalance in line-neutral voltages exceeds the specification in all cases. The unbalance is a function of amortisseur winding design. In the development stage, it was recognized that the amortisseurs might not be potent enough to limit the balance to the specification goal but a substantial improvement was expected, and realized, over similar inductor designs without amortisseur windings.

Transient response tests were conducted by suddenly applying and removing rated and twice rated load. The maximum transient in voltage and the recovery time to a plus and minus 5% band were recorded. The results, tabulated in Table III, show that the system easily meets the specification. Recordings of the transients are shown in Figure 26.

Single and three phase short circuits were conducted to prove that the VRE would deliver sufficient field power to maintain at least 3.0 per unit line current under all conditions. The results, tabulated in Table III show that the system meets the specifications. Although not shown in Table III single phase short circuits were applied to each of the three phases in separate tests.

TRANSFER FUNCTIONS OF ALTERNATOR RESEARCH PACKAGE



CONDITIONS

1. NO LOAD
2. RATED VOLTAGE AND FREQUENCY
3. HOT FIELD
4. R6=8200, C3=10MF

FIGURE 20

ALTERNATOR RESEARCH PACKAGE
SATURATION CURVES

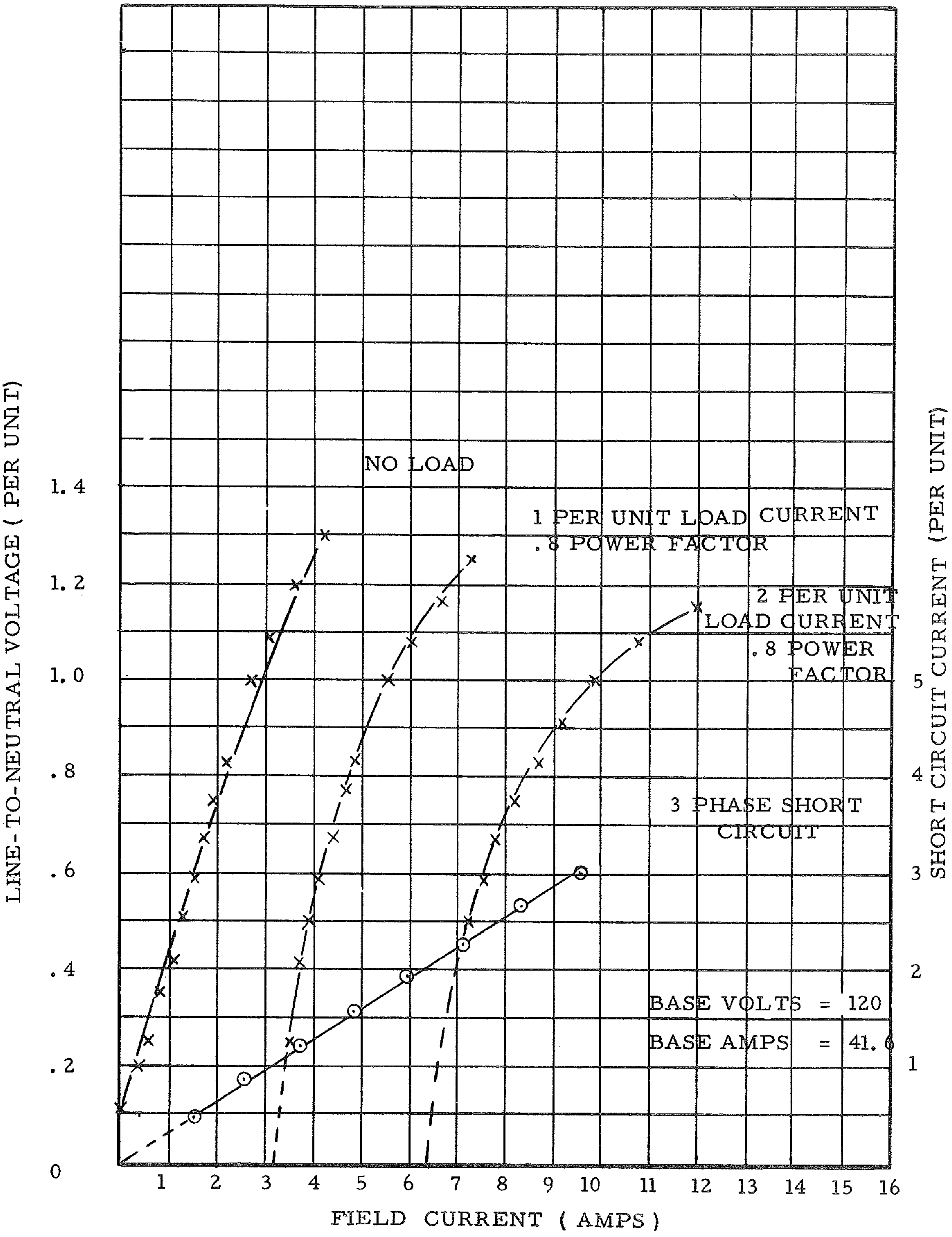


FIGURE 21

ALTERNATOR RESEARCH PACKAGE

EFFICIENCY

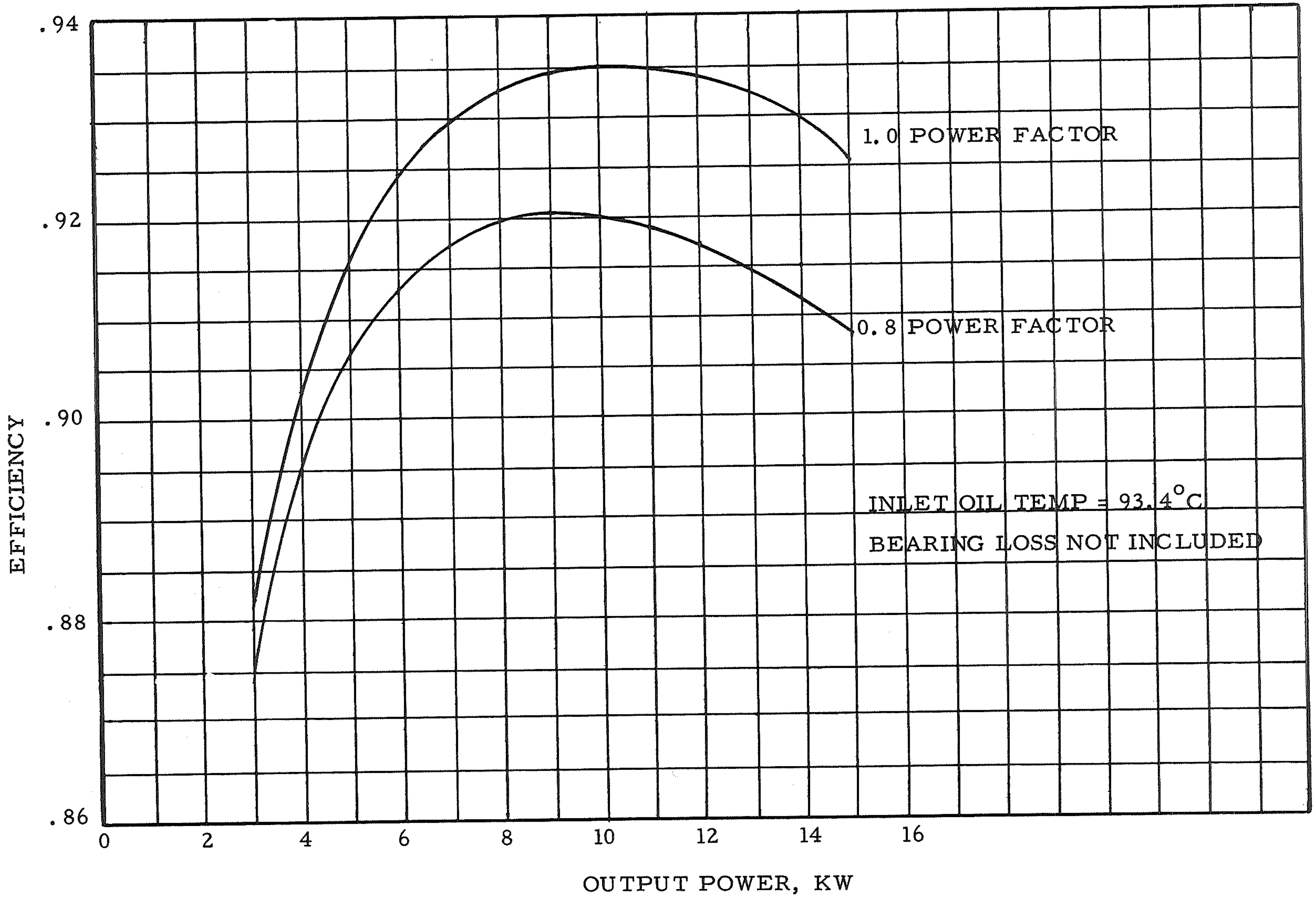


FIGURE 22

ALTERNATOR RESEARCH PACKAGE

RANGE OF ADJUSTMENT

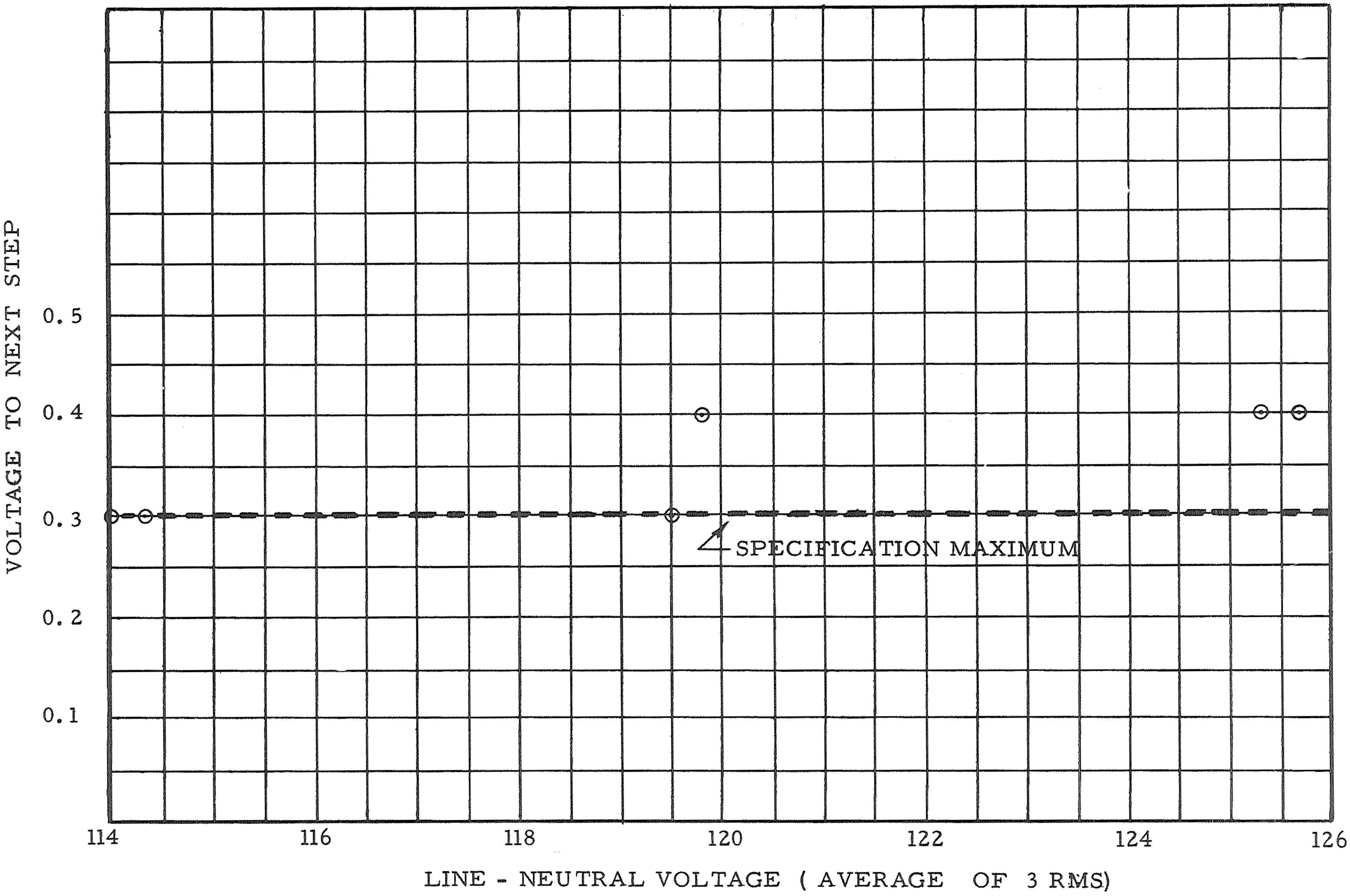


FIGURE 23

## ALTERNATOR RESEARCH PACKAGE
## FREQUENCY EFFECT TEST

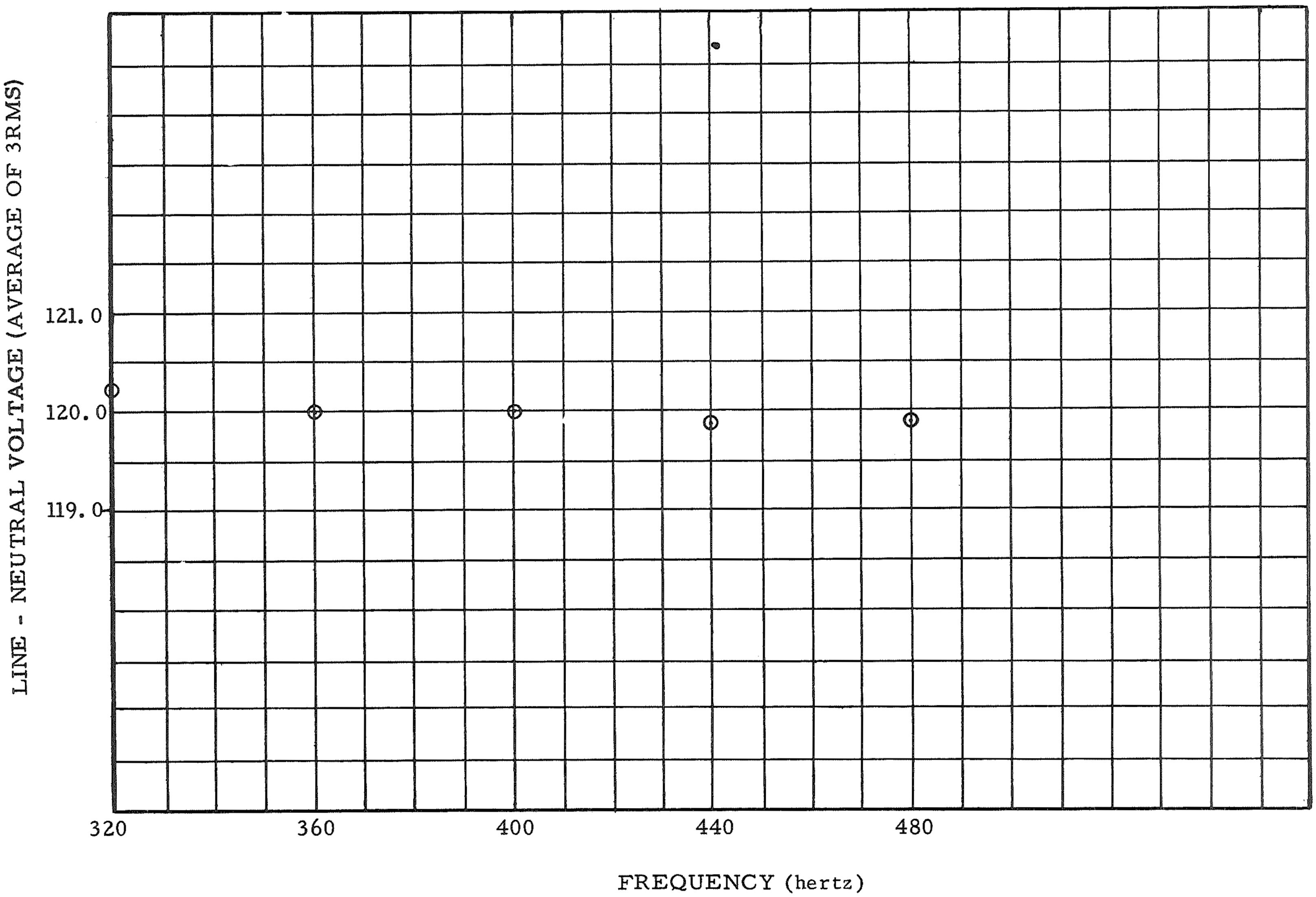


FIGURE 24

ALTERNATOR RESEARCH PACKAGE
LOAD REGULATION ( INCLUDING OVERLOAD)

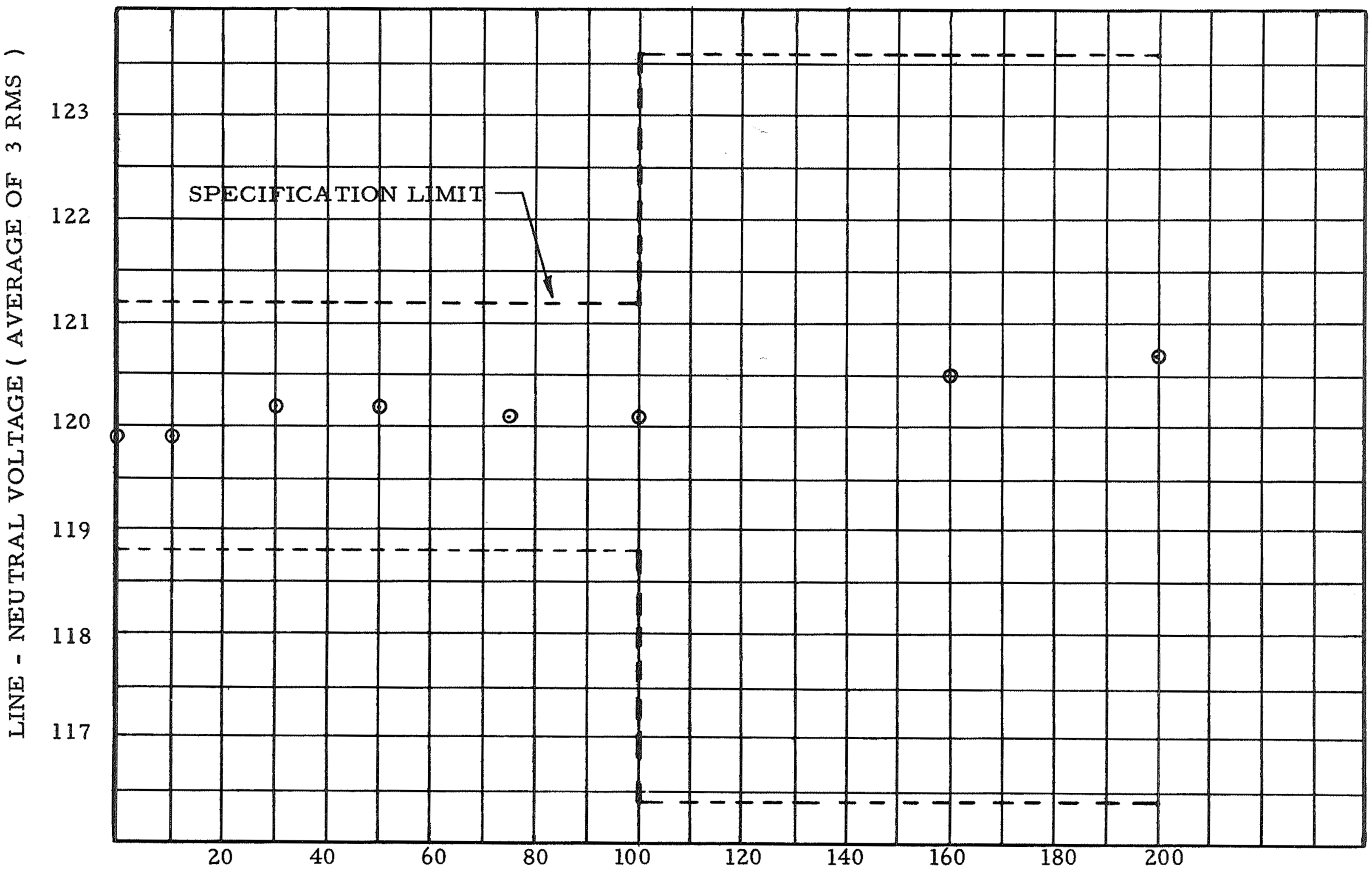
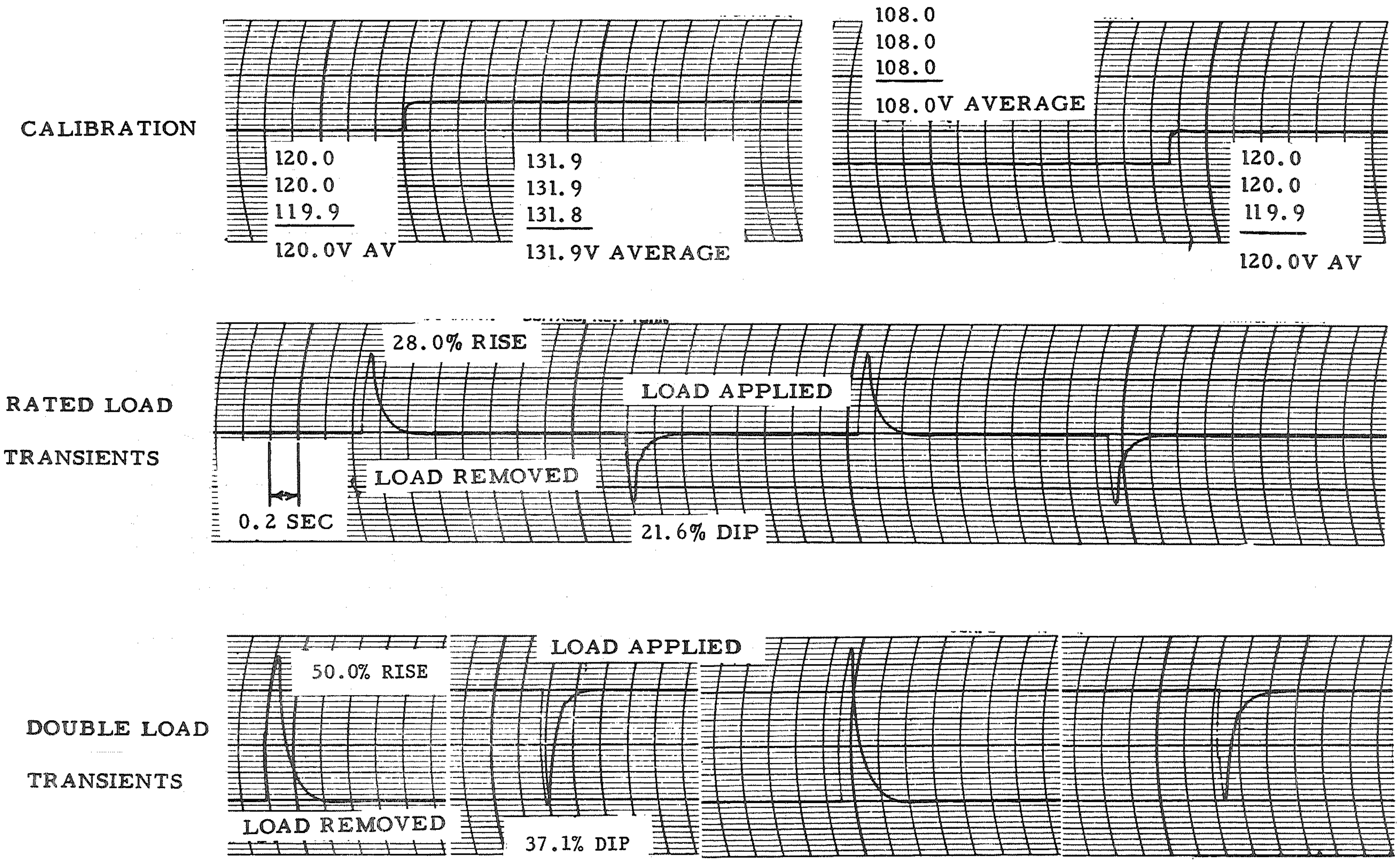


FIGURE 25



TESTS MADE 2-2-66

TRANSIENT LOAD TESTS

BRAYTON CYCLE ALTERNATOR RESEARCH PACKAGE

FIGURE 26

## TABLE III

## SUMMARY OF TEST RESULTS

## BRAYTON CYCLE ALTERNATOR RESEARCH PACKAGE

ALTERNATOR SERIAL NO. AB-374-381

VRE SERIAL NO. 5888351

| Test Description | | Test Results | Specification |
|---|---|---|---|
| Flashing | | Did not require flashing | None |
| Emergency Shutdown | | Operates (Voltage recovers after relay is de-energized) | |
| High Phase Takeover | | 109.2% | None<br>Design goal 108 ±2% |
| Range of Adjustment | | ±5% in. .33% steps | ±5% in .25% steps |
| Regulation (NL-FL) | | ±.13% | ±1% |
| Frequency Effect (320-480 hertz | | ±.13% | Operable w/o discontinuity |
| Voltage Modulation | | .61% No Load (1)<br>.165% rated load | 1% (10% to 100% load) |
| Unbalanced Load | | | |
| 3 ϕ load | 1 ϕ load | | |
| 0 | 1/6 | 1.5% | 1% |
| | 1/3 | 2.9% | 2% |
| | 2/3 | 5.9% | 4% |
| 1/3 | 1/6 | 1.4% | 1% |
| | 1/3 | 2.9% | 2% |
| | 2/3 | 5.7% | 4% |
| 2/3 | 1/6 | 1.4% | 1% |
| | 1/3 | 2.9% | 2% |
| 5/6 | 1/6 | 1.4% | 4% |
| 1.0 Per Unit Load Transient Response | | | |
| Applied | | | |
| Voltage Dip | | 21.6% | None |
| Recovery Time | | .14 sec | .25 sec |
| Removed | | | |
| Voltage Rise | | 28% | 36.4% |
| Recovery Time | | .19 sec | .25 sec |
| 2.0 Per Unit Load Transient Response | | | |
| Applied | | | |
| Voltage Dip | | 37.1% | None |
| Recovery Time | | .14 sec | None |
| Removed | | | |
| Voltage Rise | | 50% | None |
| Recovery Time | | .24 sec | None |

TABLE III (continued)

| | | |
|---|---|---|
| Short Circuit | | |
| 3 phase short circuit | 4.10 p.u. | 3.0 p.u. min. |
| 1 phase L-N short circuit | 6.23 p.u. | 3.0 p.u. min. |
| 1 phase L-L short circuit | 3.52 p.u. | None |
| Harmonic Content and Crest Factor | | |
| Maximum individual Harmonic (25th) | | |
| No Load | 5.4% | 3% |
| 1.0 Per unit load | 2.0% | 3% |
| Root-Mean-Square Total | | |
| No load | 6.47% | 7% |
| 1.0 Per unit load | 2.85% | 7% |
| Crest Factor | | |
| No load | 1.454 | 1.414 ±10% |
| 1.0 Per unit load | 1.412 | 1.414 ±10% |

NOTE: Transient response measured by Ink type recorder with a frequency response of 100 Hz.

# SECTION VII

## SUMMARY OF RESULTS

An alternator research package consisting of a liquid-cooled homopolar-inductor alternator running on rolling-element bearings and a breadboard voltage regulator-exciter were built and tested. Rated output is 15 KVA, 120/208 volts, three-phase, 400-hertz, 12,000 RPM, and 0.8 power factor. Unique design features of the alternator include laminated pole tips, amortisseur windings and polyimide film insulation. The following performance was measured:

1. The alternator efficiency exceeds 90% at power factors greater than 0.8 over the power range of 4.5 to 15 KW, which was the maximum power tested.
2. The maximum efficiency of 93.5% occurred at 10 KW and unity power factor.
3. At rated output the efficiency was 91.7%.
4. At 0.8 power factor and 15 KW (125% of rated) the efficiency was 90.8%.
5. The voltage regulator-exciter and alternator acted to limit voltage recovery time to less than 0.2 seconds with the application of one per unit load transients. For applied loads the voltage dipped to 78% of rated. For load removal the voltage increased to 128% of rated. The regulation, that is the change in voltage from no load to full load, was ±0.13%.

# MAJOR MATERIALS OF CONSTRUCTION
# ALTERNATOR
## APPENDIX A

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Copper | B11B3A | QQ-C-576 b<br>QQ-C-502 c | | Field Coil Box |
| Copper | B11B3K | QQ-C-576 b<br>QQ-C-502 c. | | Stationary Windage Baffles |
| Copper (Polyimide Enameled) | B50CD116B | | ML (Dupont) | Stator Wire (Rectangular) |
| Copper (Polyimide Enameled) | B50CD117A | | ML (Dupont) | Field Coil Wire (Round) |
| Copper (Teflon Insulated) | B50CD163A10 | | Teflon (Dupont) | Leads |
| Copper Zirconium | B50CD194-A | | | Amortisseur End Punching |
| Copper Zirconium | B50CD195-A | | | Amortisseur Bar |
| Epoxy Compound | A50CD240A | | Novolac | Impregnant |
| Epoxy Compound | A50CD241A | | Novolac | Potting Compound |
| Polyimide Film | A50CD321A5 | | Kapton (Dupont) | Slot Coil |
| Polyimide Film | A50CD321A5 | | Kapton (Dupont) | Phase Insulation |
| Polyimide Film | A50CD321A5 | | Kapton (Dupont) | Slot Liner |

| Material | G.E. Spec. | Federal or Mil Spec. | Commercial Spec. | Part of Usage |
|---|---|---|---|---|
| Polyimide Formed | A50CD337A | | Vespel (Dupont) | Topstick |
| Silicone Glass | A19B22A1 | MIL-P-997 | NEMA G-7 | Separator |
| Steel | B5F7H2 | FS 4142, QQ-S-6246 | AISI 4140 | Bearing Cartridges |
| Steel | B5F13 | | AISI 4142 | Flanges |
| Steel | B50CD189A | | AISI 4620 | Rotor |
| Steel Inconel | B14H17-F | MIL-N-6840 | Inconel B168 | Shroud |
| Steel Ingot Iron | B3A7 | | | Frame |
| Steel Silicon | B3E20L | MIL-S-46084 (MR) | AISI - M19 | Rotor Pole Punchings |
| Steel Silicon | B50CD115-A | | | Stator Punchings |
| Steel Stainless | B7A19C2 | QQ-S-766C Cl.347 | Type 347 | Coolant Headers |
| Steel Stainless | B7A25C2 | QQ-S-766C Cl.321 | Type 321 | Rotating Windage Baffles and Retainers |
| Steel Stainless | B7A54A | QQ-S-766C Cl.304 | Type 304 | End Shields |

## MAJOR MATERIALS OF CONSTRUCTION
## VOLTAGE REGULATOR-EXCITER

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Aluminum Sheet | B12H17B, C | QQ-A318 1/4, 1/2 Hard | | Volt. Reg. Chassis, Protective plates for Mag. Component |
| Aluminum Sheet | B12H24J | QQ-A355 | | Protective plate for regulator (not part of regulator) |
| Aluminum Sheet | B12H26A | QQ-A327 "O" Annual | | Volt. Reg. Chassis |
| Aluminum Sheet or Plate | B12H26J | QQ-A-327 T6 HT and AGED | 6061-T6 | Voltage regulator chassis, housing, dome, exciter housing, module housings and magnet component housings. |
| | B12H26H | QQ-A-327 T4 Solut. HT Treated | 6061-T4 | |
| Aluminum, bar rod | B12H30C | QQ-A-325 | 6061-T6 | Plugs, rectifier module housing, brackets on magnetic components and pins on main chassis asm. |
| Aluminum Tubing | B12H31J | WW-T-789 T6 HT and AGED | 6061-T6 | Shell on exciter |
| Aluminum Rod | B12H43H | QQ-A-325 | AA-6061 T4, T6 | Screws for dip brazed structures |
| Aluminum Angle | B12H46X2 | QQ-A200/9 T5 | 6063T5 | Voltage regulator |
| Aluminum Brazing Shim | B20K6 | QQ-R-556, Type 2 | 718 Brazing Alloy | Brazing on voltage regulator chassis, module housings. |
| Aluminum Brazing Filler | | | Alumibraze 400 | Brazing on voltage regulator chassis, module housings. |

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Cement Epoxy<br>Catalyst for above | | | EPON 828 (Sheel Chem)<br>Triethylene Tetramide (Shell Chem) | Cement modules to base of housing |
| Copper, strip | B11B3C2 | | ETP | Terminal ferrules and strips on voltage regulator assembly and on rectifier modules. |
| Copper, bar | B11B33A | QQ-C-576B hard oxy. free cu. | | Current coil terminal posts on exciter |
| Copper, tubing | B11B9A | | | Ferrules for welding wire to terminals. |
| Copper Wire | B11B10A5 | QQ-W-341 | | Bare wire in modules |
| Copper phosphorized | B11B45 | QQ-C-576B | | Heat sink for SCPT cores |
| Epoxy Glass | A19B51A1 | MIL-P-18177B | | Spacer in exciter |
| Impregnant: | | | | |
| Epoxy resin | | | EPON 828 | Compound used to impregnate magnetic components. |
| Catalyst | | | BF3-400 | |
| Filler | | | Mica Dust | |
| Flexibilizer | | | Cardolite NC-513 | |
| Mica | A14A1D | | | Rectifier insulation in rectifier modules |
| Nickel, Grade A, wire | B14H18B | (1/4 Hard) | | Wire leads on rectifier modules |
| Nickel, Grade A ribbon | B14H35X | (dead soft) | | Terminal and component interconnections on rectifier and resistor modules |
| Potting Compound<br>Epoxy resin | | | MPC-52A (GE) | Potting of modules, magnetic components |

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Catalyst for above | | | V-40 (Shell Chem.) | |
| Phosphor Bronze | B11H14C | | ASTMB103-55 Alloy C | Banding SCPT (Plain), L7 (Tinned) |
| Rubber synthetic | A12C6B7 | MIL-R-00 Type 3065 Class JB | BUNA-N | Protective gaskets under regulator - exciter |
| Rubber Silicone | | | 76-128 (Parker) | "O" Ring rectifier stud insulation |
| Rubber Silicone | | | 916 (Dow-Corning) | Grommets in exciter |
| Sealant, RTV | A15F6A2 | | RTV-102 | Sealing compound for magnetic components |
| Sealant, RTV | A15F6A8 | | RTV 108 (GE) | Conformal coating of components |
| Solvent for above | D5B79 | | Chlorothene Nu | |
| Catalyst for above | | | Thermolite 12 (GE) | |
| Silicone, glass base | | | Grade 11556 NEMA Grade 7 | Insulation in Exciter |
| Silicone Compound | A15F5D2 | | RTV-30 | Protective coating on interconnecting wires in voltage regulator final assembly |
| Silicone, Laminated Sheet | A19B22A1 | MIL-P-997 | | Component holder (insulating board) in rectifier and resistor modules. |
| Sleeving | A16B24B1 | | Teflon (Dupont) | Wire insulation in modules |
| Solder | B20D6B | | | Bands and seals on L7 |
| Steel, cold rolled, cad, plate | | | | Frame for laminating on L5 |

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Steel, Silicon Electrical | B3E10, 15 | | SILECTRON | Cores for L5, L7, SCPT |
| Steel, Silicon grain oriented electrical | B3F6 | None | DELTAMAX | Core laminations in L4, L6 |
| Steel Stainless | | | #303 | Press nuts in various assemblies. |
| Steel Tinned | | | | Seals (clips) for bands on L7 |
| Tape, Kapton, | A50CD321A1-5 | | Dupont Kapton | Insulation in modules, magnetic components, regulator asm. |
| Tape, adhesive backed | | | Parmacel type EE6379 | Magnetic component coil and lead insulation |
| Tape, Glass | A2L7B<br>A23B5A3 | MIL-Y-11400 Form 5 | | Final assembly wiring cord ties.<br>Wrap for metal cable clamps. (Final Assembly) |
| Tape, Silicone rubber | | | Self Fusing (H K Porter) | Seal magnetic components against potting stress |
| Tape | | MIL-I-15126 MFT 2.5 | | Capacitor module |
| Tubing fiberglass epoxy | | MIL-P-18177A | | Core tubes |
| Tubing, glass and sil. rubber | | | BH1151 Class HA1 | SCPT self lead insulation |
| Welding wire | B21B26 | | | SCPT core heat sink |
| Welding Rod | | QQ-R-571a, Class FSRCu2 | | SCPT Current Coils |

| Material | G. E. Spec. | Federal or Mil. Spec. | Commercial Spec. | Part or Usage |
|---|---|---|---|---|
| Welding Filler Rod | | QQ-R-566 | | Plugs in housings for VR exciter |
| Wire Hookup | | | Novathene NRRC | Rectifier modules; voltage regulator interconnection wiring. |
| Wire copper ML insulated | | MIL-W-583, Type M, M2, M3 | M.L. (Dupont) | Magnetic component windings, rectifier module leads. |
| Wire copper HML insulated | | MIL-W-583, Type H, H2, H3 | H.M.L. (Dupont) | Magnetic component windings |

# VRE RADIATION RESISTANT COMPONENTS

1. Resistors
   a. Low Power - use metal film type with ceramic or boron free glass core. Protective coating must be ceramic, silicone or diallyl phthlate

   b. High Power -use wire wound type with nickel-chromium alloy resistance element. Cores and protective coating must be same as above.

2. Capacitors
   a. Low capacitance - use glass dielectric type

   c. High Capacitance - use tantalum foil type with hermetic seal (not teflon)

3. Rectifiers
   Use silicon type only, with glass or ceramic and metal case. Specify required dosage.

4. Transistors
   Same as for rectifiers

5. Zener Diodes
   Same as for rectifiers

# APPENDIX B

## Memo Report A-65-001

# Develop Method of Welding Laminations to the Pole Faces of Rotors, Such as the Inductor type Generators

by

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Advance Projects and Laboratories Operation
Direct Current Motor and Generator Department
Erie, Pennsylvania

February 12, 1965

Abstract: This development is covered by the following three phases.

1. Two rotors were built and spun at 24,000 RPM without any measurable deformation. The laminations attached to these rotors did not have intra-laminar insulation. Since there were some defects in the Electron Beam welds, and the laminations were not oxidized before welding, the second step in this development was required.

2. Sample welded assemblies of oxidized laminations and rotor material were made by Inert Arc welding the edges of the laminations adding a deoxidizing material to reduce porosity. The welded surfaces were ground flat and Electron Beam welded to rotor material. These samples were X-rayed and tensile tested.

3. Packs of oxidized silicon iron laminations were prepared for Electron Beam welding by first welding a layer of low alloy steel by two methods - MIG (Metal Inert Gas) and TIG (Tungsten Inert Gas).

## SUMMARY

Part I of this report establishes the method which was selected to attach 3% silicon iron laminations to an AISI 4620 steel alternator rotor pole face. The X-ray of the sample rotors showed that the Electron Beam welding could be improved; however, the strength of the unimproved weld was adequate to withstand 24,000 RPM without any deformation.

Part II reveals methods of improving the condition of the face of the laminated pole which is attached to the rotor by Electron Beam welding. Tensile and Metallurgical tests indicated that a complete seal weld of a low alloy steel would be advantageous in obtaining a joint between the 3% silicon iron laminations and the rotor material. This type of joint would have maximum heat transfer, excellent magnetic qualities, and would have more strength than the laminated material.

Part III explains a method of manufacturing this joint which can be controlled thoroughly by welding a known material such as 1.5% nickel low carbon steel to the edges of the lamination, grinding flat and Electron Beam welding to the rotor material. The quality of these welding processes are certified by X-ray inspection.

## CONCLUSION

The method detailed in Part III of this report was used to Electron Beam weld the laminated pole tips to the AISI 4620 rotor for the Brayton Cycle alternator.

# DEVELOP METHOD OF WELDING LAMINATIONS TO THE POLE FACES OF ROTORS, SUCH AS THE INDUCTOR TYPE ALTERNATORS

Methods of attaching laminations to pole faces of the rotor used in the Brayton Cycle Alternator were reviewed, and it was decided to make sample rotors which could be spun at overspeed to determine feasibility of the joints considered.

The attached sketch #36B625013 shows the two methods of attaching laminations. One face of the rotor shows a dovetail, while the other depends on welding only. Two rotors were constructed from this drawing as shown in Photo #1.

These two rotors were manufactured as follows by our Tool Room:

1. The main body of these rotors were machined from a B5Y18 (AISI 4620) forged billet.
2. Stacks of rectangular laminations (B3E20L) (3 to 3.5 Si. Steel) .014 x 7/8" x 2-3/4" were pressed together with approximately 200 lbs./sq. in.
3. These stacks were held together by inert arc welding across the laminations in three places on the 2-3/4" dimension and one weld across the 7/8" dimension.
4. Two of these stacks were dry ground on each side so that the edges of all laminations were in the same plane. These two stacks were used on the ends of the rotors which were not dovetailed.
5. Two packs were machined with dovetails to accurately fit the dovetails machined in the rotors.
6. The rotor designated as No. 1 was fit with laminations as explained in item 5, and while the laminated pack (noted on drawing as Pt. 4) was clamped tightly to the other end of the rotor, this pack of laminations was Electron Beam welded from each side of the two inch dimension.
7. Test samples were assembled by clamping packs of .014" laminations 1" x 3" two inches high, and the edges were inert arc welded to hold them in place. The ends of these packs were then ground so the edges of all laminations were exposed. Pieces of machine steel 1/2" x 1" x 2" were ground to clean up on each side. These pieces were clamped to the ends of the laminations and Electron Beam welded.

These pieces were used to determine the program used to weld the laminated faces to the rotors. The program which was finally adapted was 150KV, 25-30 milliamp, 4 in. per min. while in a vacuum of $4 \times 10^{-6}$ Torrs.

It was noticed that the silicon was drawn out by the vacuum and that the vacuum system did not keep up with the outgassing during the welding cycle. Later experience with Electron Beam welding indicated that a more concentrated beam did not outgas the material as much, and more satisfactory welds could be made.

The rotor shown at top of Photo #1 was welded with the above program. The penetration of this welding program was over 1" on trial runs, but the loss of vacuum while welding the rotor decreased the penetration so that there was not an overlap of weld as anticipated.

Rotor #1 was sectioned as shown on top of Photo #2. The three pieces removed from this rotor were polished and etched, then photographed in Photo #6.

The top macro, Photo #6, is of the piece removed from edge of the welded end without dovetail. This picture enlarges the piece a little over 3 times. This indicates that the electron beam melted a section of at least 7/64", which means that the beam was wider than it should be in order to get good penetration.

The center macro of Photo #6 is of the piece cut diagonally across the welded end of Rotor #1. This macro showed that there was little porosity in this weld as indicated by the X-ray of this rotor.

The bottom macro is of a section of Rotor #1 taken parallel to the dovetail through the area which was Electron Beam welded from the side of the rotor with the beam parallel to the laminations.

Photo #5 is an enlargement of the center of the end of No. 1 rotor without dovetail showing how the laminations were held together by an inert arc weld which fell in the area which was not welded by Electron Beam.

Photo #4 is an enlargement of a defect which was located by X-ray on the No. 2 rotor. This defect has been marked on the accompanying X-ray, and in Photo #3, center view.

In this photo, the hole appears to be completely surrounded by solid material; however, the outgassing of the material is of such a nature that a sealing type of weld will be required on the edges of the punching before electron welding them to the rotor face. Since this electron beam welding was done before oxidizing the laminations, the necessity for applying a seal weld will have added requirements.

Other defects shown in Photo #3 are due to the starting and stopping of the Electron Beam welding on the piece without slope control of the power on electron gun. Due to these defects, it was decided to make a set of samples with the edges of the lamination seal welded with inert arc welding.

Two metallurgical mounts were made of the welded sections to determine hardness, diffusion areas, and grain structure of the different materials, namely, high silicon steel laminated steel to low alloy rotor steel. Due to the high silicon of the laminations, it was considered possible that the Electron Beam welded section might become brittle. The attached micro hardness tabulation shows that the line of fusion was quite hard 45 R.C., but a reduction of hardness on either side of this line of fusion was gradual enough to prevent stress concentration. Tabulation 1-C starts in the rotor material and progresses through the Electron Beam weld then through the inert arc melted laminations on into the lamination which have not been effected by welding. This sample is shown in Photo 5313 and magnified 50 times in Photo 5316. 2-B tabulation and Photo 5314 and magnified Photo 5317 shows a hardness pattern similar to 1-C.

Dovetailing of the laminated pole tips was rejected since it required several starts and stops of the electron beam weld which resulted in considerable porosity where the starting and stopping occurred.

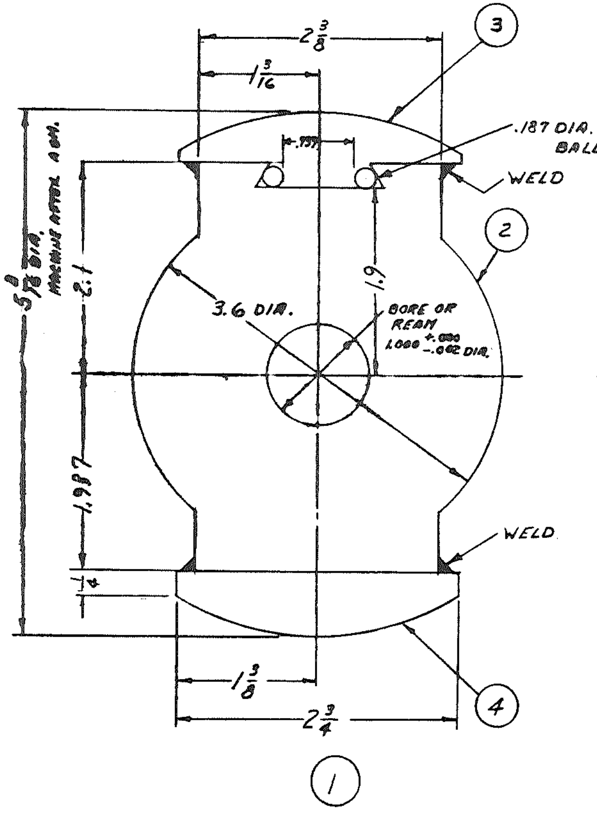
# MICRO HARDNESS

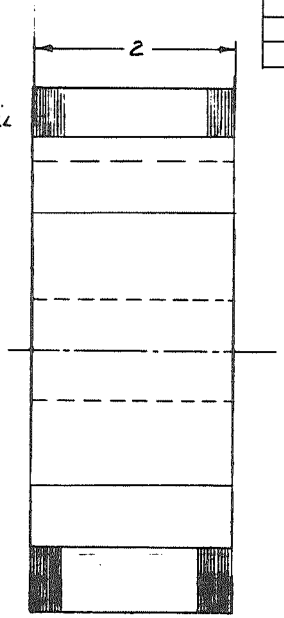
| | #1-C | | #2-B | |
|---|---|---|---|---|
| Distance from Line of Fusion | 300 Knoop | Approx. $R_C$ | 300 Knoop | Approx. $R_C$ or $R_B$ |
| .220" | | | 205 | $90_B$ |
| .200 | | | 247 | $20_C$ |
| .170 | 290 | 27 | 313 | 30 |
| .120 | | | 310 | 29 |
| .100 | 257 | 22 | | |
| .080 | | | 380 | 37 |
| .060 | | | 282 | $25_C$ |
| .050 | 247 | 20 | | |
| .030 | 376 | 37 | | |
| .020 | 412 | 40 | 297 | $28_C$ |
| .008 | 425 | 42 | 282 | 25 |
| .002 | | | 282 | $25_C$ |
| .000 | 440 | 45 | 243 | $97_B$ |
| .002 | 376 | 37 | 212 | 92 |
| .020 | 318 | 30 | 218 | 93 |
| .040 | 420 | 41 | 212 | 92 |
| .060 | 376 | 37 | 208 | 91 |
| .070 | 270 | 24 | | |
| .100 | 243 | 20 | 215 | 92 |
| .120 | | | 227 | 95 |
| .140 | 227 | $95_B$ | 215 | $92_B$ |

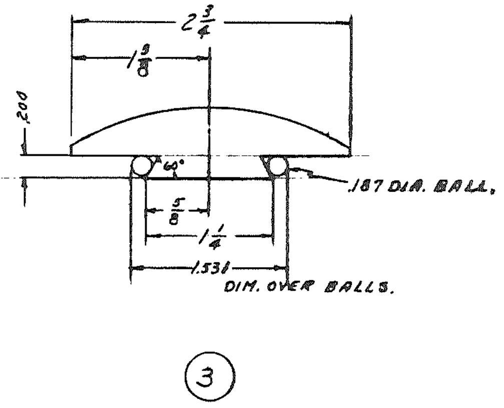
36B625013
DWG NO.

SAMPLE BRAYTON ROTOR
BRAYTON CYCLE

| GROUP NO. AND QUANTITY |  |  |  |  | G1 | PART NO. | NAME | DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | X | 1 | ASSEMBLY |  |
|  |  |  |  |  | 1 | 2 | BODY | A1S1 4620 2 X 3 9/16 X 4[illegible] |
|  |  |  |  |  | 143 | 3 | TIP | B3E20L .014 X 7/[illegible] X 2[illegible] |
|  |  |  |  |  | 143 | 4 | TIP | B3E20L .014 X 5/[illegible] X 2[illegible] |







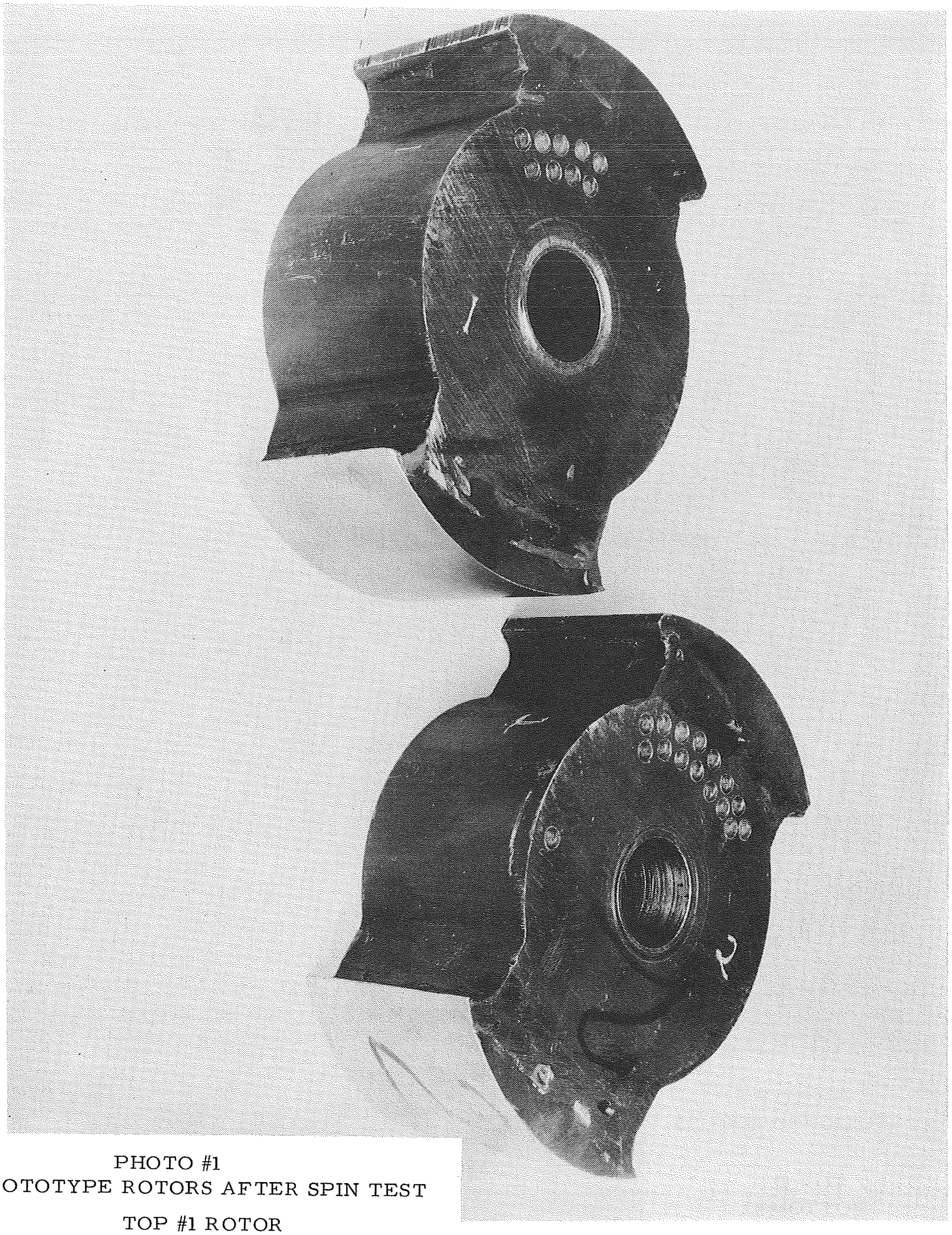


PHOTO #1
PROTOTYPE ROTORS AFTER SPIN TEST

TOP #1 ROTOR
BOTTOM #2 ROTOR

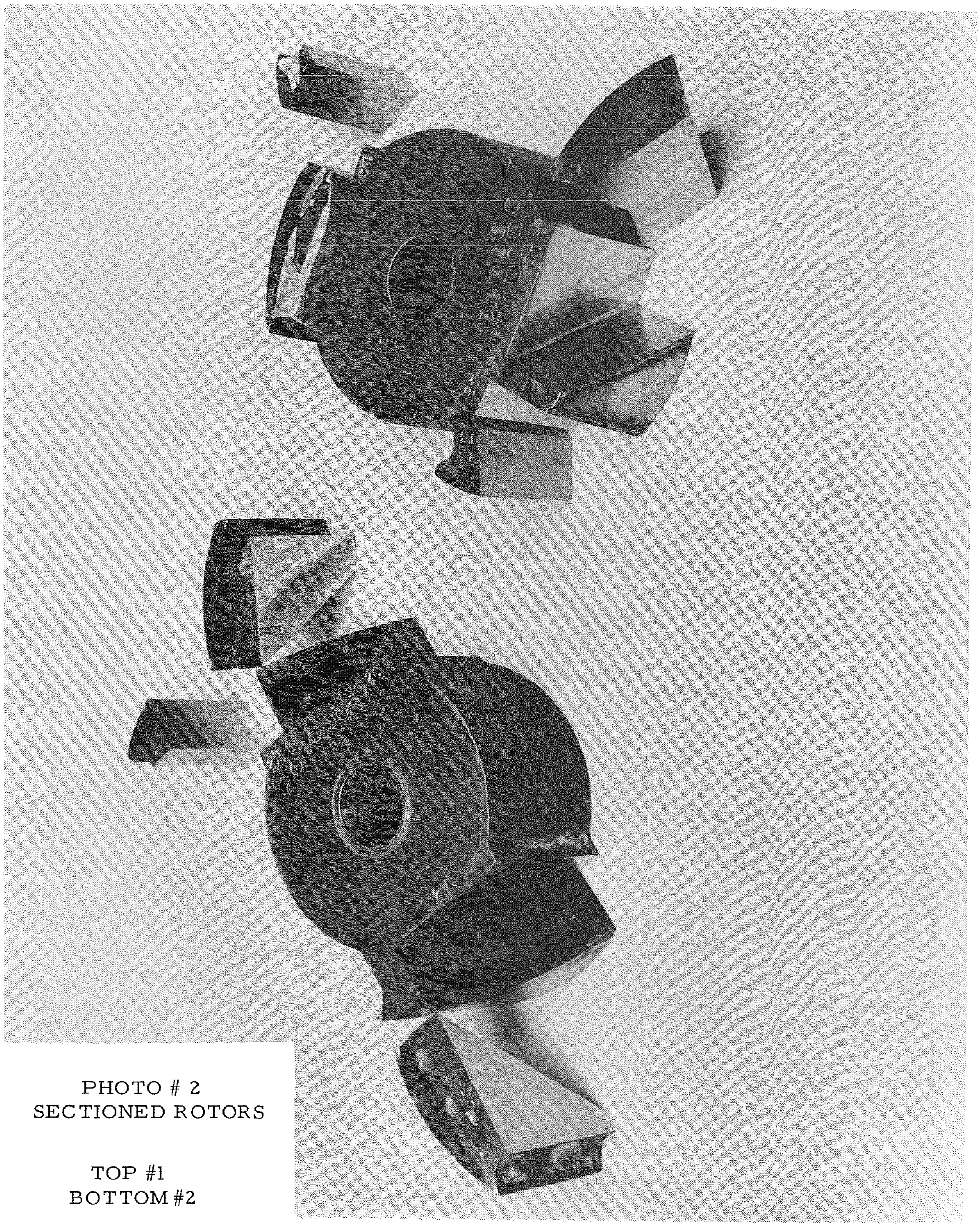


PHOTO # 2
SECTIONED ROTORS

TOP #1
BOTTOM #2

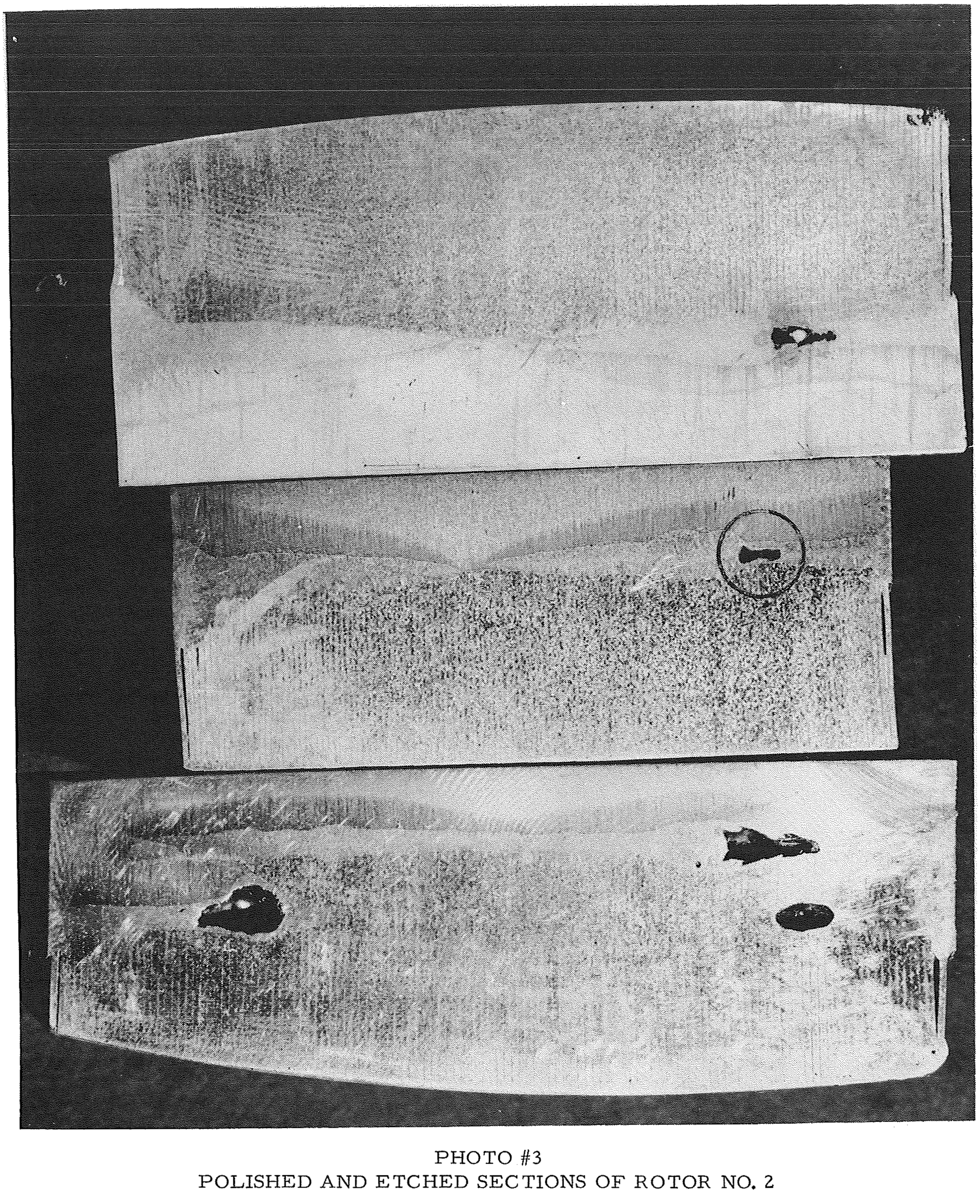
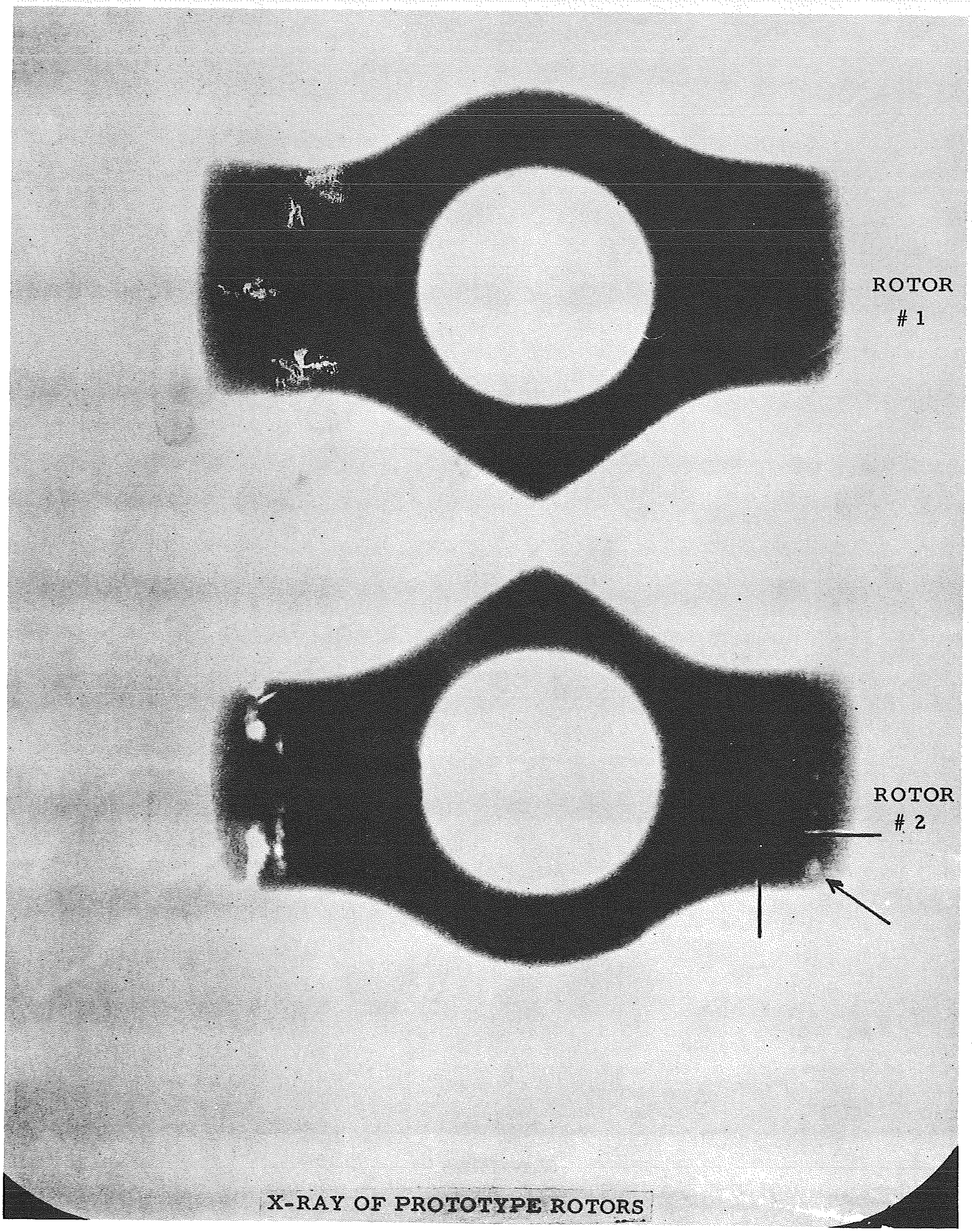


PHOTO #3
POLISHED AND ETCHED SECTIONS OF ROTOR NO. 2

NOTE: X-RAY SHOWED DEFECT SHOWN IN PHOTO #4
FOR MACRO AND CIRCLED ON THIS PHOTO.



X-RAY OF PROTOTYPE ROTORS

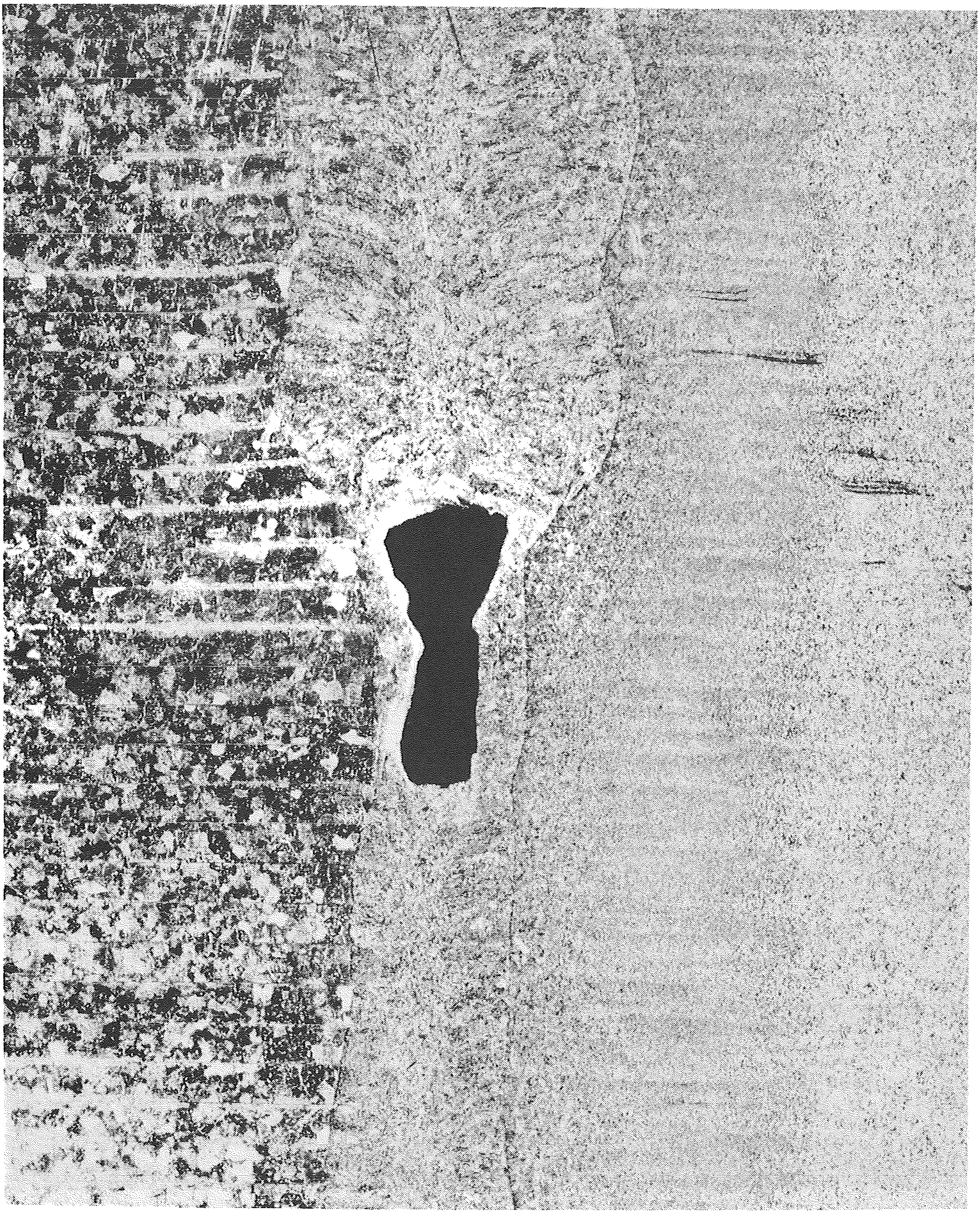


PHOTO # 4
MACRO OF DEFECT MARKED ON X-RAY TO DETERMINE
SIZE OF DEFECT 20X ACTUAL SIZE

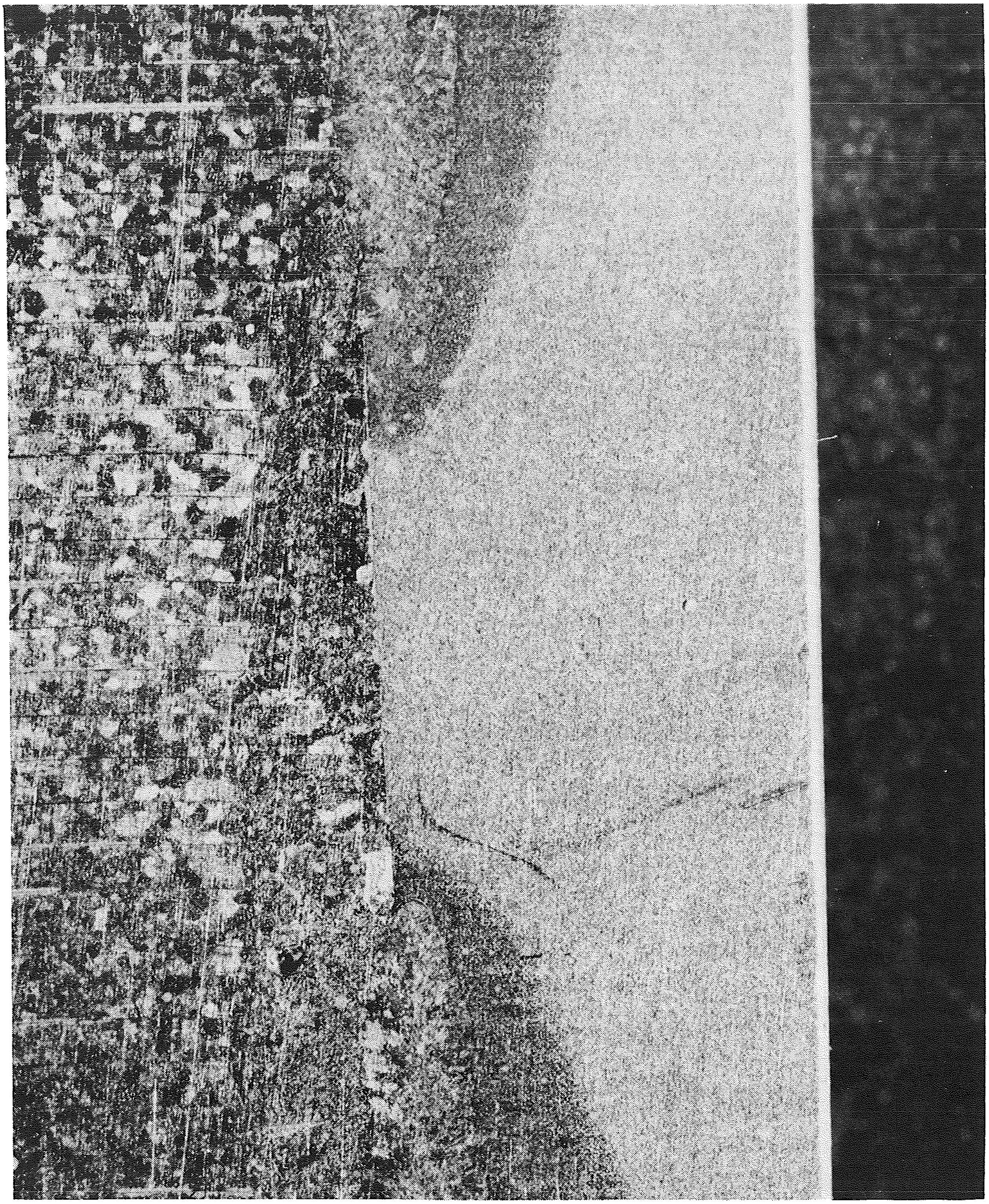


PHOTO #5

MACRO OF ELECTRON BEAM WELD OF NO. 1 ROTOR
ON THE END WITHOUT DOVETAIL

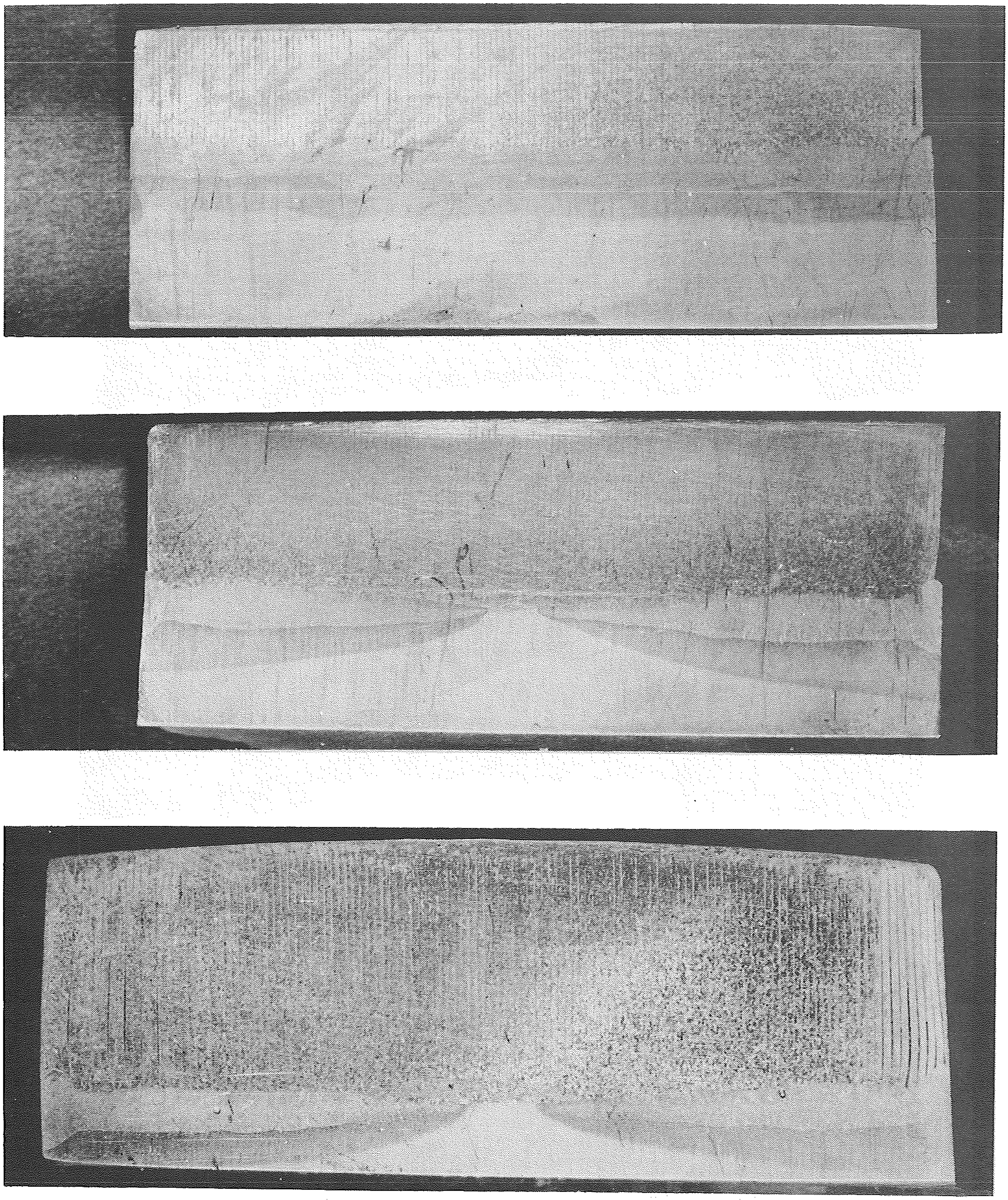
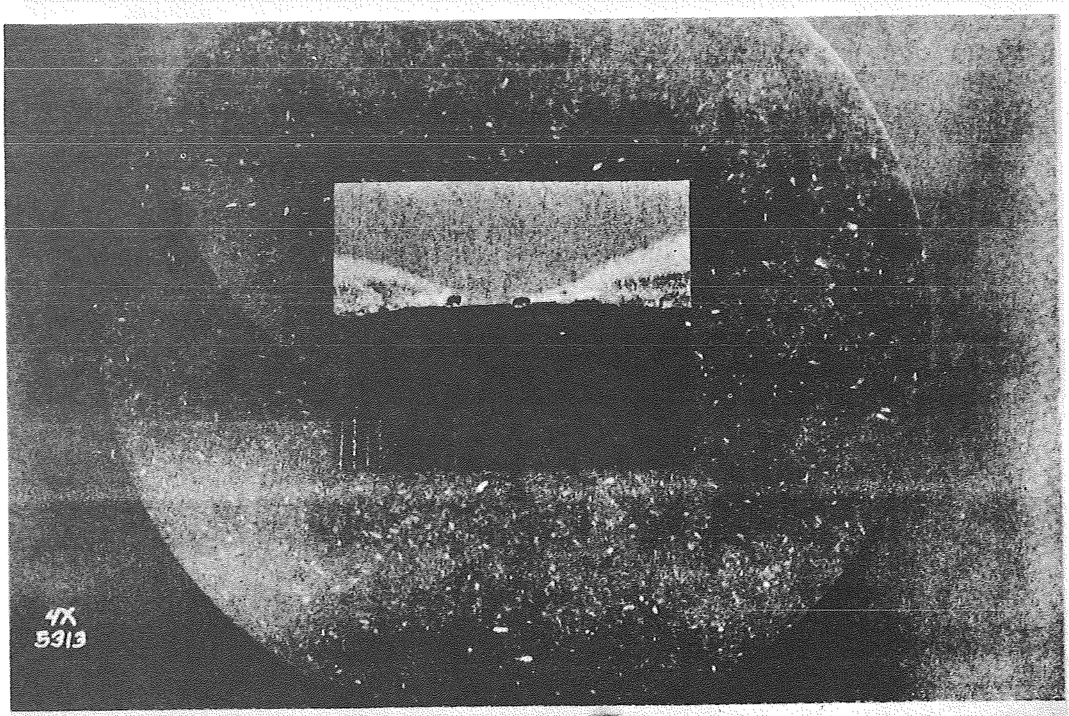
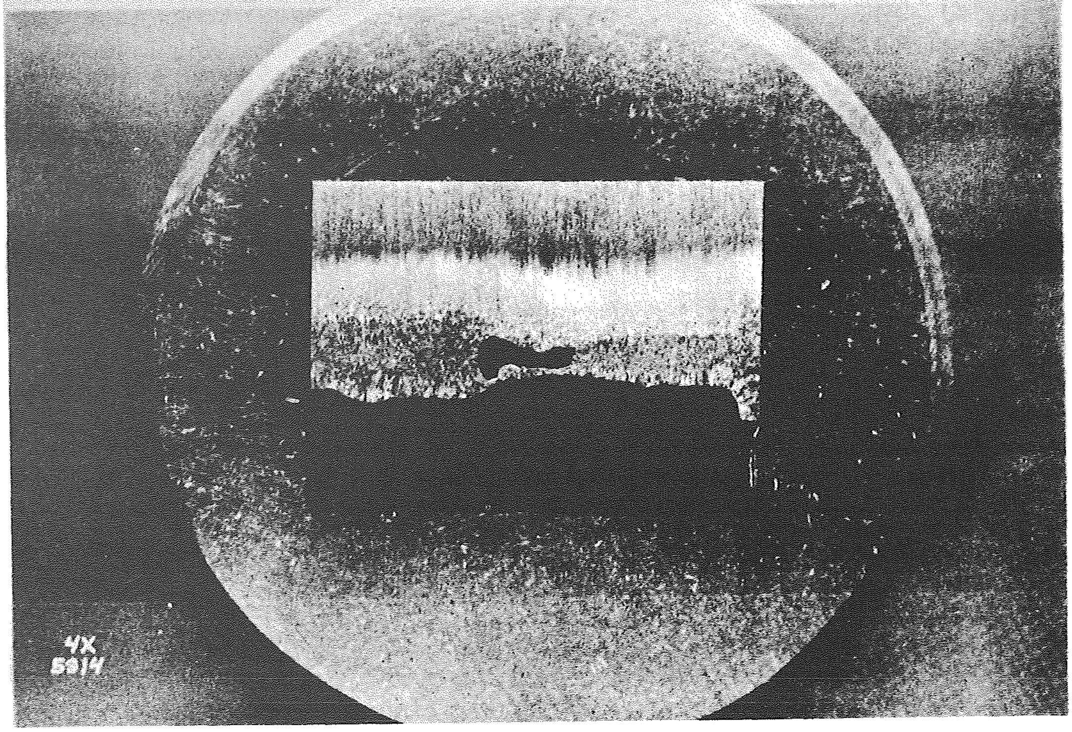


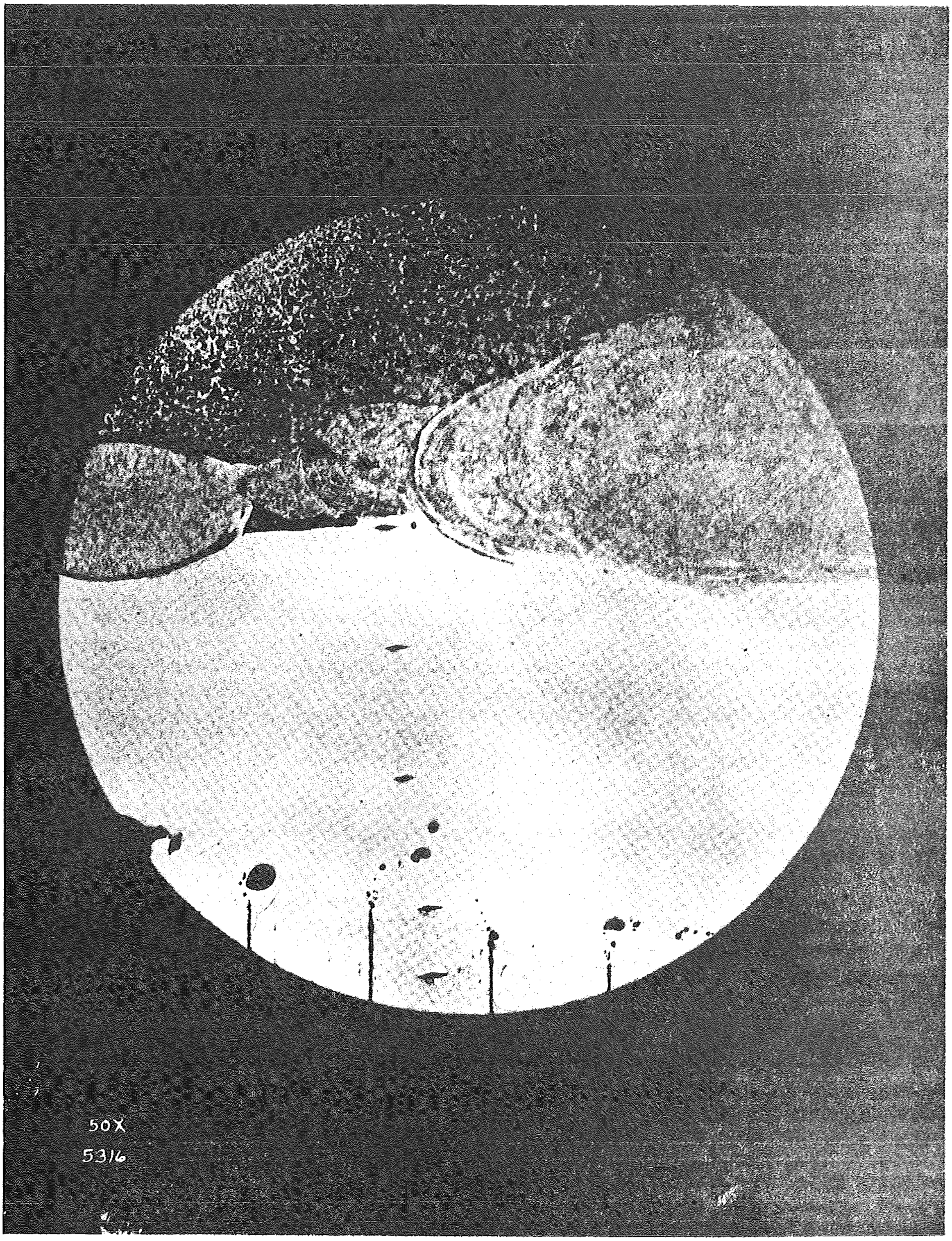
PHOTO #6
POLISHED AND ETCHED SECTIONS OF ROTOR NO. 1



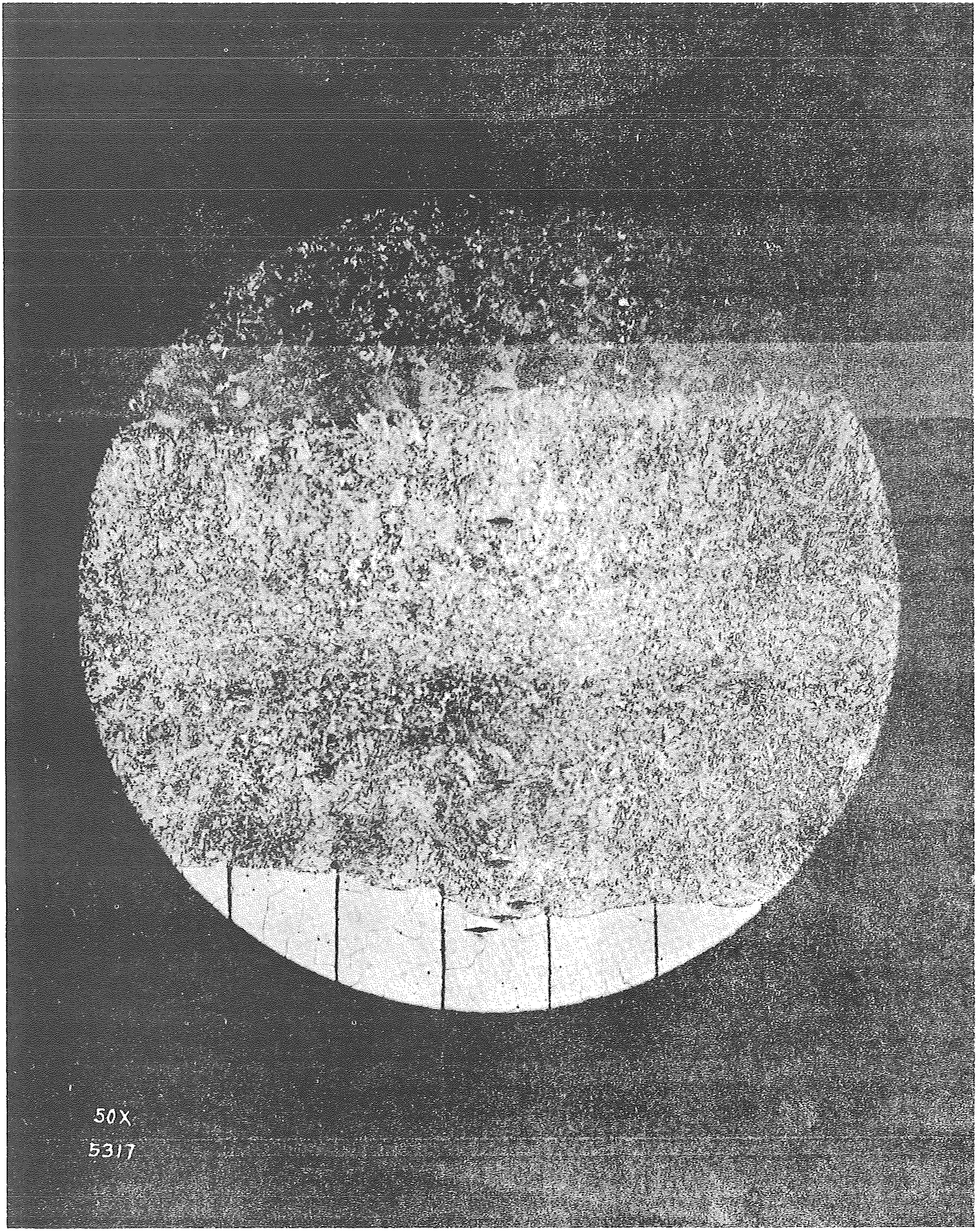
METALLURGICAL MOUNT



METALLURGICAL MOUNT



50X MAGNIFICATION OF PHOTO 5313



50X MAGNIFICATION OF PHOTO 5314

# SECTION II

As stated previously, the rotors built were not faced with laminations having intra-laminar insulation. Different materials were considered for intra-laminar insulation, but due to the reliability necessary for this application a tight oxide of iron was considered most desirable. However, the oxide between laminations would contaminate the Electron Beam welding. The silicon iron, B3E20L, laminations will vaporize excessively when welded due to the high silicon content. Due to these known factors which might prevent a good Electron Beam weld, it was considered advisable to inert arc weld (referred to as TIG weld) the edges of the laminations adding a killer such as Titanium Hydride or Ferromanganese. The latter has been used with TIG welding for many applications where steel with oxide inclusion are apparent. It was agreed that these two materials should be tried, and the samples were constructed in the following manner:-

1. Silicon steel B3E20L, .014" thick, was cut into 1" x 3" pieces. A quantity of 600 of these were used.

2. The above laminations were oxidized in our lamination treating furnace which is operated as per attached Manufacturing Process P10-CD3-1.

3. These laminations were then clamped in approximately two inch high stacks, clamped tightly together, and TIG welded at three places on each side of the stack to hold them securely together. Four stacks of these laminations were prepared in this manner.

4. The 1" x 2" ends of these stacks were ground square with the side of stack and parallel to each other.

5. The ends of one stack were painted a heavy coat of Ferromanganese (60 mesh or finer) mixed with Alcohol, and the ends of the laminations melted with TIG weld.

6. The welded ends of this stack of laminations were ground to obtain a flat clean surface.

7. Two of the samples were TIG welded to melt the ends of the laminations without a killing media. These samples were ground to obtain a clean flat surface.

8. Blocks of A.I.S.I. 4620 were cut from the rotors used in the first tests and Electron Beam welded to the ends of these stacks of laminations.

9. The fourth sample was TIG welded on the ends after applying a coat of Titanium Hydride mixed in Alcohol to the surface. The ends were finished parallel and Electron Beam welded to blocks of A.I.S.I. 4620 steel and processed in the same way as the other samples.

One of the two samples which were TIG welded without a killing media was used as a sample for setting the Electron Beam welder. The other three samples were Electron Beam welded through the two inch dimensions by welding from each side, penetrating a little over one inch so that the Electron Beam welds overlap at the center.

The above welds have been polished and photographed as shown in Photos #2A, #2B, #2C.

MN. designates those welds which were TIG welded, previous to Electron Beam welding, with Ferromanganese as a killer, shown in Photo 2A. (Ti) designates the welds which were TIG welded previous to Electron Beam welding with Titanium Hydride as a killer, shown in Photo 2B.

Photo 2C is of the sample which was welded on the ends by the TIG process without a killing media before it was Electron Beam welded to the A.I.S.I. 4620 block.

Also, attached are X-rays of these welded samples which show that the Ferromanganese killed TIG welding previous to Electron Beam welding, producing a much cleaner weld than did the other processes.

To further substantiate the benefits of Ferromanganese killing of the TIG welding before Electron Beam welding, these samples were prepared for tensile tests by cutting each sample in two parts lengthwise. These parts were then threaded on each end for 5/8-11 tensile test holder. The welded area were then milled with 1/8" radius mill to reduce the sections as noted on the attached tensile test record.

Tensile tests attached show that the Ferromanganese-killed specimens were superior to the other specimens.

It was decided at this point that a better controlled method of welding the ends of the laminations should be provided, and so MIG welding with Airco #609 wire having 1.9 manganese was tried. This process is explained in Part III of this memo report.

# TENSILE TESTS

Date: 1/4/65

Apparatus Tested: Welds on Laminations.

| Identification | No. | Size In. | End In. | A Sq. In. | Size In. | End In. | B Sq. In. | Ultimate Load | UTS PSI | Broke End |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 1 | .375 | .375 | .141 | .375 | .375 | .141 | 6,920 | 49,100 | A |
| T1 | 2 | .375 | .300 | .112 | .375 | .375 | .141 | 10,960 | 77,700 | B |
| M | 3 | .368 | .310 | .114 | .375 | .375 | .141 | 11,460 | 100,500 | A |
| M | 4 | .350 | .375 | .131 | .375 | .375 | .141 | 11,400 | 80,800 | A & B |
| - | 5 | .375 | .375 | .141 | .375 | .375 | .141 | 12,540 | 89,000 | A & B |
| - | 6 | .375 | .375 | .141 | .375 | .375 | .141 | 9,380 | 66,500 | A & B |

| Base Material Properties | UTS (PSI) | Yield (PSI) |
|---|---|---|
| Pole Tip Laminations (B3E20L, AISI M19) | 79,000 | 61,000 |
| Rotor (B5Y18, AISI 4620) | 132,500 | 104,000 |

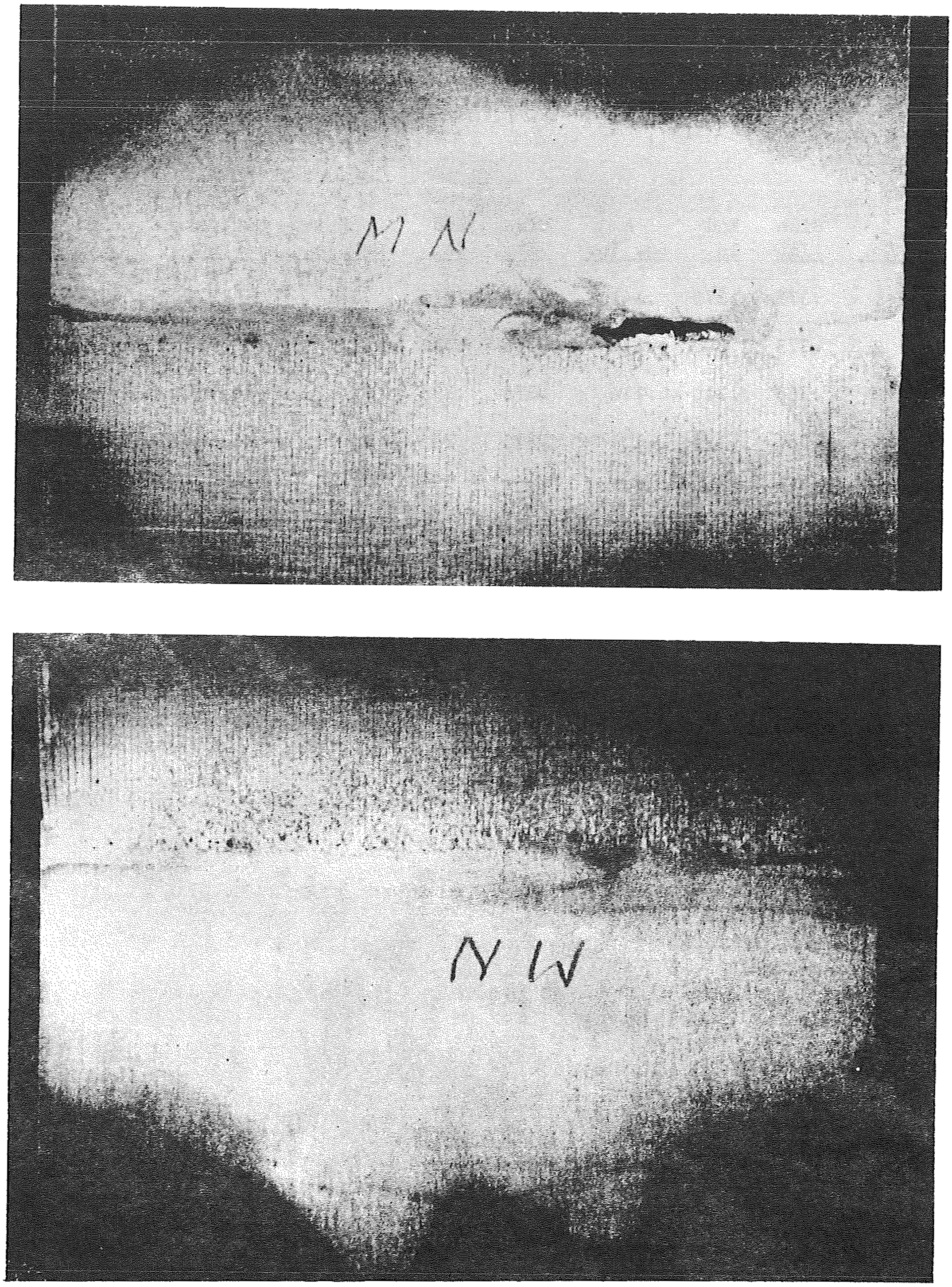


PHOTO #2A: Ferromanganese killed TIG welded edges of B3E20L laminations with subsequent Electron Beam weld to AISI 4620 block.

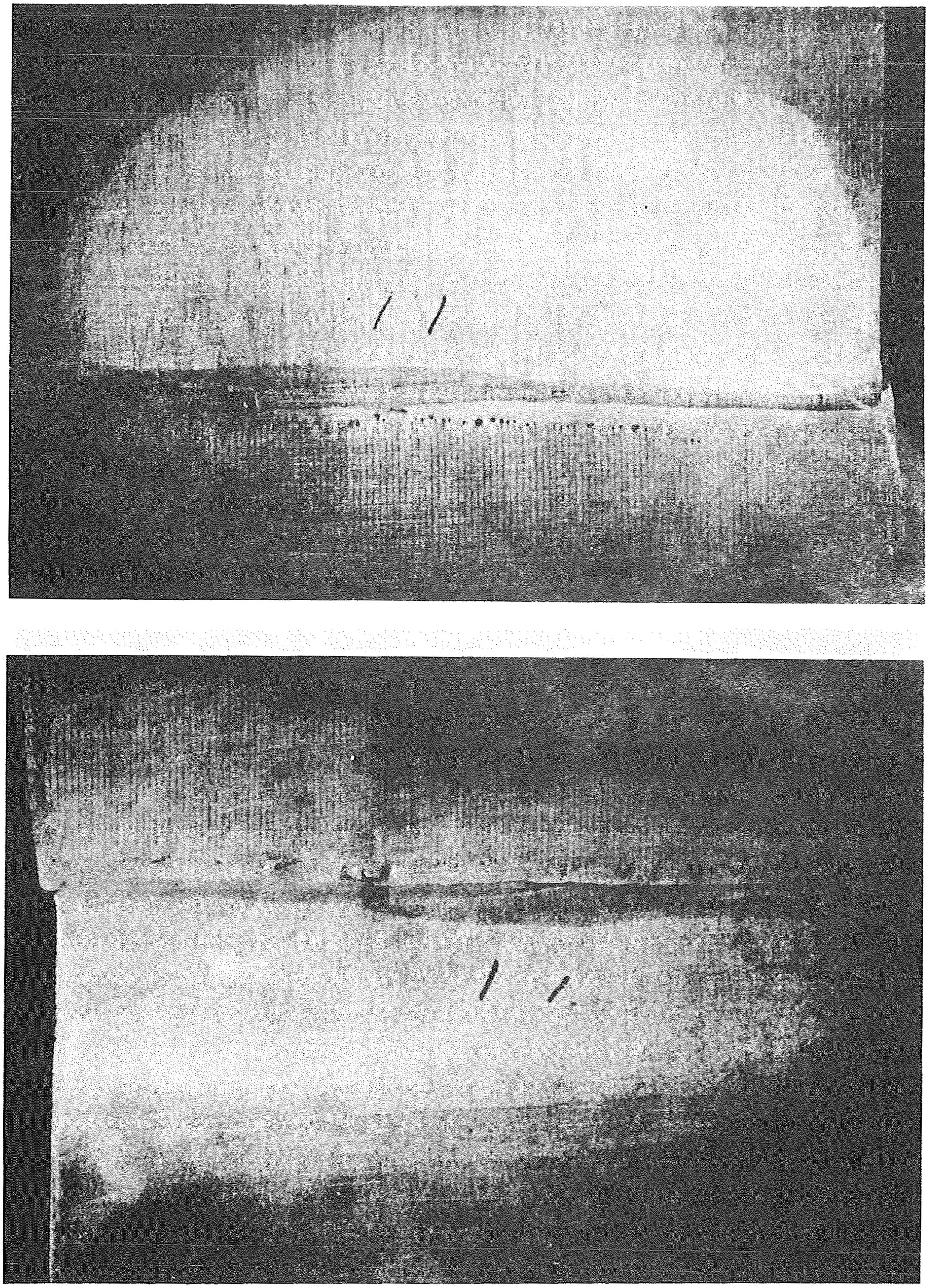


PHOTO #2B: Titanium Hydride killed TIG welded edges of B3E20L lamination with subsequent Electron Beam weld to AISI 4620 block.

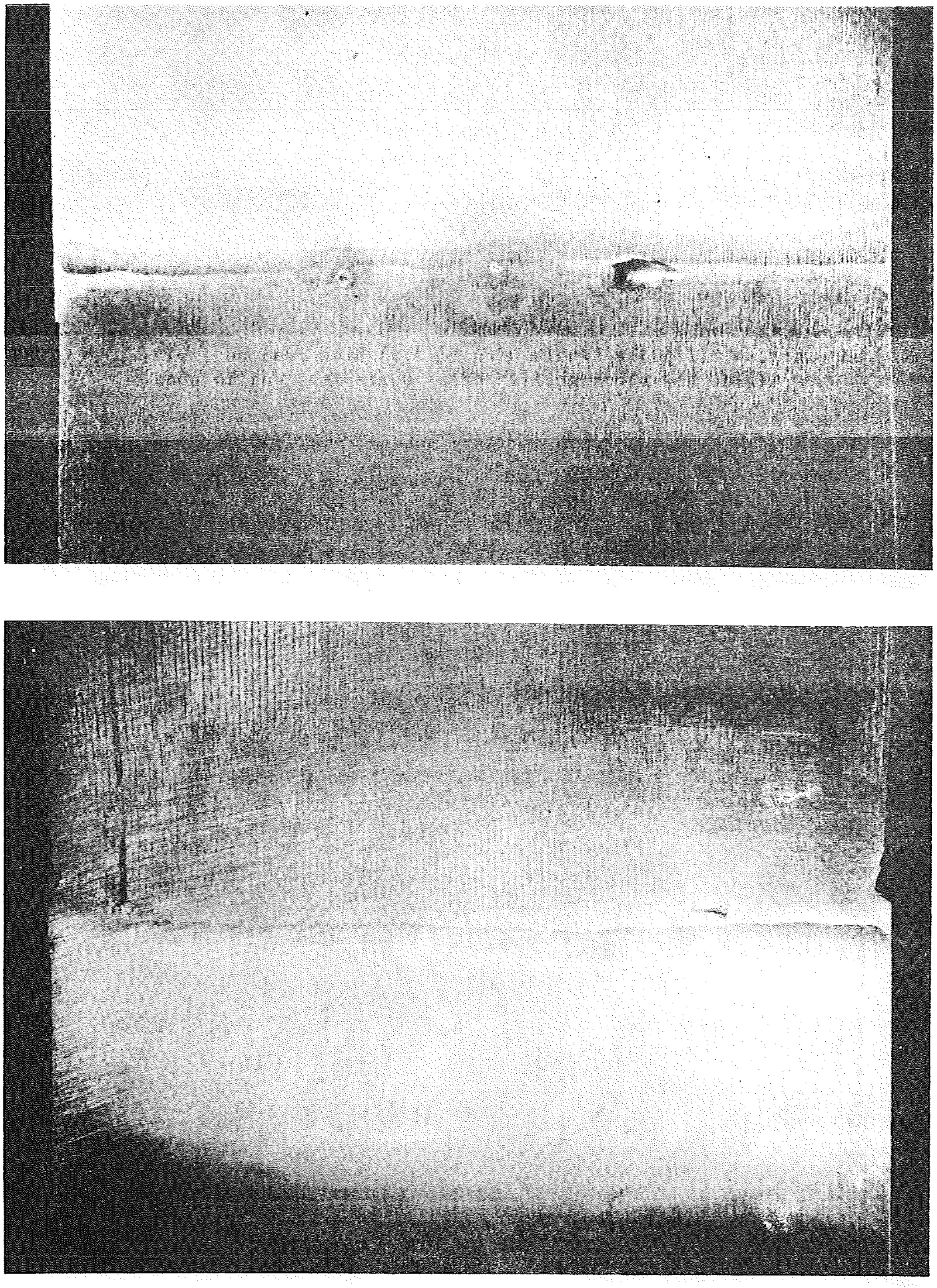
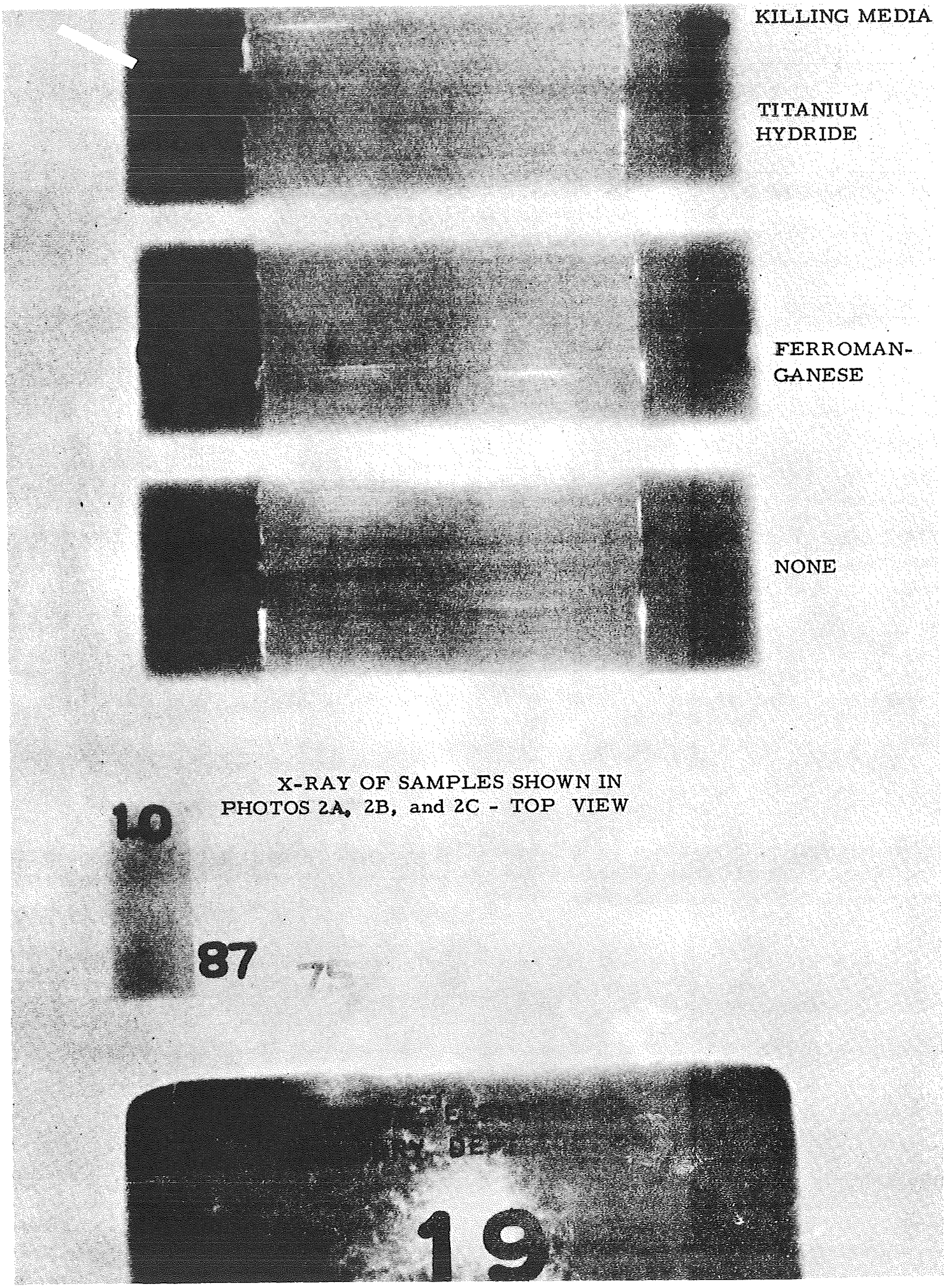
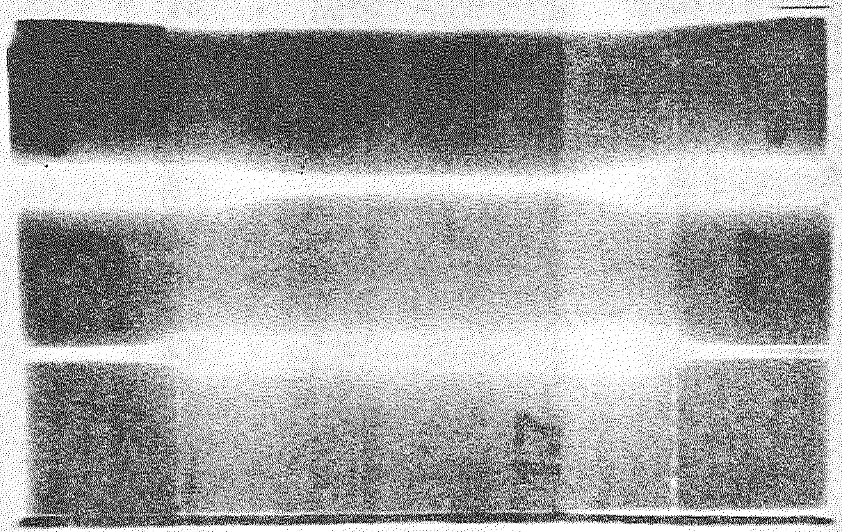


PHOTO #2C: Electron Beam weld to AISI 4620 blocks after TIG welding the ends of the lamination. (No killing media was used).



X-RAY OF SAMPLES SHOWN IN PHOTOS 2A, 2B, and 2C - TOP VIEW



X-RAY OF SAMPLES SHOWN IN
PHOTOS 2A, 2B, and 2C - SIDE VIEW

# SECTION III

Ferromanganese treatment of the TIG weld applied to edges of the silicon steel lamination was effective in making a surface which produces a strong weld when joined to the AISI 4620 rotor material. Since the amount of Ferromanganese used in the TIG weld could not be controlled, it was decided that a weld should be added to the edges of these laminations using a welding rod of known alloy.

Four laminated samples were prepared as shown in Photo 3A. The exposed laminations were welded with the MIG process using Airco A608 as filler wire. The chemical specification on this wire is as follows:

| | |
|---|---|
| Carbon | 0.10% |
| Manganese | 1.95% |
| Silicon | 0.65% |
| Phosphorus | 0.025% Max. |
| Sulphur | 0.025% Max. |
| Nickel | .15% Max. |
| Molybedum | .50% |
| Iron | Remainder |

After building up each end of these laminations approximately 1/16", they were ground flat and then Electron Beam welded to AISI 4620 steel blocks. There were some noticeable pin holes in the MIG weld buildup when ground. One set of laminations was TIG welded with a buildup with No. 1 Airco on one end and No. 4 Airco on the other end. These welds appeared to be free of pin holes when ground, and the X-ray of the Electron Beam welds where this surface was joined to the AISI 4620 were practically free of pinholes while the pinhole which appeared in the MIG welded parts were increased to blow holes when welded with Electron Beam to AISI 4620 blocks.

It is therefore recommended that the edges of the laminations be sealed by TIG welding two layers of Airco #1 wire filler. These two layers should buildup the surface so that it will finish .040" to .060" thick.

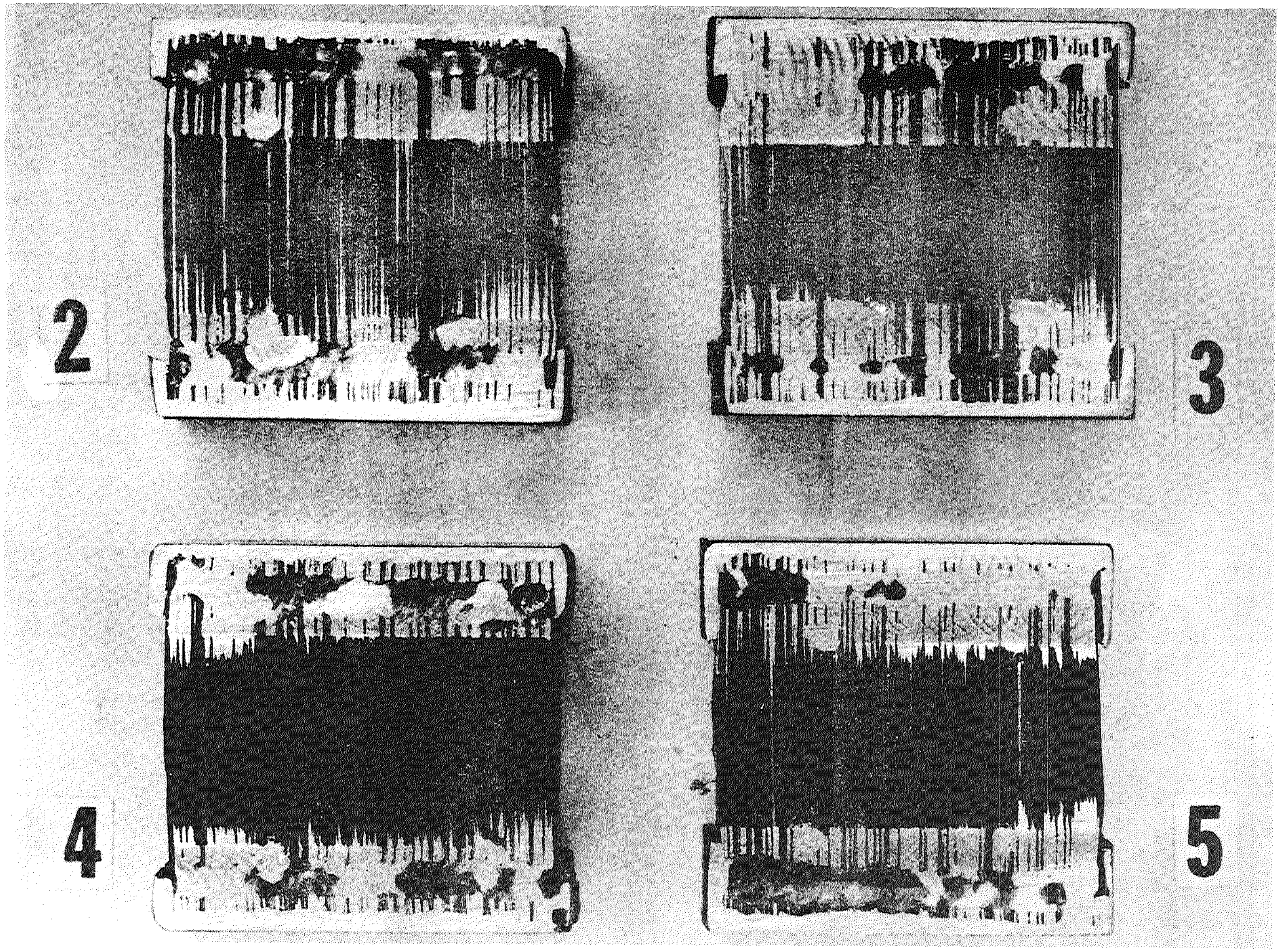
During the experimental Electron Beam welding, it was evident that the alignment of the beam with the ground joints was very critical. To insure that the beam has been located correctly, a reference mark should be scribed on the rotor 3/16 inch from the joint and parallel to the ground surface. This line will be used to check the position and alignment of the Electron Beam weld with joint.

A fixture was designed to hold the rotor in alignment with the Electron Beam while welding. Since the rotor is to be welded from both sides, facilities were provided in this fixture to rotate the rotor exactly 180° so that alignment can be maintained for the weld on each side of the rotor.

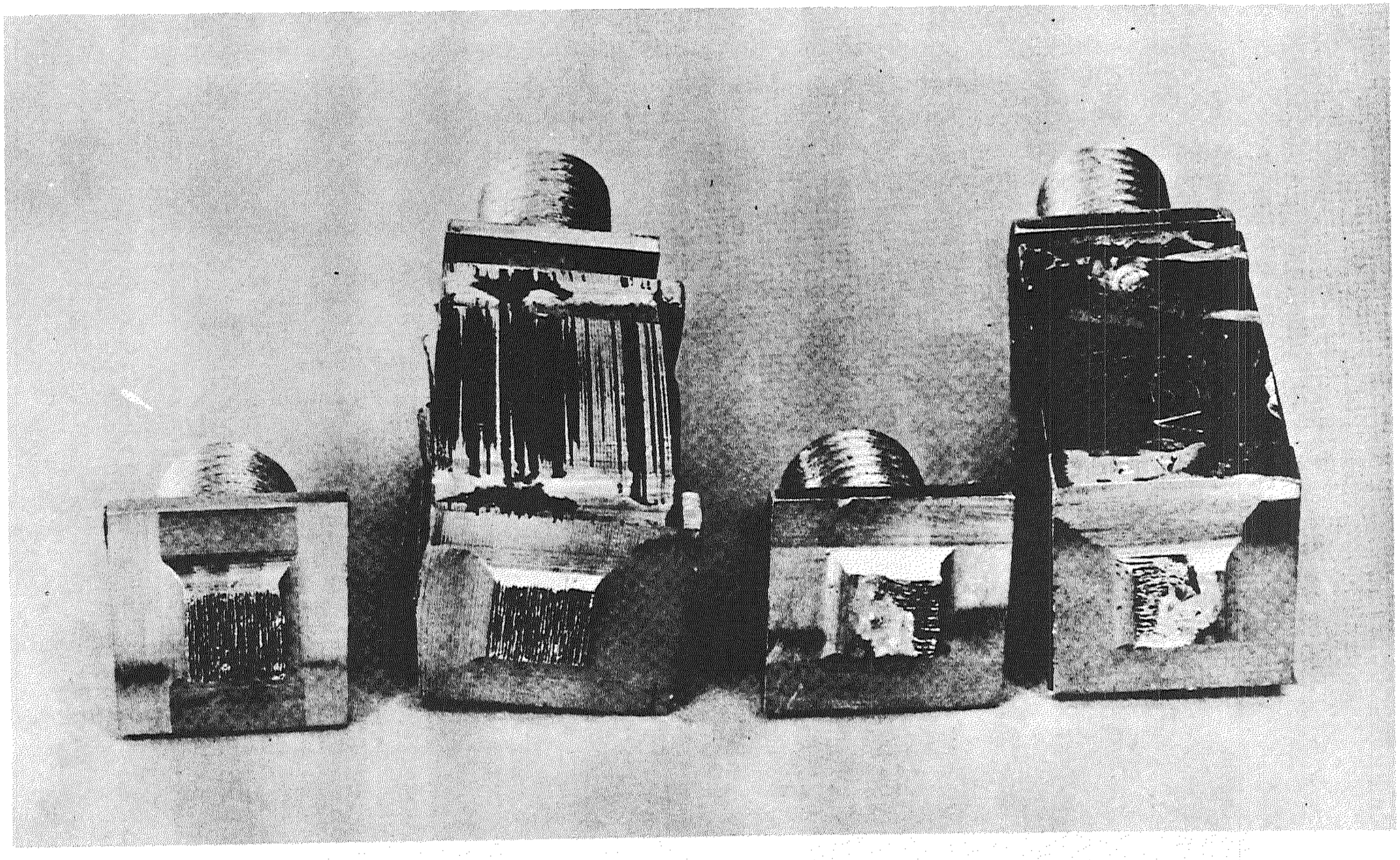
Airco #1 chemical specification are as follows:

| | |
|---|---|
| Carbon | 0.15% Max. |
| Manganese | 0.3-0.6% |
| Phosphorus | 0.035% Max. |
| Sulphur | 0.040% Max. |
| Silicon | 0.10-0.30% |
| Nickel | 1.00-1.50% |
| Chrome | 0.30% Max. |
| Iron | Remainder |

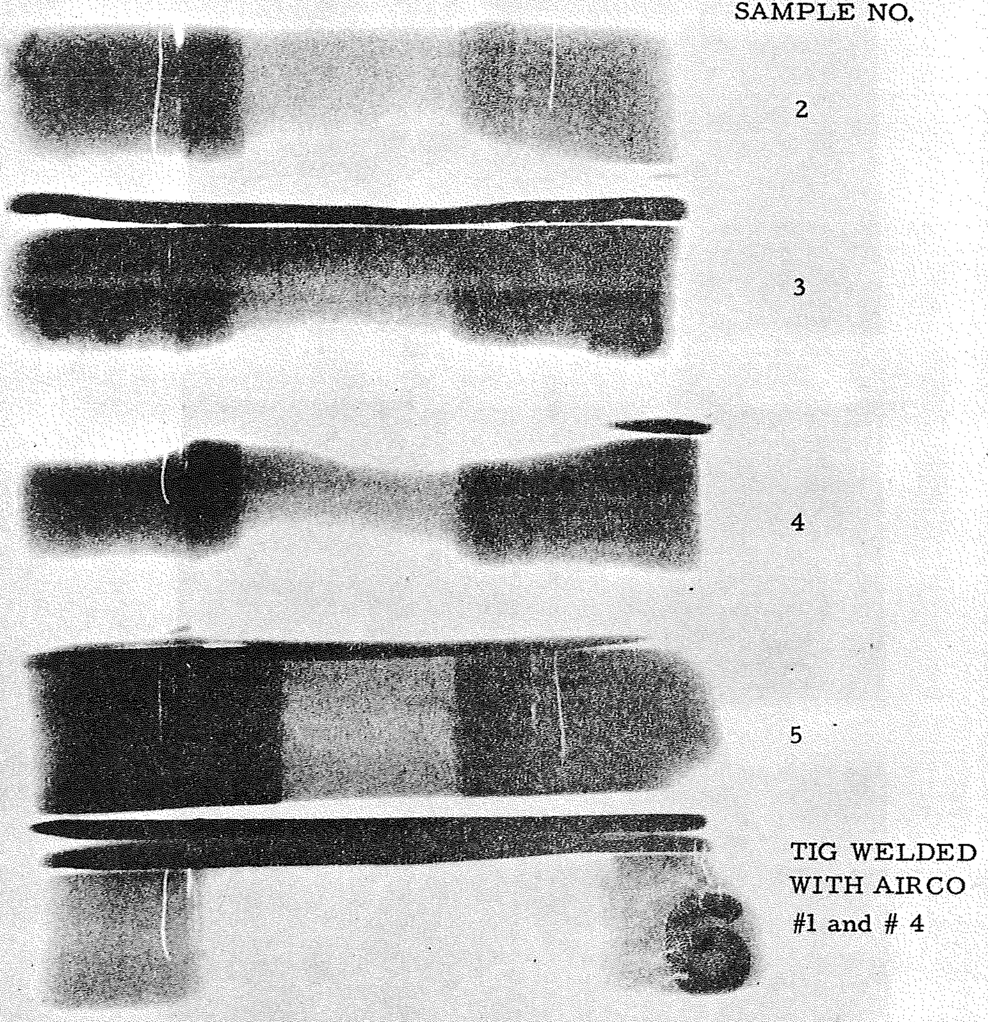
The following tensile tests substantiate that this process produces a strong joint. The above mentioned sample was prepared for tensile tests by cutting the sample in half lengthwise so that the AISI 4620 ends could be threaded 5/8 - 11 and the Electron Beam welded joint was ground to a section 3/8" square. Tensile tests had an ultimate strength of 12,750 and 9,280 lbs. or 90,500 lbs./sq. in. and 66,000 lbs./sq. in. These test samples are shown on Photo 3B. The ultimate strength of the AISI 4620 is 132,500 lbs/sq. in.



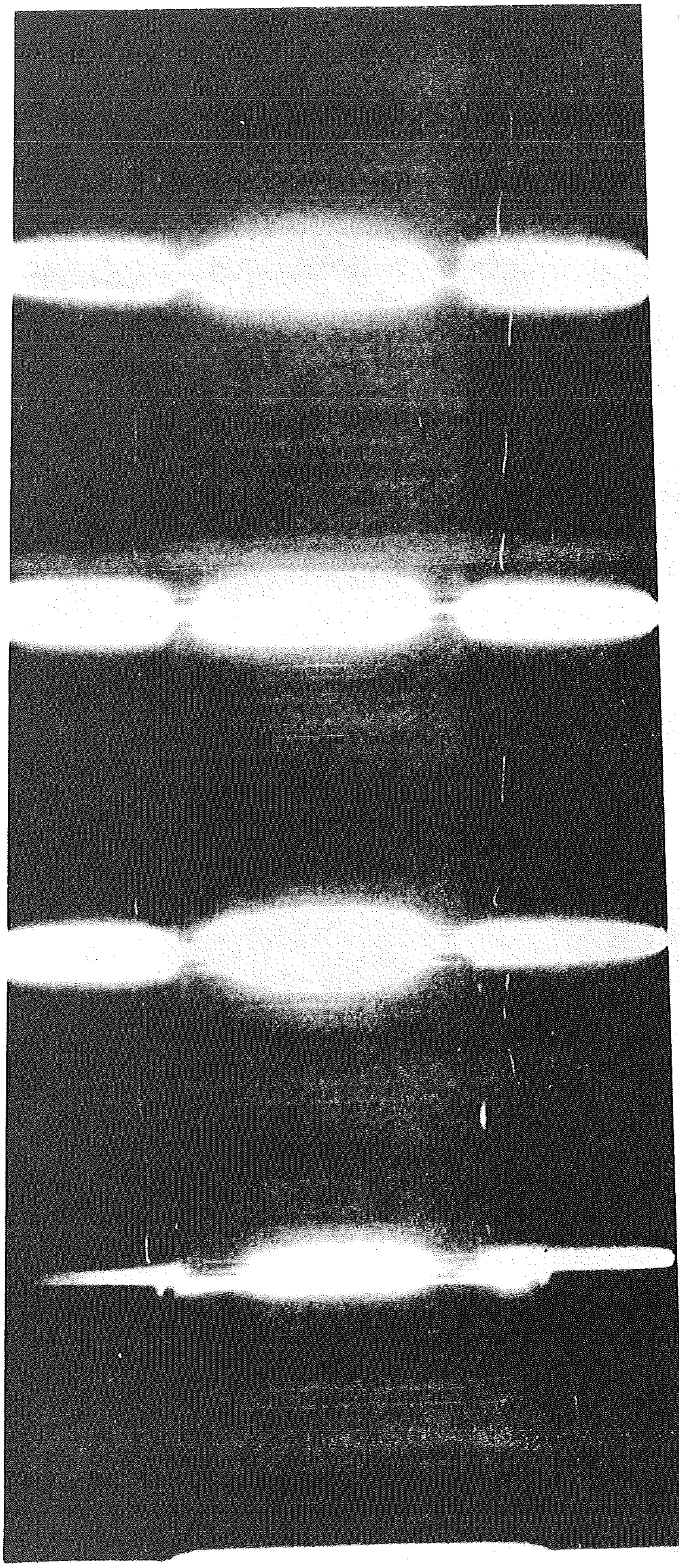
LAMINATED PACKS WITH MIG WELDED FACES #3A



TENSILE TEST SAMPLES



X-RAYS OF SAMPLES SHOWN
IN PHOTO 3A -SIDE VIEW



SAMPLE NO.

2

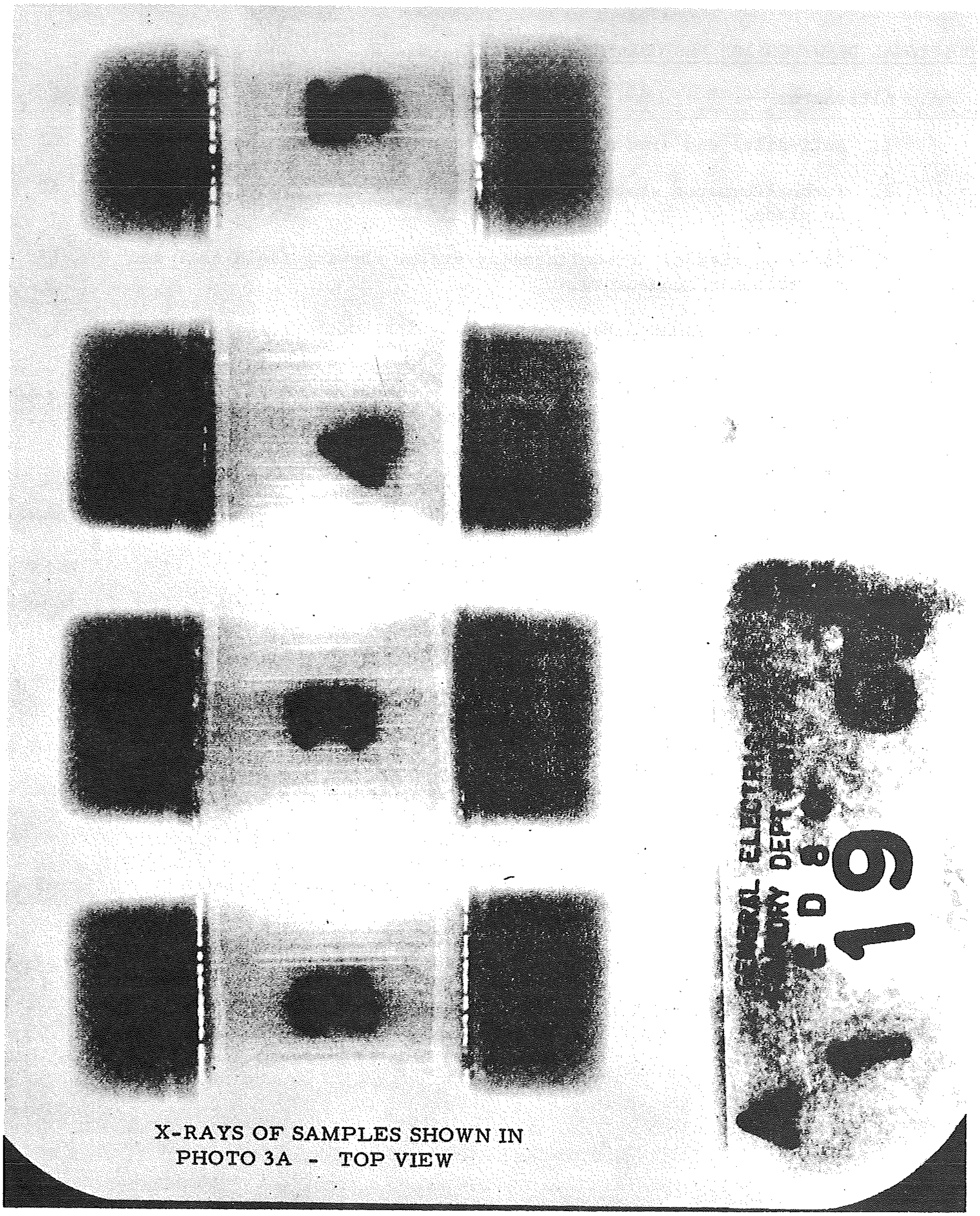
3

X-RAYS OF SAMPLES
SHOWN IN PHOTO 3A-
TOP VIEW

4

5

**TIG WELDED**
**WITH AIRCO**
**# 1 and # 4**



X-RAYS OF SAMPLES SHOWN IN
PHOTO 3A - TOP VIEW

## APPENDIX C

### ADDITIONAL DRAWINGS AND PHOTOGRAPHS

| A. Alternator | Figure |
|---|---|
| 1. Anti-drive end view of turboalternator stator showing connections. | 61 |
| 2. Turboalternator stator ready for shipment with protective covers in place. | 62 |
| 3. Close-up view of turboalternator stator showing field coil and thermocouple connectors. | 63 |
| 4. Alternator Research Package Assembly instructions (E.I. 718A303JF) | |
| 5. Load bank schematic and mechanical detail | |

B. Voltage Regulator-Exciter

1. Breadboard

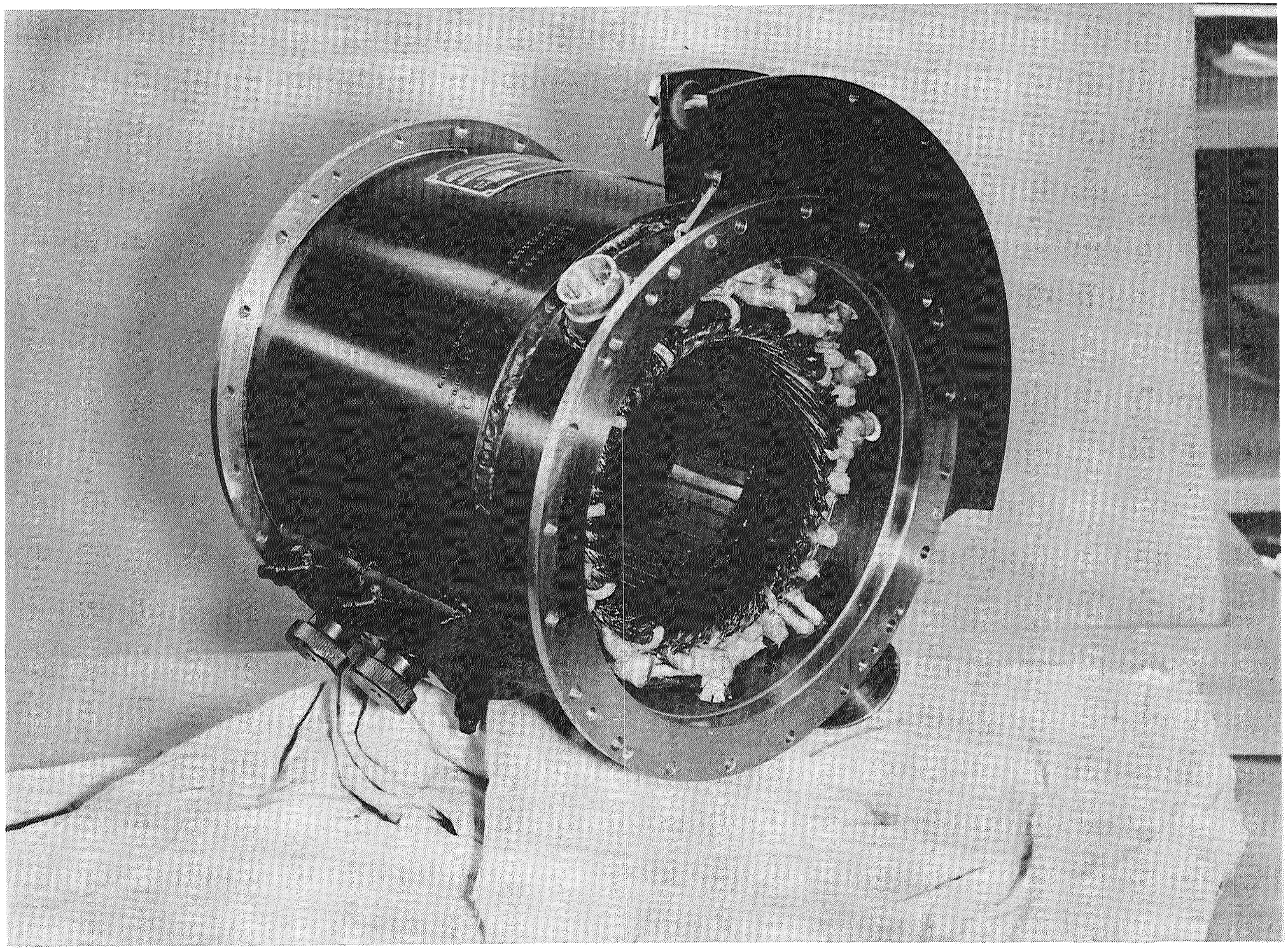
| | | |
|---|---|---|
| Outline | 44D241419 | |
| Assembly | 44E250497 | |
| Connection Diagram | 44F242243 | |
| Elementary Diagram | 44D241414 | |

2. Flyable

| | | |
|---|---|---|
| Outline | 44F242235 | |
| Assembly | 44F250560 | |
| Module (Typical) | 44C350707 | |
| Connection Diagram | 44D242107 | |
| Photo | Typical Module | 64 |
| Outline | 44D253742 | |
| Assembly | 44D253741 | |
| Connection Diagram | 44C350747 | |
| Photo | Reactor transformer without case | 65 |

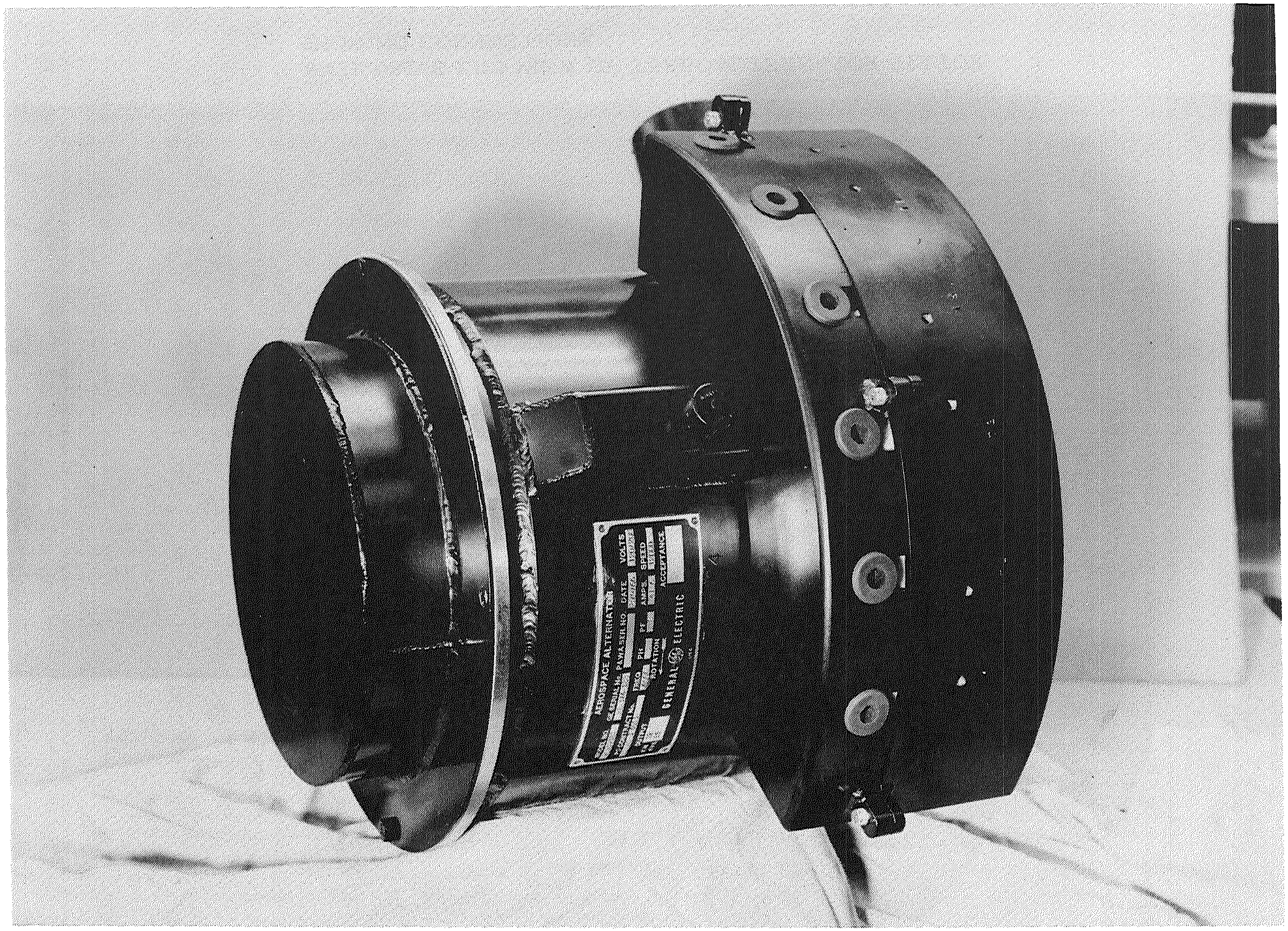
3. System

| | | |
|---|---|---|
| Elementary Diagram | 44D242103 | |

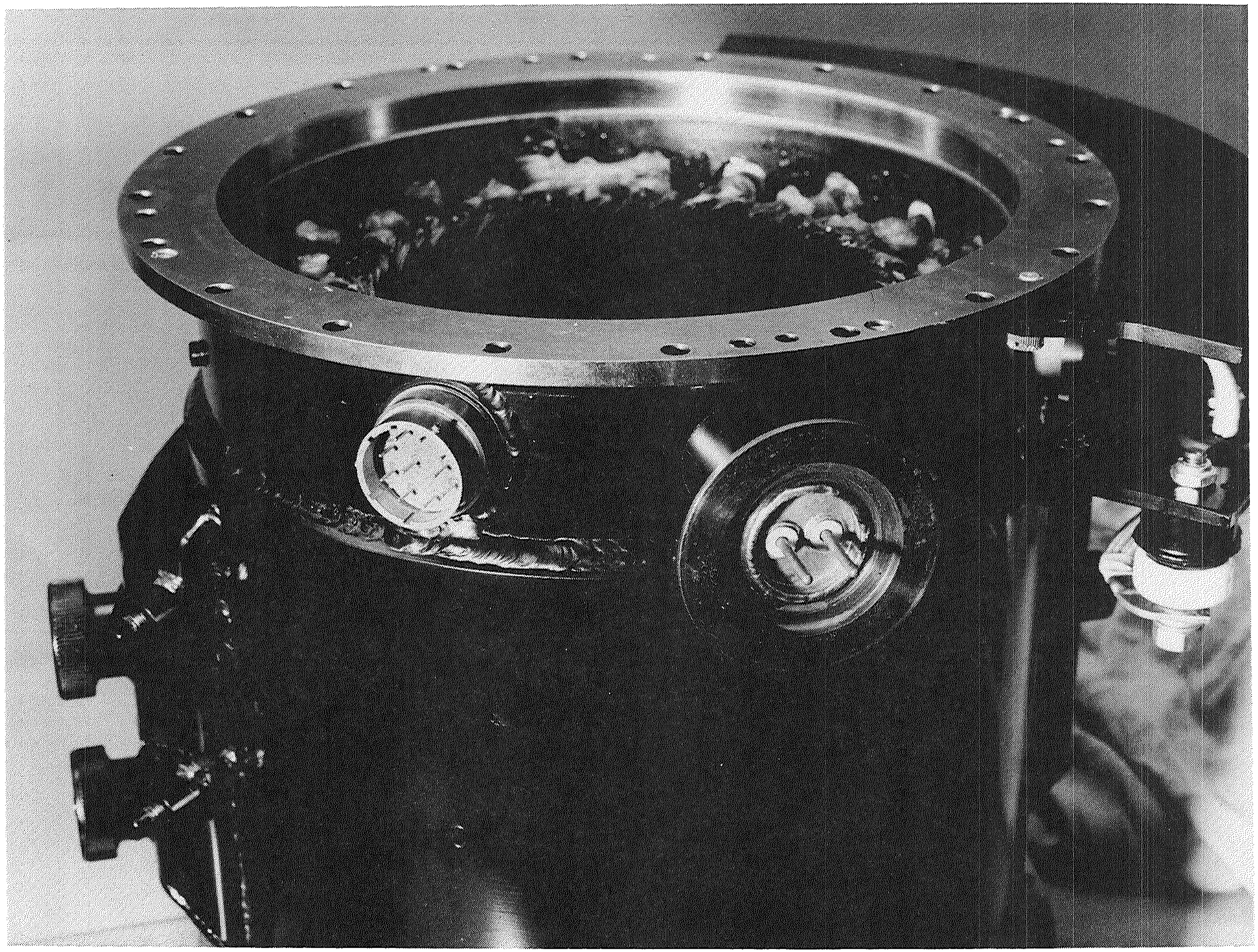


ANTI-DRIVE END VIEW OF TURBOALTERNATOR STATOR SHOWING CONNECTIONS.

FIGURE 61



TURBOALTERNATOR STATOR READY FOR SHIPMENT WITH PROTECTIVE COVERS IN PLACE.
FIGURE 62



FIELD COIL AND THERMOCOUPLE CONNECTORS

FIGURE 63

# ASSEMBLY PROCEDURE FOR THE 2CM393A1

I THIS INSTRUCTION SPECIFIES THE SEQUENCE OF OPERATIONS, ENGINEERING REQUIREMENTS, CLEANLINESS, AND THE INSPECTION OPERATIONS TO BE PERFORMED DURING ASSEMBLY OF THE 2CM393A1 GENERATOR. REFER TO DRAWING 36D831188 AND PLANNING FOR ADDITIONAL DETAILS. REFER TO QUALITY CONTROL INSTRUCTION 9.2.12 FOR INSPECTION PLANNING. MEASURE PREHEAT AND COOLING TEMPERATURES WITH A TOUCH PYROMETER. IF ANY OF THE INSPECTION DATA DOES NOT MEET THE SPECIFIED LIMITS, STOP ASSEMBLY AND ADVISE ENGINEERING OF THE DATA IN QUESTION FOR EVALUATION.

II SPECIAL TOOLING REQUIRED FOR ASSEMBLY WILL BE:

A) TWO ASSEMBLY FIXTURES

1) D65998-900GF-P1
2) D65998-900GF-P7

B) A TOUCH PYROMETER

C) A TORQUE WRENCH (20 IN LB TO 200 IN LB)

III RECORD THE FOLLOWING INFORMATION:

MODEL 2CM393A1 SERIAL NO. ________________

| NAME | DRAWING NO. | REV. NO. | SERIAL NO. |
|---|---|---|---|
| 1. ROTOR | 36D831193 | | |
| 2. FRAME | 36D831183 | | |
| 3. DE END SHIELD | 194E748 | | |
| 4. ADE END SHIELD | 194E749 | | |
| 5. DE BEARING CARTRIDGE | 36B508809 | | |
| 6. ADE BEARING CARTRIDGE | 36B508812 | | |
| 7. DE SEAL CARTRIDGE | 36B508808 | | |
| 8. ADE SEAL CARTRIDGE | 36B508813 | | |
| 9. ADE CAP | 36B508814 | | |

## CONDITIONS

IV 1. FINAL ASSEMBLY OF A 2CM393A1 GENERATOR SHALL BE PERFORMED IN THE LAMINAR FLOW CLEAN ROOM, BAY A, BUILDING 64.

2. THE AIR CONTAMINATION LEVEL SHALL BE IN ACCORDANCE WITH E.I. 718A301 CM LEVEL 4 WHILE THE BEARINGS ARE EXPOSED TO DIRECT FALLOUT AND PER E.I. 718A301 CM LEVEL 5 WHILE THE BEARINGS ARE NOT EXPOSED TO DIRECT FALLOUT.

3. PARTS USED IN THE ASSEMBLY SHALL BE ULTRASONICALLY CLEANED PRIOR TO USE IN THE ASSEMBLY.

4. COMPONENTS SHALL BE HANDLED ONLY WITH CLEAN PLASTIC GLOVES OR TONGS THAT HAVE BEEN ULTRASONICALLY CLEANED PRIOR TO USE.

A) PRE-ASSEMBLY OF STATIONARY PARTS A.D.E.

1. ULTRASONICALLY CLEAN THE A.D.E. END SHIELD (36B508879G1). CLEAN AND CHECK BEARING OIL INLET PASSAGE PER E.I. 718A301 CL. CLEANLINESS TO BE CHECKED AT LEVEL 7.

2. ULTRASONICALLY CLEAN SEAL CARTRIDGE (36B508813P1).

3. ULTRASONICALLY CLEAN THE SEAL (36B508803P1). CLEAN AND CHECK THE STATIONARY PORTION OF THE SEAL PER E.I. 718A301 CL. CLEANLINESS CHECK AT LEVEL 7.

4. ULTRASONICALLY CLEAN "O" RING (962A796P42), GUARD SEAL (36A227610P1), AND PIN (962A159P11).

5. COAT THE STATIONARY PORTION OF THE SEAL (36B508803P1) WITH ANTI-SIEZE COMPOUND 962A285BC (NO-LOX). ASSEMBLE THIS PORTION OF THE SEAL CARTRIDGE (36B508813P1). THE SEAL MUST BE FLUSH TO .005" BELOW THE SEAL CARTRIDGE.

6. ASSEMBLE PIN (962A149P11) AND GUARD SEAL (36A227610P1) INTO END SHIELD ASSEMBLY (36B508879G1). COAT THE BORE OF THE END SHIELD, THE O.D. OF THE END SHIELD, THE O.D. OF THE SEAL CARTRIDGE AND THE "O" RING (962A796P42) WITH SAE 20 OIL FROM THE SPECIAL 5 MICRON FILTERED OIL CAN. (SEE NOTE 1 BELOW.

7. SLIP THE "O" RING OVER THE "O" RING GROOVE OF THE SEAL CARTRIDGE. USING HAND PRESSURE, ASSEMBLE THE SEAL AND SEAL CARTRIDGE ASSEMBLY INTO THE END SHIELD MAKING SURE THAT THE PIN IS IN LINE WITH THE HOLE IN THE CARTRIDGE.

B) ASSEMBLY OF ROTOR & PARTS TO A.D.E. END SHIELD

1. ULTRASONICALLY CLEAN ROTOR (36D831187).

NOTE (1) HEREAFTER ALL REFERENCE TO OIL WILL PERTAIN TO SAE 20 OIL USED FROM THE SPECIAL 5 MICRON FILTER OIL CAN.

2. COAT THE O.D. OF THE ROTOR FROM BEARING JOURNAL TO BEARING JOURNAL WITH A LIGHT FILM OF D6C3B RUST PREVENTATIVE (RUST BAN 624) PER MANUFACTURING PROCESS (P6B-CD3-25).

3. SET THE ROTOR INTO THE ASSEMBLY FIXTURE (NO. D65998-900GF-P1) WITH THE DRIVE END OF THE ROTOR DOWN.

4. ASSEMBLE THE A.D.E. END SHIELD OVER THE ROTOR AND SECURE IT TO THE FIXTURE WITH THE SCREWS PROVIDED WITH THE FIXTURE.

5. WRAP ONE LAYER OF MYLAR TAPE AROUND THE THREADS ON THE SHAFT. THIS IS TO PREVENT THE THREADS FROM DAMAGING THE "O" RING WHEN THE SEAL FACE IS ASSEMBLED.

6. APPLY A THIN FILM OF OIL FROM THE FILTERED OIL CAN TO THE SHAFT EXTENSION.

7. APPLY A THIN FILM OF OIL TO THE ROTATING PORTION OF THE SEAL (36B508803P1 AND PUSH IT ONTO THE SHAFT, TAKING CARE NOT TO DAMAGE THE "O" RING.

8. ULTRASONICALLY CLEAN THE BEARING (36A227386P1). CLEAN AND CHECK BEARING PER E.I. 718A301 CL. CLEANLINESS TO BE CHECKED AT LEVEL 7.

9. REMOVE TAPE FROM THE THREADS AND CLEAN THREADS.

10. APPLY A THIN COAT OF OIL TO THE BEARING AND ASSEMBLE IT ONTO THE SHAFT. MAXIMUM PRESSING FORCE IS 1000 LBS. APPLY A FILM OF OIL TO THE LOCKNUT AND ASSEMBLE LOCK WASHER AND LOCK NUT. TORQUE NUT TO 180-200 IN.LBS.

11. ASSEMBLE THE ULTRASONICALLY CLEANED BEARING CARTRIDGE (36B508812) INTO THE END SHIELD AFTER FIRST HAVING COATED THE PART WITH SAE 20 OIL. BE SURE THE BREATHER HOLE IN THE CARTRIDGE LINES UP WITH THE BREATHER HOLE IN THE END SHIELD.

12. ASSEMBLE PIN (962A159P11).

13. COAT THE CAP (36B508814P1) WITH OIL. PLACE "O" RING (962A796P40) INTO THE CAP. ASSEMBLE ONTO THE END SHIELD AND BOLT DOWN. TORQUE SCREWS, MS24678-22, TO 60-67 IN.LBS. NOTE: COAT SCREWS WITH OIL.

C. ASSEMBLY OF STATOR WOUND TO A.D.E. END SHIELD AND ROTOR ASSEMBLY

1. REMOVE THE ASSEMBLY FIXTURE FROM THE A.D.E. END SHIELD AND ROTOR ASSEMBLY.

2. CLEAN THE STATOR AND COAT THE BORE AND ALL FINISH SURFACES OF THE STATOR WITH A LIGHT FILM OF D6C3B RUST PREVENTATIVE (RUST BAN 624) PER MANUFACTURING PROCESS (P6B-CD3-25).

3. COAT THE RABBET OF THE END SHIELD AND THE "O" RING (962A796P4) WITH A LIGHT FILM OF OIL. PLACE THE "O" RING IN THE GROOVE ON THE END SHIELD AND LOWER THE END SHIELD AND ROTOR ASSEMBLY ONTO THE STATOR. (NOTE END SHIELD AND STATOR ARE DOWELLED FOR POSITIONING).

4. BOLT THE END SHIELD TO THE STATOR USING SCREWS MS24678-26 AND NUTS AN365-428C. TORQUE TO 120 - 150 IN.LBS. NOTE: COAT SCREWS AND NUTS WITH OIL.

5. WEDGE THE ROTOR TO PREVENT IT FROM BRINELLING THE BEARING BY PLACING A TEFLON WEDGE BETWEEN THE STATOR IRON AND THE ROTOR POLES. (2 PLACES 180° APART).

6. ROTATE THE ASSEMBLY OVER AND PREPARE TO ASSEMBLE THE D.E. END SHIELD.

D. PRE-ASSEMBLY OF STATIONARY PARTS D.E.

1. ULTRASONICALLY CLEAN THE DRIVE END END SHIELD (36B508878G1). CLEAN AND CHECK BEARING OIL INLET PASSAGES PER EI 718A301 CL. CLEANLINESS TO BE CHECKED AT LEVEL 7.

2. ULTRASONICALLY CLEAN THE SEAL CARTRIDGE (36B508808P1).

3. ULTRASONICALLY CLEAN "O" RING (962A796P42) AND SCREWS (AN505C-8-7).

4. ULTRASONICALLY CLEAN THE SEAL (36B508803P1). CLEAN AND CHECK THE STATIONARY PORTION OF THE SEAL PER E.I. 718A301 CL. CLEANLINESS CHECK AT LEVEL 7.

5. COAT THE STATIONARY PORTION OF THE SEAL (36B508803P1) WITH NO-LOX. ASSEMBLE THIS PORTION OF THE SEAL INTO THE SEAL CARTRIDGE (36B508808P1). THE SEAL MUST BE FLUSH TO .005" BELOW THE SEAL CARTRIDGE.

6. COAT THE BORE OF THE END SHIELD, THE O.D. OF THE SEAL CARTRIDGE AND THE "O" RING WITH OIL.

7. CLEAN AND ASSEMBLE THE GUARD SEAL (36A227610P1) INTO THE END SHIELD.

8. SLIP THE "O" RING OVER THE "O" RING GROOVE OF THE SEAL CARTRIDGE. USING HAND PRESSURE, ASSEMBLE THE SEAL AND SEAL CARTRIDGE ASSEMBLY INTO THE END SHIELD MAKING SURE THAT THE FOUR 8-32 HOLES IN THE CARTRIDGE LINE UP WITH THE FOUR HOLES IN THE END SHIELD.

9. PULL THE CARTRIDGE UP TIGHT WITH THE FOUR AN505C-8-7 SCREWS AND TORQUE TO 18-20 IN.LBS. STAKE PER P13D-CD3-3. NOTE: COAT SCREWS WITH OIL.

E. ASSEMBLY OF D.E. END SHIELD AND PARTS TO STATOR WOUND

1. COAT THE RABBET OF THE END SHIELD AND THE "O" RING (962A796P4) WITH A LIGHT FILM OF OIL. NOTE: REMOVE WEDGES ON THE ROTOR BEFORE ASSEMBLY OF END SHIELD. PLACE THE "O" RING IN THE GROOVE ON THE END SHIELD AND LOWER THE END SHIELD ONTO THE STATOR AND ROTOR ASSEMBLY. NOTE: END SHIELD AND STATOR ARE DOWELLED FOR POSITIONING.

2. BOLT THE END SHIELD TO THE STATOR USING SCREWS MS24678-26 AND NUTS AN965-428C. TORQUE TO 120 - 150 IN.LBS. NOTE: COAT SCREWS AND NUTS WITH OIL.

3. WRAP ONE LAYER OF MYLAR TAPE AROUND THE THREADS OF THE SHAFT TO PREVENT DAMAGE TO THE "O" RING WHEN THE SEAL FACE IS ASSEMBLED.

4. PERFORM THE FOLLOWING MEASUREMENTS AND CALCULATIONS. SEE SKETCH 1 FOR REFERENCE TO LETTERS.

MEASURE "A" ____________ (FROM END SHIELD TO SEAL CARTRIDGE)

MEASURE "M" ____________ (DISTANCE FROM E.S. TO SEAL SHOULDER ON THE SHAFT)

MEASURE "N" ____________ (WIDTH OF SEAL FACE)

SUBTRACT "N" FROM "M" LEAVING DIM "B"
(M) ____________
(N) ____________ (SUBTRACT)
(B) ____________

SUBTRACT "B" FROM "A" LEAVING DIM "C"
(A) ____________
(B) ____________ (SUBTRACT)
(C) ____________

SUBTRACT "D" WORKING HEIGHT OF WAVY WASHER FROM "C" (D) .062" (SUBTRACT)

THIS LEAVES DIM "E" WHICH IS THE SHIM THICKNESS (E) ____________ (SHIM 36A227469P1)

ADD DIMENSIONS "F" - BRG WIDTH (INNER RACE) (F) ____________
"G" - ROT SEAL WIDTH (G) ____________
"H" - MEAN WORKING HEIGHT OF THE STATIONARY SEAL (H) .500"
TOTAL ____________

SUBTRACT THE TOTAL OF F, G, AND H (B) ________ (FROM END SHIELD TO SEAL ON ROTOR)

FROM DIMENSION "B" (TOTAL F,G, &H) ________ (SUBTRACT)

THIS LEAVES DIMENSION "J" (J) ________

SUBTRACT DIMENSION "K" DISTANCE FROM FLANGE FACE TO SEAL SEAT ON BEARING CARTRIDGE 36B508809P1
(J) ________
(K) ________ (SUBTRACT)
(L) ________

THIS LEAVES DIMENSION "L" WHICH IS THE SHIM BEHIND THE SEAL.

5. APPLY A THIN FILM OF OIL TO THE SHAFT.

6. APPLY A THIN FILM OF OIL TO THE ROTATING PORTION OF THE SEAL (36B508803P1) AND PUSH IT ONTO THE SHAFT, TAKING CARE NOT TO DAMAGE THE "O" RING. BE SURE TO SEAT SEAL AGAINST THE SHAFT SHOULDER.

7. CLEAN AND ASSEMBLE SHIM (36A227469P1) AND WAVY WASHER (36A227455P1).

8. ULTRASONICALLY CLEAN THE BEARING (36A227386P1). CLEAN AND CHECK BEARING PER E.I. 718A301 CL. CLEANLINESS TO BE CHECKED AT LEVEL 7.

9. REMOVE THE TAPE FROM THE THREADS AND CLEAN THREADS, THEN APPLY A THIN FILM OF OIL ON THE BEARING AND NO-LOX ON THE I.D. OF THE INNER RACE, THEN ASSEMBLE IT.

10. RE-TAPE THE THREADS.

11. APPLY A THIN FILM OF OIL TO THE ROTATING SEAL FACE AND ASSEMBLE IT ONTO THE SHAFT, TAKING CARE NOT TO DAMAGE THE "O" RING.

12. REMOVE THE TAPE AND CLEAN THE THREADS.

13. PRE-HEAT THE BEARING AND SEAL CARTRIDGE TO 150°C/175°C. PLACE THE STATIONARY PORTION OF THE SEAL IN DRY ICE UNTIL IT REACHES THE ICE TEMPERATURE.

14. WHEN THE CARTRIDGE AND THE SEAL ARE AT THE RIGHT TEMPERATURE, POSITION THE SHIM (36A227515P1) AND THEN DROP IN THE SEAL. APPLY A SLIGHT PRESSURE, 40 - 50#, TO THE SEAL CASE TO INSURE THAT IT IS SEATED. ALLOW PARTS TO COOL TO ROOM TEMPERATURE.

15. COAT THE O.D. AND THE I.D. OF THE BEARING AND SEAL CARTRIDGE INCLUDING THE SEAL WITH OIL.

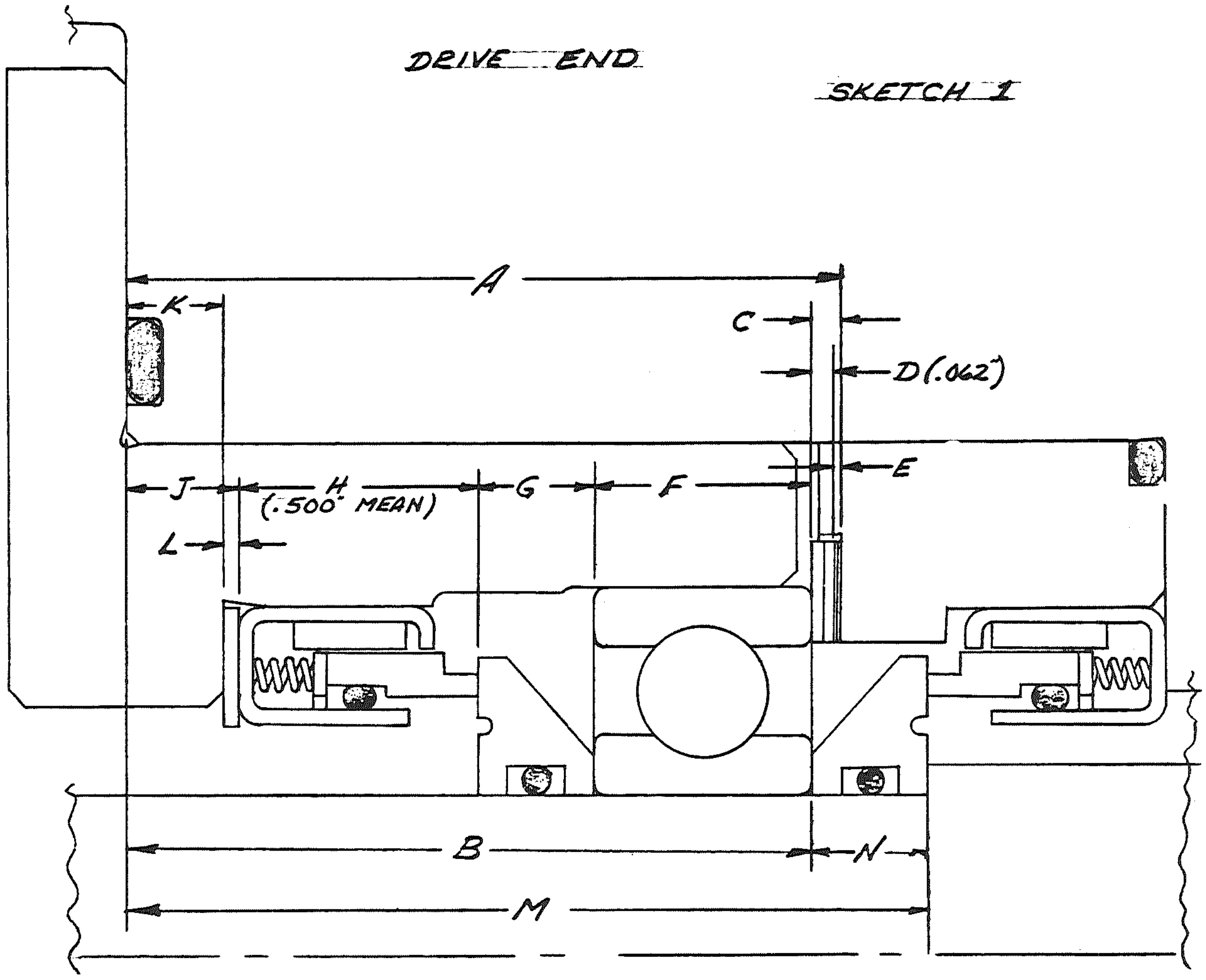
16. POSITION THE LINE UP FIXTURE (D65998-900GF-P7) INTO THE CARTRIDGE.

17. PLACE THE "O" RING (962A796P40) INTO THE GROOVE ON THE END SHIELD.

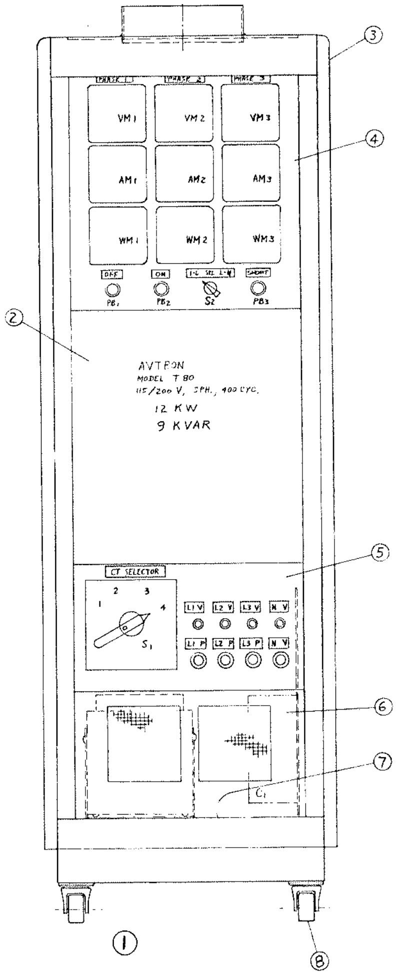
18. USING GUIDE PINS FOR EACH OF LINEUP, BEGIN PUSHING THE CARTRIDGE INTO PLACE ON THE END SHIELD USING THE SHAFT EXTENSION AS A PILOT. THIS SHOULD REQUIRE ONLY HAND PRESSURE. BE SURE NOT TO PINCH THE "O" RING.

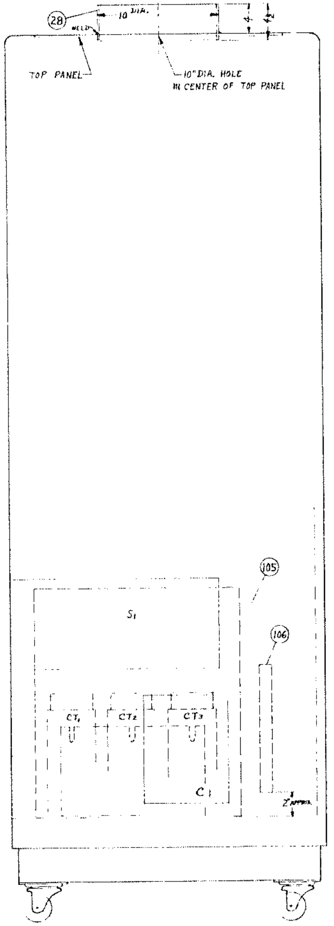
19. ASSEMBLE SCREWS (MS24678-22) AND NUTS (AN365-428C). TORQUE TO 60/70 IN.LBS. REMOVE THE LINE UP FIXTURE. NOTE: COAT THE SCREWS AND NUTS WITH OIL.

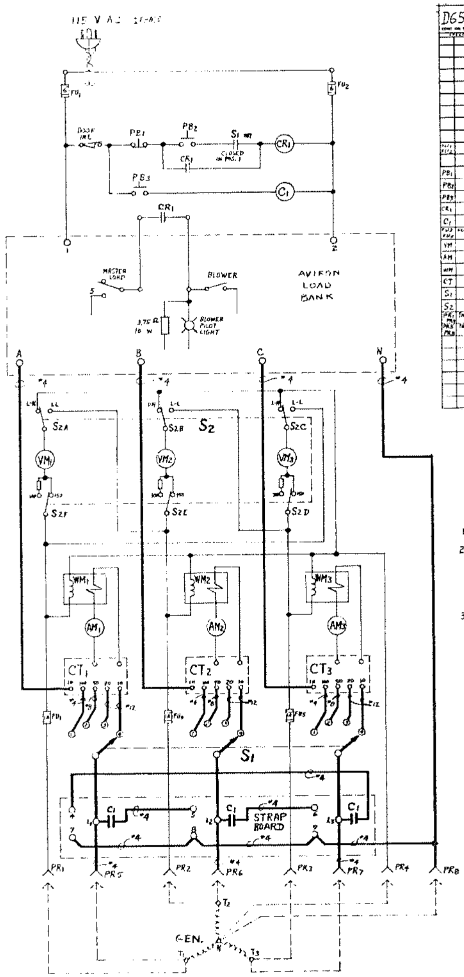
20. APPLY A FILM OF SAE 20 OIL TO THE SPACER (36A227391P1) AND ASSEMBLE IT, THE LOCK WASHER (128B354P8), AND THE LOCK NUT (36A227416P1). TORQUE THE LOCK NUT TO 180 - 200 INCH-POUNDS.



718A303 JF
SH NO 8
CONT ON SH F
REV 0







D65999-601FG

A.C. GENERATOR LOAD BANK ~ 15 KVA

FIRST MADE FOR PRATT & WHITNEY SPEC. NO. 6373

| | | G-1 | PART NO | NAME | DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT |
|---|---|---|---|---|---|
| | | X | 1 | ASSEMBLY | |
| | | 1 | 2 | LOAD BANK | AVTRON MFG. CO. MODEL T80 |
| | | 1 | 3 | CABINET | BUD RADIO INC. # 60-2311 SB |
| | | 1 | 4 | PANEL | PS-1260 SB (19¼) |
| | | 1 | 5 | PANEL | PS-1260 SB (10½) |
| | | 1 | 6 | GRILL PANEL | PS-811 SB (10½) |
| | | 1 | 7 | SHELF | 60-2381 |
| | | 1 SET | 8 | CASTERS | BUD RADIO, INC. RC-7758 (SET OF 4) |
| FU1 FU2 | | 2 | 9 | FUSE HOLDER | G E CO. #189666 FUSE #GF4A6 |
| | | 1 | 10 | DOOR INTERLOCK | ROBERTSHAW ACRO #BRD2 LV12B 15 |
| PB1 | | 1 | 11 | PUSHBUTTON | G.E. CO. CR 2940 UA 202 C |
| PB2 | | 1 | 12 | PUSHBUTTON | CR 2940 UA 202 B |
| PB3 | | 1 | 13 | PUSHBUTTON | CR 2940 UA 202 D |
| CR1 | | 1 | 14 | RELAY | CR 2790 E 100 A2 |
| C1 | | 1 | 15 | CONTACTOR | CR 105 E 002 SIZE 3 100A |
| FU3 FU4 | FU5 | 3 | 16 | FUSE HOLDER | 189666 FUSE #GF4A1 |
| VM | | 3 | 17 | VOLT METER | AB 40 150/300 V 50-103061 PZRYIJA |
| AM | | 3 | 18 | AMMETER | AB 18 5A 8AB18A3AL1 |
| WM | | 3 | 19 | WATTMETER | AB 18 500 W 5A 120V 50-102111 FCDKIJF |
| CT | | 3 | 20 | CURRENT TRANS. | GE. CO. TYPE JP1 CAT. 750X996 |
| S1 | | 1 | 21 | SWITCH | BARKELEW ELEC. MFG. CO. SEE NOTE 2 |
| S2 | | 1 | 22 | SWITCH | MALLORY #1361L 4 GANG NON-SHORTING 2 CIRCUIT ROTARY SWITCH |
| PR1 PR2 PR3 PR4 | THRU | 4 | 23 | PIN RECEPTACLE | SUPERIOR ELEC. CO. #RP 25 GB |
| PR5 PR8 | THRU | 4 | 24 | PIN RECEPTACLE | SUPERIOR ELEC. CO. #RP 100 GB |
| | | 9 | 25 | STUD | BRASS ½-13 × 4" LONG |
| | | 36 | 26 | HEX NUT | BRASS ½-13 |
| | | 54 | 27 | WASHER | BRASS 1⅛ O.D. 17/32 I.D. × 3/32 |
| | | 1 | 28 | FLANGE | SH. STL. 1/16 × 4½ × 31⅞ |

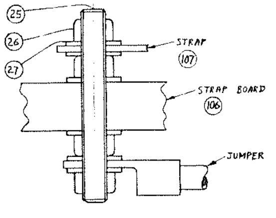
NOTE

1.) ALL WIRING #16 UNLESS OTHERWISE SPECIFIED

2.) S1 SWITCH
SPECIAL TYPE T TANDEM TAP SWITCH MAKE BEFORE BREAK BLADE
3 PHASE, 100 AMP, ⅛" PANEL MOUNTING, AUX. MICRO SWITCH
CLOSED IN #1 POSITION ONLY
SIMILAR TO BARKELEW DWG 1-T-280 REV. 2 EXCEPT OMIT 15 AMP KNIFE SWITCH

3.) S1 MUST BE IN POSITION 1 BEFORE LOAD CAN BE APPLIED.

TYPICAL STRAP BOARD CONNECTION



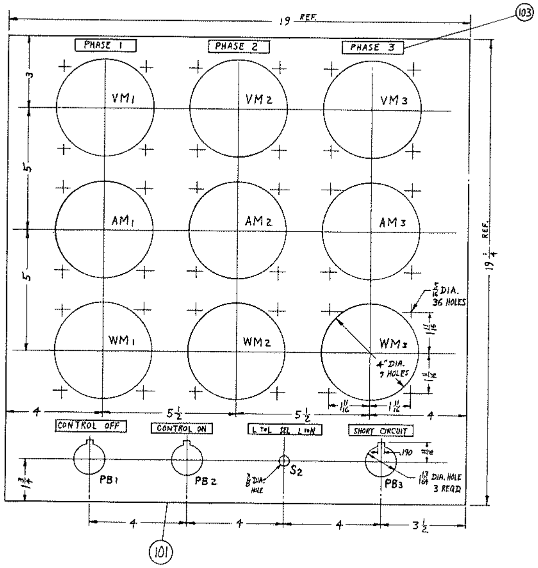
D65999-601 FG
CONT ON SHEET SH NO 2

D65999-601 FG

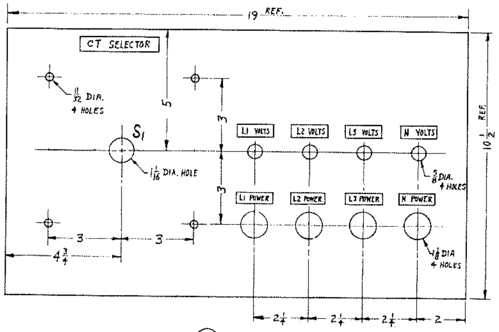
# A.C. GENERATOR LOAD BANK ~ 15 KVA

FIRST MADE FOR PRATT & WHITNEY SPEC. NO. 6373

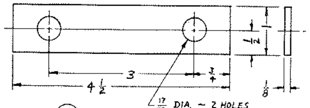
| G-1 | PART NO. | NAME | DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT |
|---|---|---|---|
| 1 | 101 | PANEL | MAKE FROM D65999-601 FG P 4 |
| 1 | 102 | PANEL | MAKE FROM D65999-601 FG P 5 |
| A.R. | 103 | NAMEPLATE | DYMO-MITE EMBOSSED TAPE #158 BLACK |
| 1 | 104 | C.T. BRKT | SH. STL. 1/8 × 12 × 23 1/4 |
| 1 | 105 | DEVICE PANEL | SH. STL. 1/8 × 17 × 19 1/4 |
| 1 | 106 | STRAP BOARD | TEXTOLITE 1 × 10 1/2 × 18 3/8 |
| 3 | 107 | STRAP | COPPER 1/8 × 1 × 4 1/2 |
| 1 | 108 | NAMEPLATE | G.E.CO. 2040-C COMPOUND ENGRAVE AS SHOWN |



(101)



(102)



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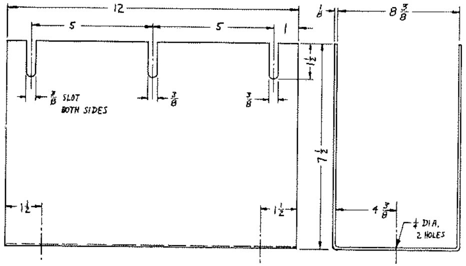
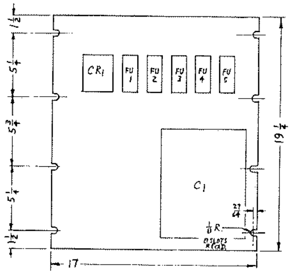
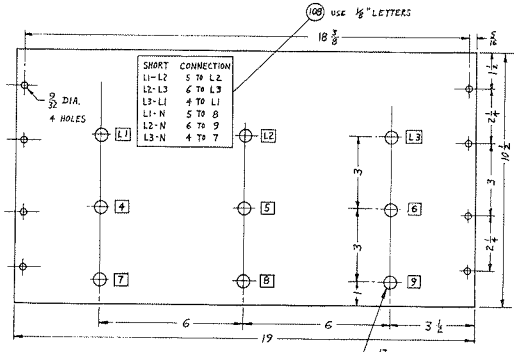


(104)

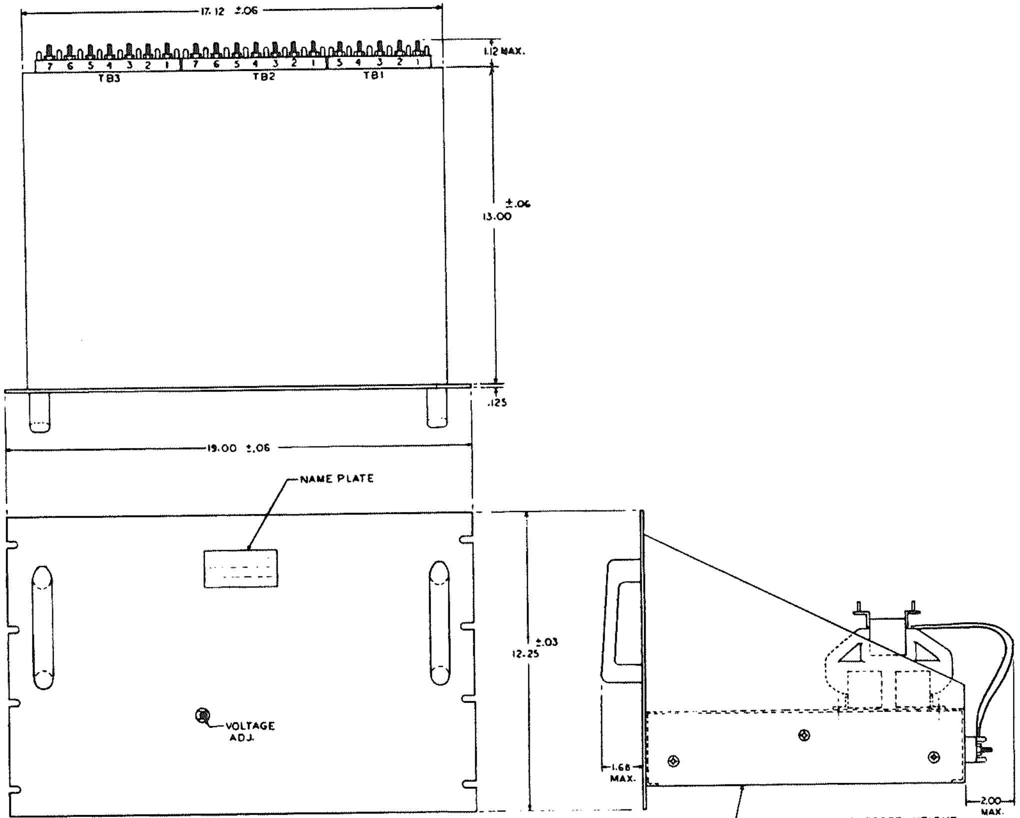
PAINT ~ GRAY ~ GE8112 OR EQUIV.



(105) 1/8 THICK



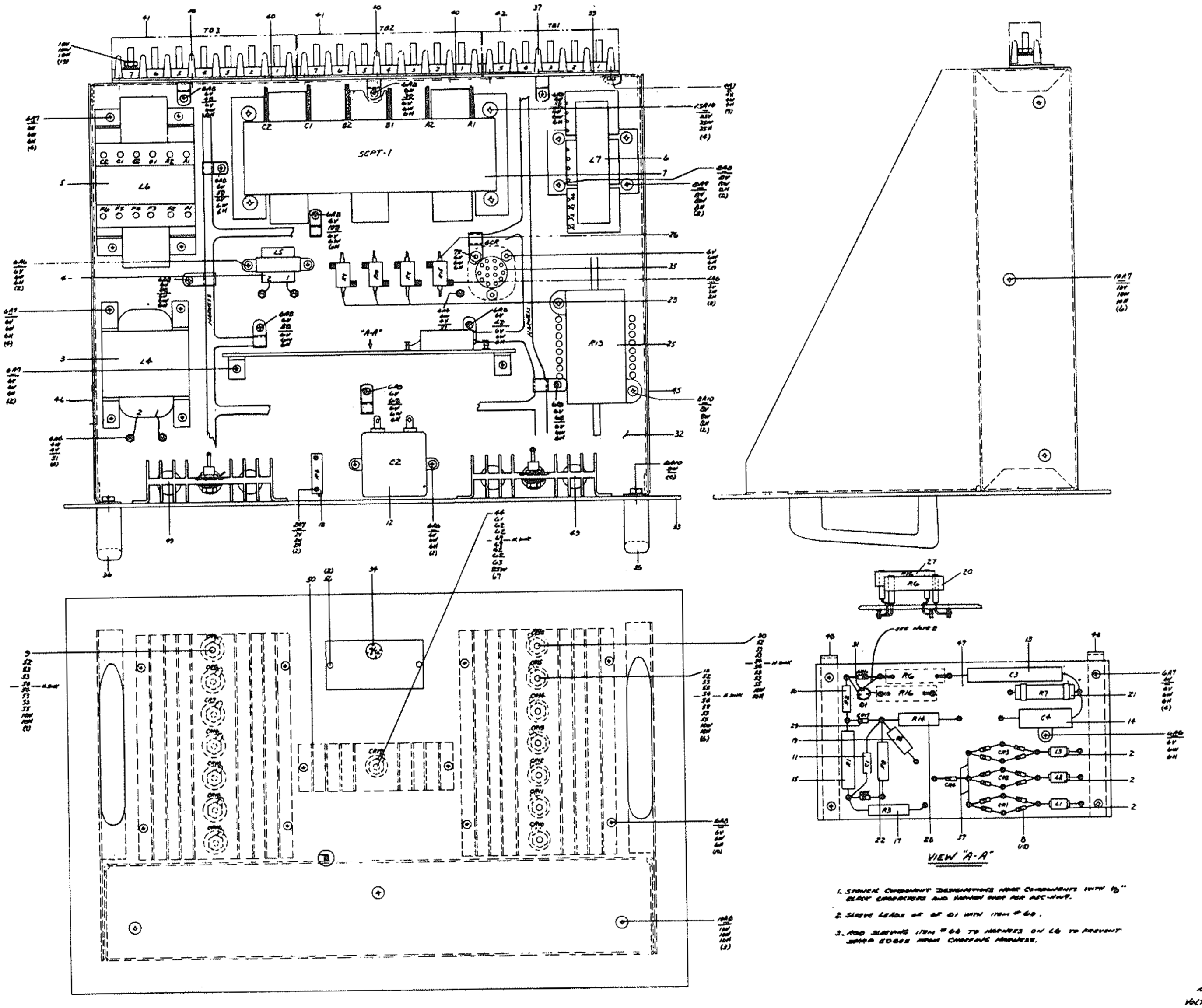
(106) 1" THICK



TO ADEQUATELY SUPPORT WEIGHT OF UNIT, CUSTOMER MUST PROVIDE CHANNEL OR RAIL SUPPORTS ALONG BOTTOM EDGES OF BOTH SIDES OF CHASSIS.

VOLTAGE REGULATOR-EXCITER

DWG NO.
44D241419



1. STENCIL COMPONENT DESIGNATIONS NEAR COMPONENTS WITH 1/8" BLACK CHARACTERS AND VARNISH OVER PER A5C-NN7.

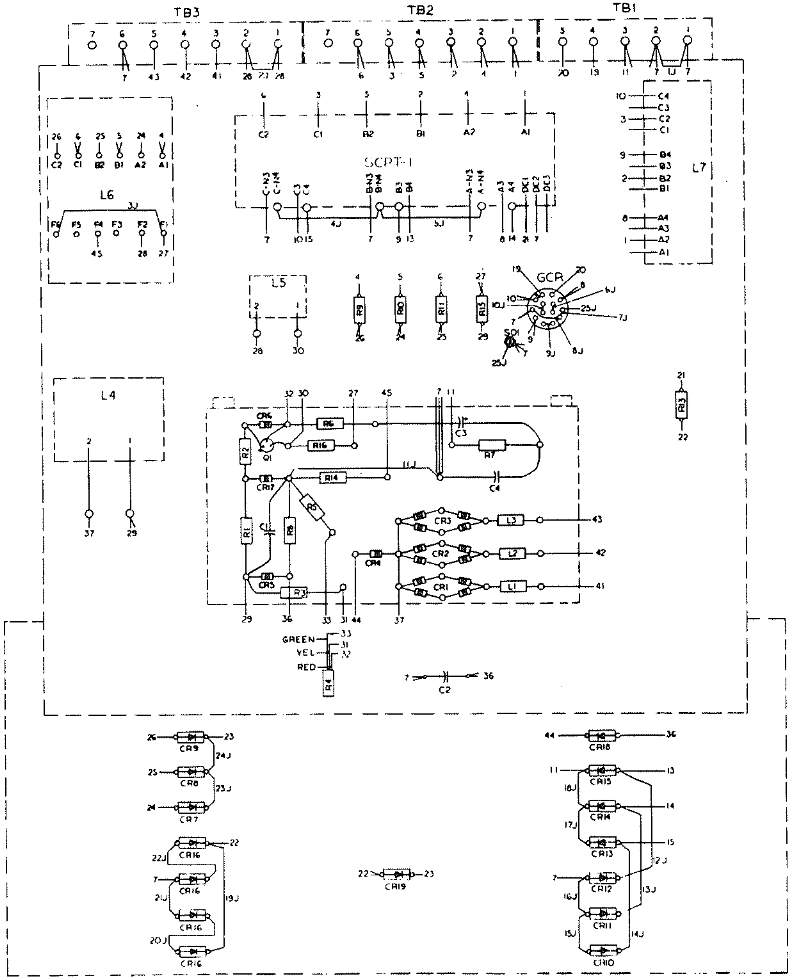
2. SLEEVE LEADS OF OF Q1 WITH ITEM #60.

3. ADD SLEEVING ITEM #66 TO HARNESS ON L6 TO PREVENT SHARP EDGES FROM CHAFFING HARNESS.

ASSEMBLY
VOLTAGE REGULATOR-EXCITER

44E250497

①



WIRE TABLE

| CIR. NO. | WIRE SIZE | SEQUENCE OF CONNECTIONS |
|---|---|---|
| 4 | 20 | TB2-2, L6, R9 |
| 5 | 20 | TB2-4, L6, R10 |
| 6 | 20 | TB2-6, L6, R11 |
| 7 | 20 | TB1-2, TB3-6, C4, C2, CR16 |
| 7 | 20 | C4, GCR |
| 7 | 14 | TB1-2, CR12 |
| 11 | 14 | TB1-3, CR15 |
| 11 | 20 | TB1-3, R7 |
| 13 | 14 | SCPT-1, CR15 |
| 14 | 14 | SCPT-1, CR14 |
| 15 | 14 | SCPT-1, CR13 |
| 19 | 20 | TB1-4, GCR |
| 20 | 20 | TB1-5, GCR |
| 22 | 20 | R13, CR19, CR16 |
| 23 | 20 | CR19, CR9 |
| 24 | 20 | L6, R10, CR7 |
| 25 | 20 | L6, R11, CR8 |
| 26 | 20 | L6, R9, CR9 |
| 27 | 20 | L6, R15, R16 |
| 28 | 20 | L6, TB3-2 |
| 28 | 20 | L5, TB3-1 |
| 29 | 20 | R15, L4, R3 |
| 30 | 20 | L5, R16 |
| 36 | 20 | CR18, C2, R8 |
| 37 | 20 | L4, CR1 |
| 41 | 20 | TB3-3, L1 |
| 42 | 20 | TB3-4, L2 |
| 43 | 20 | TB3-5, L3 |
| 44 | 20 | CR18, CR4 |
| 45 | 20 | L6, R14 |

JUMPER TABLE

| J NO. | CIR NO. | WIRE SIZE | CONNECTIONS |
|---|---|---|---|
| 1J | 7 | 20 | TB1-1, TB1-2 |
| 2J | 28 | 20 | TB3-1, TB3-2 |
| 3J | 27 | 20 | L6, L6 |
| 4J | 12 | 14 | SCPT-1, SCPT-1 |
| 5J | 12 | 14 | SCPT-1, SCPT-1 |
| 6J | 46 | 20B | GCR, GCR |
| 7J | 7 | 20 | GCR, GCR |
| 8J | 7 | 20 | GCR, GCR |
| 9J | 45 | 20B | GCR, GCR |
| 10J | 47 | 20B | GCR, GCR |
| 11J | 7 | 20 | C4, R14 |
| 12J | 13 | 14 | CR12, CR15 |

JUMPER TABLE

| J NO. | CIR NO. | WIRE SIZE | CONNECTIONS |
|---|---|---|---|
| 13J | 14 | 14 | CR11, CR14 |
| 14J | 15 | 14 | CR10, CR13 |
| 15J | 4 | 14 | CR10, CR11 |
| 16J | 7 | 14 | CR11, CR12 |
| 17J | 11 | 14 | CR13, CR14 |
| 18J | 11 | 14 | CR15, CR14 |
| 19J | 22 | 20 | CR16, CR16 |
| 20J | 49 | 20 | CR16, CR16 |
| 21J | 7 | 20 | CR16, CR16 |
| 22J | 50 | 20 | CR16, CR16 |
| 23J | 23 | 20 | CR7, CR8 |
| 24J | 23 | 20 | CR8, CR9 |
| 25J | 7 | 20 | GCR, SO1 |

SCPT-1

| LEAD | CIRCUIT NO | CONNECT TO |
|---|---|---|
| A1 | 1 | TB2-1 |
| A2 | 4 | TB2-2 |
| B1 | 2 | TB2-3 |
| B2 | 5 | TB2-4 |
| C1 | 3 | TB2-5 |
| C2 | 6 | TB2-6 |
| A3 | 8 | GCR |
| A-N3 | 7 | SO1 |
| B3 | 9 | GCR |
| B-N3 | 7 | SO1 |
| C3 | 10 | GCR |
| C-N3 | 7 | SO1 |
| DC1 | 21 | R13 |
| DC2 | 7 | TB1-1 |
| DC3 | — | TAPE |

L7

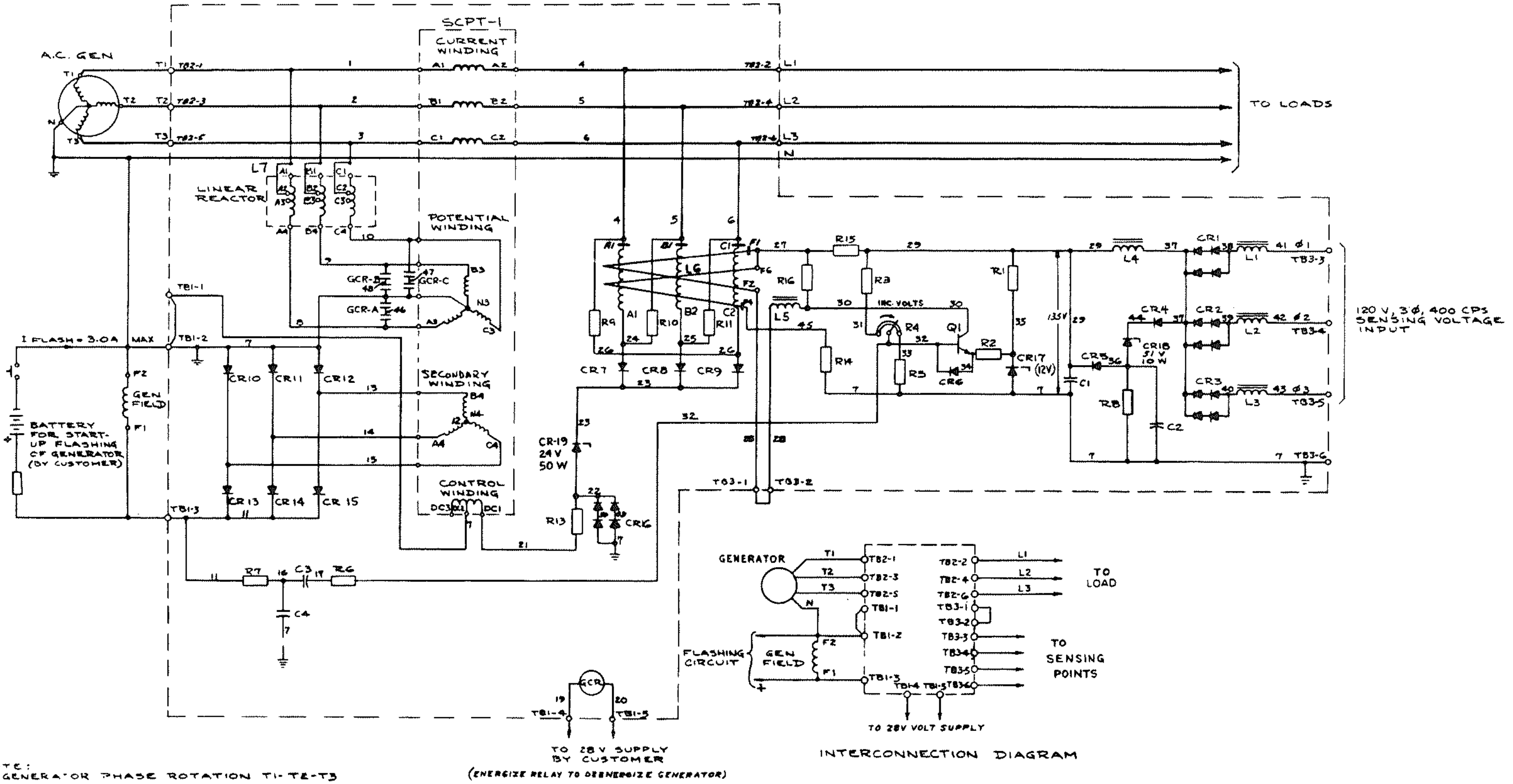
| LEAD | CIRCUIT NO. | CONNECT TO |
|---|---|---|
| A1 | — | TAPE |
| A2 | 1 | TB2-1 |
| A3 | — | TAPE |
| A4 | 8 | GCR |
| B1 | — | TAPE |
| B2 | 2 | TB2-3 |
| B3 | — | TAPE |
| B4 | 9 | GCR |
| C1 | — | TAPE |
| C2 | 3 | TB2-5 |
| C3 | — | TAPE |
| C4 | 10 | GCR |

R4

| LEAD | CIRCUIT NO. | CONNECT TO |
|---|---|---|
| RED | 32 | R6 |
| YEL | 31 | R3 |
| GREEN | 33 | R5 |

CONNECTION DIAGRAM
VOLTAGE REGULATOR—EXCITER

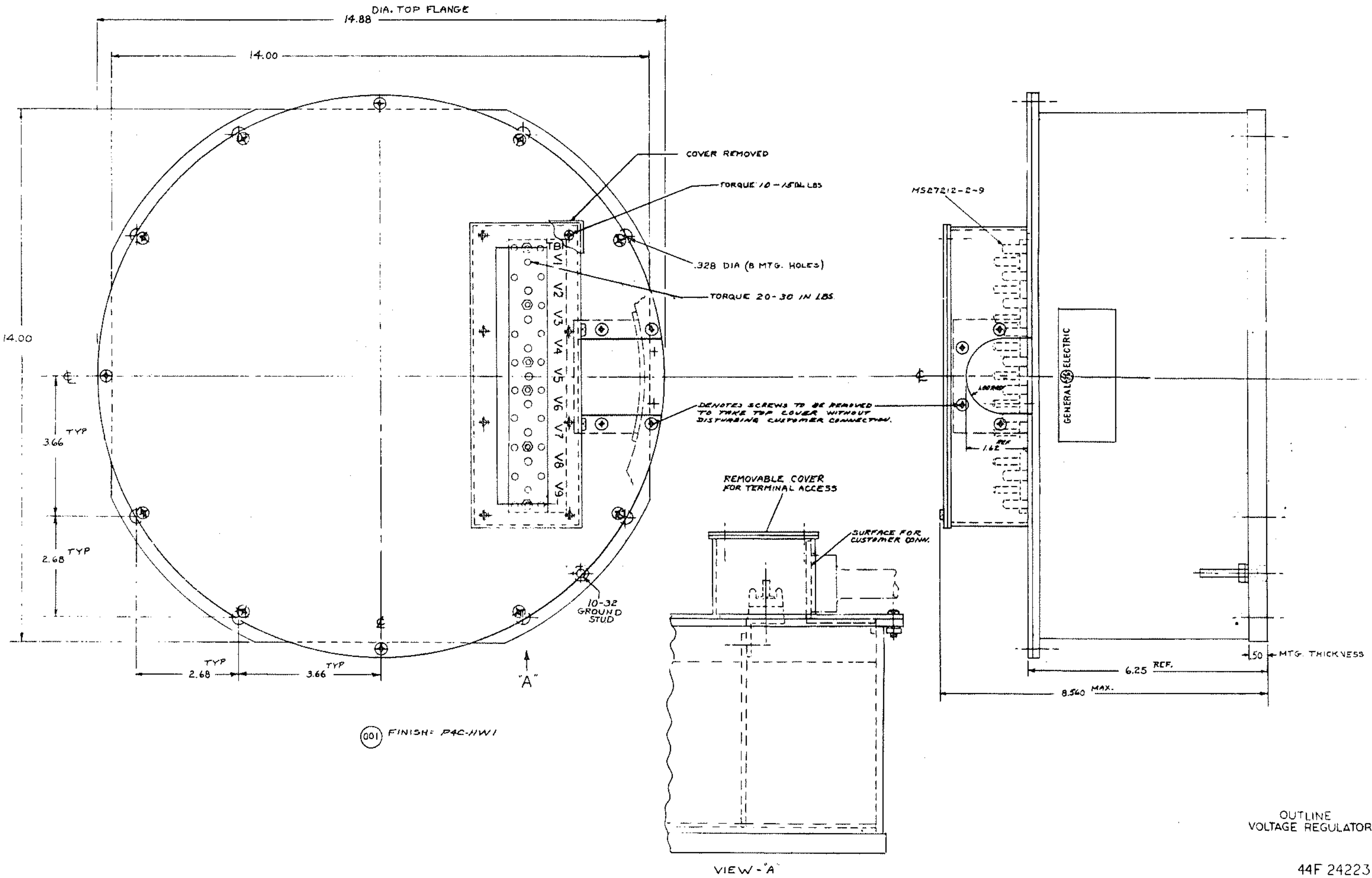
44F242243



NOTE:
GENERATOR PHASE ROTATION T1-T2-T3

SCHEMATIC DIAGRAM
VOLTAGE REGULATOR-EXCITER
BRAYTON CYCLE BREADBOARD

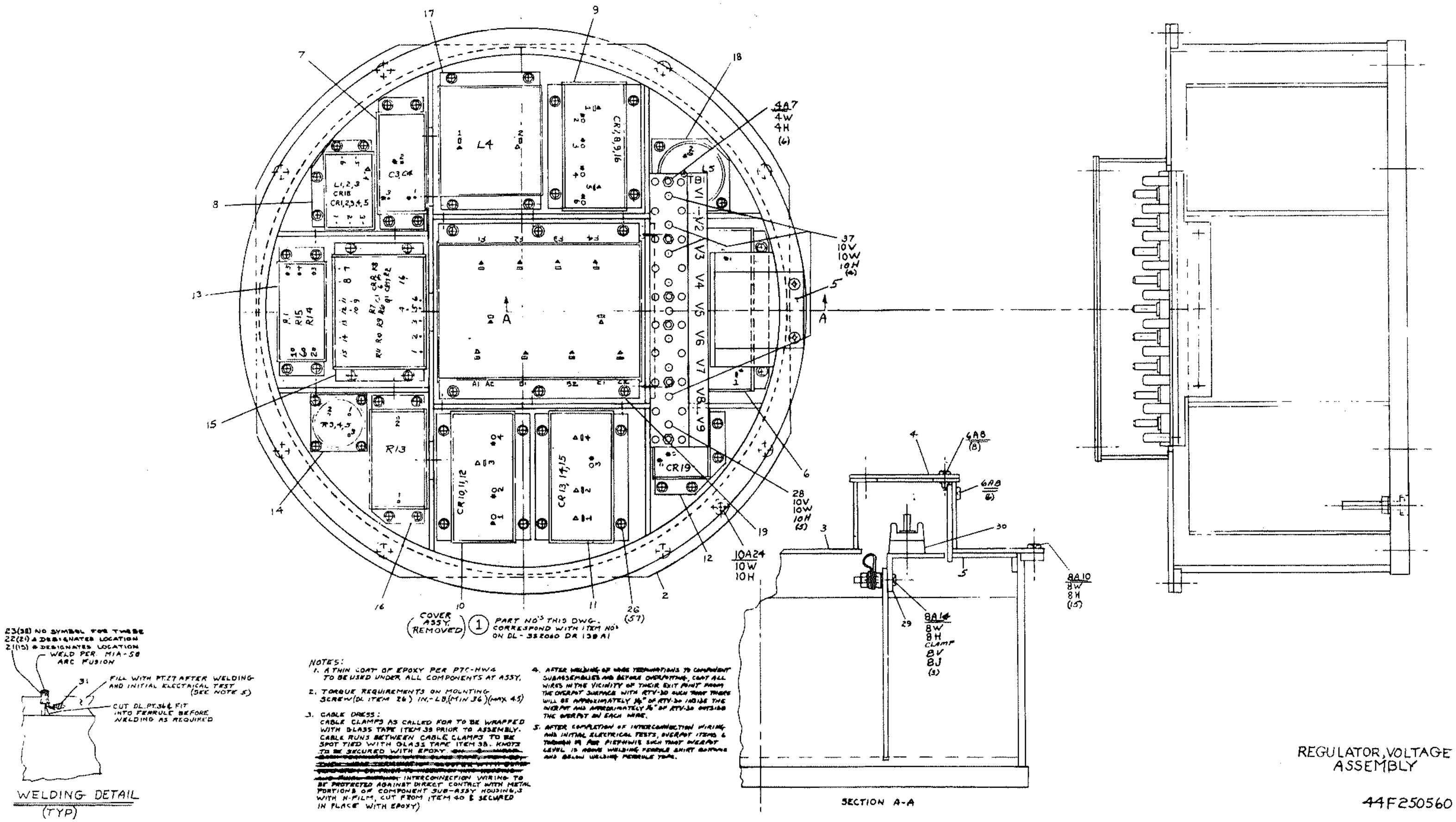
44D241414



(001) FINISH: P4C-11W1

OUTLINE
VOLTAGE REGULATOR

44F 242235



COVER ASSY. (REMOVED)

① PART NO'S THIS DWG. CORRESPOND WITH ITEM NO'S ON DL-332060 DR 138A1

23(38) NO SYMBOL FOR THESE
22(21) ▲ DESIGNATES LOCATION
21(15) ● DESIGNATES LOCATION
WELD PER MIA-58 ARC FUSION

FILL WITH PT.27 AFTER WELDING AND INITIAL ELECTRICAL TEST (SEE NOTE 5)

CUT DL.PT.36 & FIT INTO FERRULE BEFORE WELDING AS REQUIRED

WELDING DETAIL
(TYP)

NOTES:

1. A THIN COAT OF EPOXY PER P7C-HW4 TO BE USED UNDER ALL COMPONENTS AT ASSY.

2. TORQUE REQUIREMENTS ON MOUNTING SCREW (DL ITEM 26) IN.-LB.(MIN 36)(MAX 45)

3. CABLE DRESS: CABLE CLAMPS AS CALLED FOR TO BE WRAPPED WITH GLASS TAPE ITEM 38 PRIOR TO ASSEMBLY. CABLE RUNS BETWEEN CABLE CLAMPS TO BE SPOT TIED WITH GLASS TAPE ITEM 38. KNOTS TO BE SECURED WITH EPOXY. ~~[illegible]~~ INTERCONNECTION WIRING TO BE PROTECTED AGAINST DIRECT CONTACT WITH METAL PORTIONS OF COMPONENT SUB-ASSY HOUSINGS WITH H-FILM, CUT FROM ITEM 40 & SECURED IN PLACE WITH EPOXY)

4. AFTER WELDING OF WIRE TERMINATIONS TO COMPONENT SUBASSEMBLIES AND BEFORE OVERPOTTING, COAT ALL WIRES IN THE VICINITY OF THEIR EXIT POINT FROM THE OVERPOT SURFACE WITH RTV-30 SUCH THAT THERE WILL BE APPROXIMATELY 1/16" OF RTV-30 INSIDE THE OVERPOT AND APPROXIMATELY 1/16" OF RTV-30 OUTSIDE THE OVERPOT ON EACH WIRE.

5. AFTER COMPLETION OF INTERCONNECTION WIRING AND INITIAL ELECTRICAL TESTS, OVERPOT ITEMS 6 THROUGH 19 [illegible] PIECEWISE SUCH THAT OVERPOT LEVEL IS ABOVE WELDING FERRULE SKIRT BOTTOM AND BELOW WELDING FERRULE TOPS.

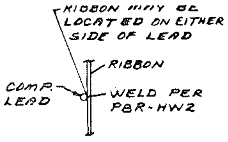
SECTION A-A

REGULATOR, VOLTAGE
ASSEMBLY

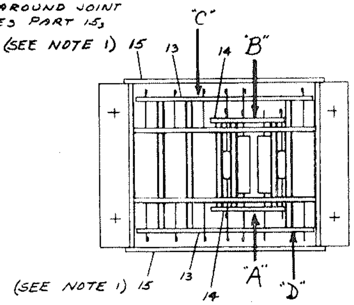
44F250560

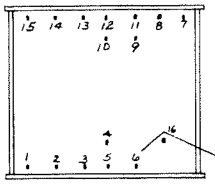
NOTES:

1. SANDBLASTED SIDE OF PT. 15 TO BE ON INSIDE.
2. MIN. CLEARANCE OF .060 TO BE MAINTAINED BETWEEN RIBBON & CHASSIS OR BETWEEN ADJACENT RIBBONS.
3. A POSITIVE CLEARANCE MUST BE MAINTAINED BETWEEN TOP COMPONENT IN ANY VERTICAL STACK, AND UPPER LONGITUDINAL MEMBER OF CHASSIS. FILE LONGITUDINALS IF NECESSARY TO OBTAIN CLEARANCE.
4. STAKE WITH EPOXY, TABS HOLDING INSULATORS, PARTS 13 & 14 IN PLACE. RUN A BEAD OF EPOXY AROUND JOINT BETWEEN CHASSIS AND SIDE ENCLOSURES PART 15, CURE, BEFORE FINAL POTTING.
5. GLASS TO METAL SEALS OF PTS. 2-11 TO HAVE CONFORMAL COATING PT. 22 PRIOR TO FINAL POTTING PT. 24.



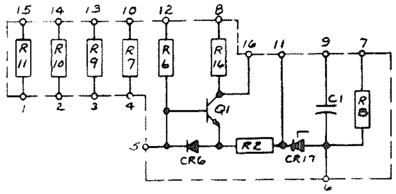
DETAIL "D"



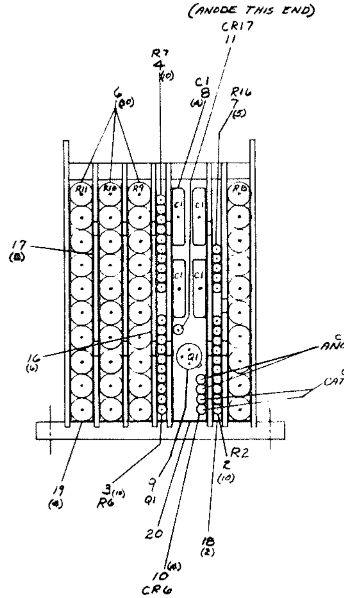


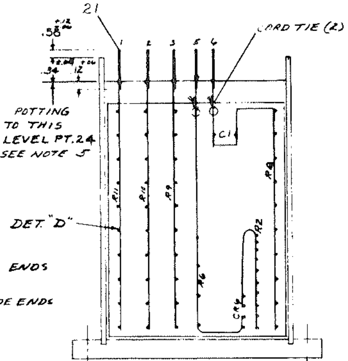
TOP VIEW AFTER POTTING

STENCIL 1/8 BLACK CHARACTERS APPROX. AS SHOWN



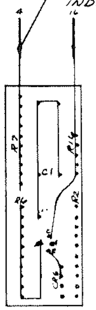
SCHEMATIC



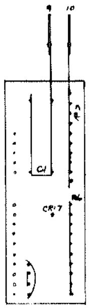


VIEW "D"

ALL RIBBON TERMINAL ENDS TO BE DOUBLED & WELDED APPROX AS INDICATED.

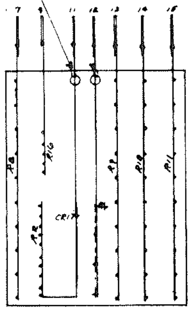


VIEW "A"



VIEW "B"

CORD TIE (2)



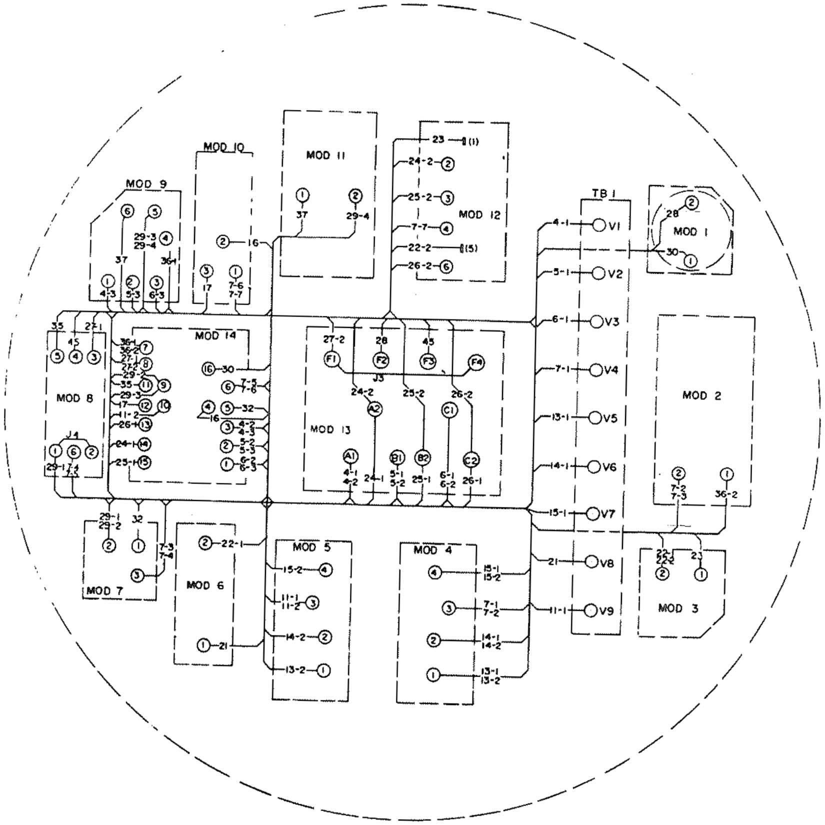
VIEW "C"

G01

SEE SEPARATE PARTS LIST

RESISTOR ASSY.

44C350707



WIRE TABLE

| CKT. NO. | WIRE SIZE | SEQUENCE OF CONNECTIONS |
|---|---|---|
| 4 | 20 | TB1-V1 MOD 13 MOD 14 MOD 9 |
| 5 | 20 | TB1-V2 MOD 13 MOD 14 MOD 9 |
| 6 | 20 | TB1-V3 MOD 13 MOD 14 MOD 9 |
| 7 | 14 | TB1-V4 MOD 4 |
| 7 | 20 | MOD 4 MOD 2 MOD 7 MOD 3 MOD 14 MOD 10 MOD 12 |
| 11 | 14 | TB1-V9 MOD 5 |
| 11 | 20 | MOD 5 MOD 14 |
| 13 | 14 | TB1-V5 MOD 4 MOD 5 |
| 14 | 14 | TB1-V6 MOD 4 MOD 5 |
| 15 | 14 | TB1-V7 MOD 5 MOD 4 |
| 16 | 20 | MOD 14 MOD 10 |
| 17 | 20 | MOD 14 MOD 10 |
| 21 | 20 | TB1-V8 MOD 6 |
| 22 | 20 | MOD 6 MOD 3 MOD 12 |
| 23 | 20 | MOD 3 MOD 12 |
| 24 | 20 | MOD 14 MOD 13 MOD 12 |
| 25 | 20 | MOD 14 MOD 13 MOD 12 |
| 26 | 20 | MOD 14 MOD 13 MOD 12 |
| 27 | 20 | MOD 8 MOD 14 MOD 13 |
| 28 | 20 | MOD 13 MOD 1 |
| 29 | 20 | MOD 8 MOD 7 MOD 14 MOD 9 MOD 11 |
| 30 | 20 | MOD 14 MOD 1 |
| 32 | 20 | MOD 7 MOD 14 |
| 35 | 20 | MOD 8 MOD 14 |
| 36 | 20 | MOD 9 MOD 14 MOD 2 |
| 37 | 20 | MOD 9 MOD 11 |
| 45 | 20 | MOD 8 MOD 13 |

LEGEND

| MODULE NO. | COMPONENTS CONTAINED |
|---|---|
| MOD 1 | L5 |
| MOD 2 | C2 |
| MOD 3 | CR19 |
| MOD 4 | CR13, 14, 15 |
| MOD 5 | CR10, 11, 12 |
| MOD 6 | R13 |
| MOD 7 | R3, 4, 5 |
| MOD 8 | R1, 14, 15 |
| MOD 9 | CR1, 2, 3, 4, 5, 18<br>L1, 2, 3 |
| MOD 10 | C3, 4 |
| MOD 11 | L4 |
| MOD 12 | CR7, 8, 9, 16 |
| MOD 13 | L6 |
| MOD 14 | R2, 6, 7, 8, 9, 10, 11, 16<br>CR6, 17, Q1, C1 |

CONNECTION DIAGRAM
VOLTAGE REGULATOR

DWG NO. 44D242107

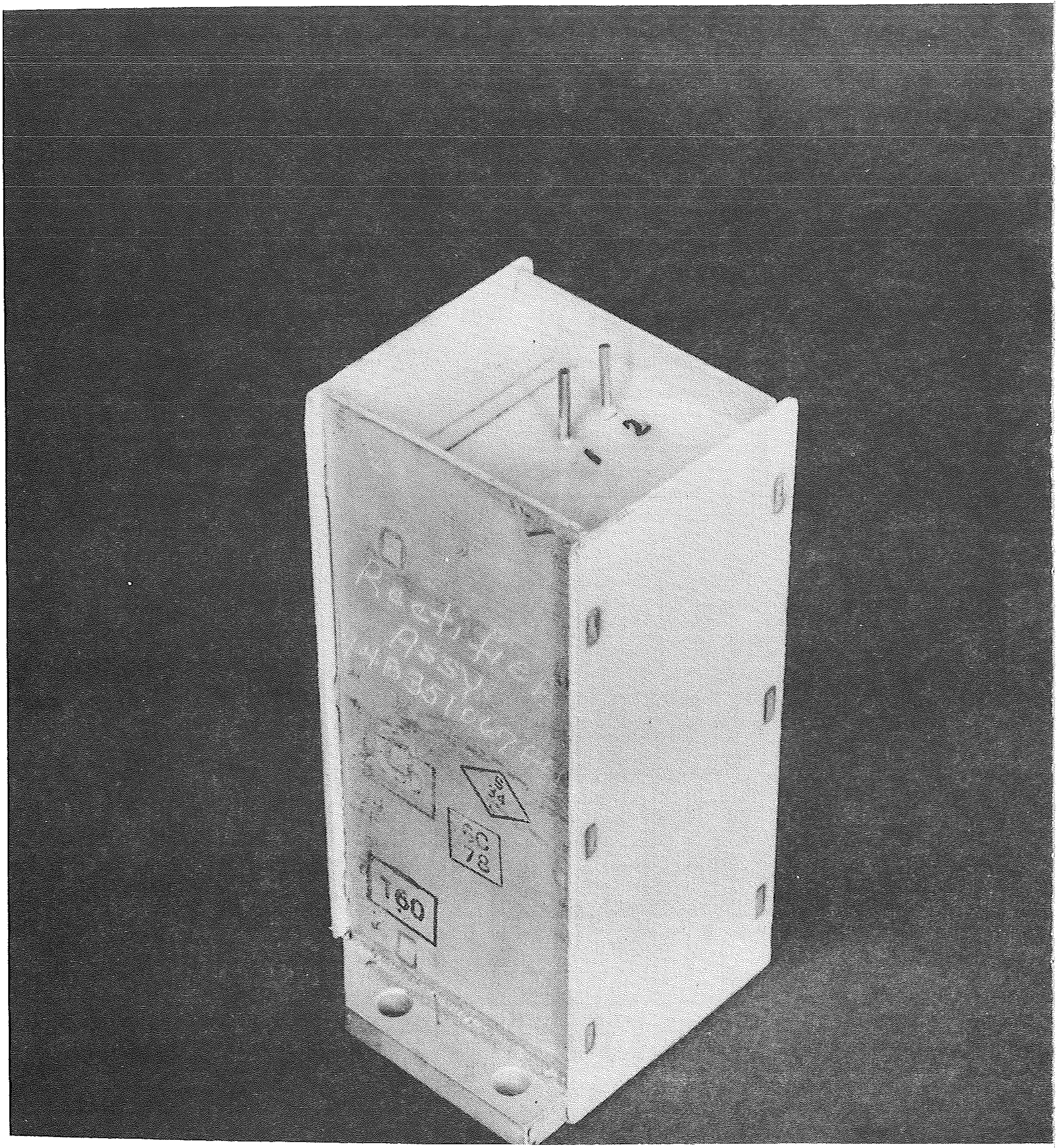
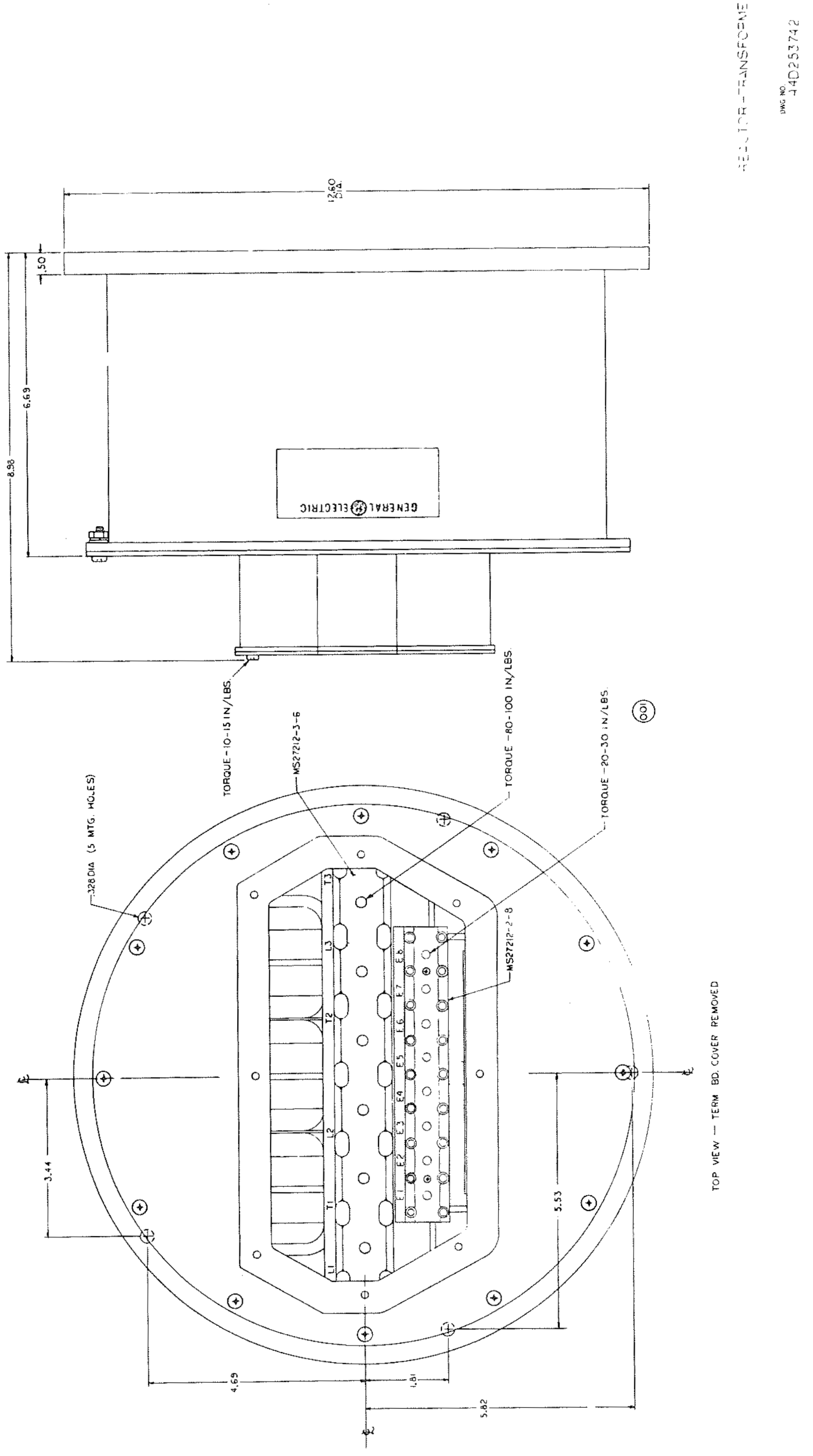
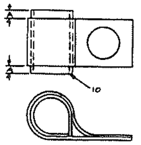


FIGURE 64
TYPICAL MODULE


REACTOR-TRANSFORMER
DWG NO. 44D253742
12.60 DIA.
.50
6.69
8.98
GENERAL ELECTRIC
TORQUE-10-15 IN/LBS.
MS27212-3-6
TORQUE-80-100 IN/LBS.
TORQUE-20-30 IN/LBS.
MS27212-2-8
.328 DIA (5 MTG. HOLES)
001
T3
L3
T2
L2
T1
L1
E1
E2
E3
E4
E5
E6
E7
E8
3.44
5.53
4.69
1.81
5.82
TOP VIEW — TERM. BD. COVER REMOVED

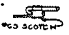
44D253741
REACTOR-TRANS MFG.

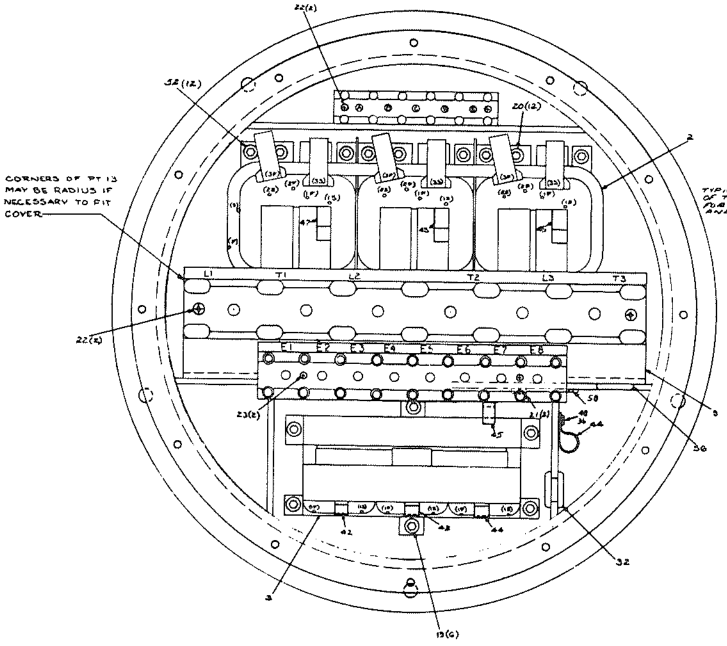
3F LEADS TO BE HAND FORMED
TO BE PARALLEL WITH 3S LEAD APPROX



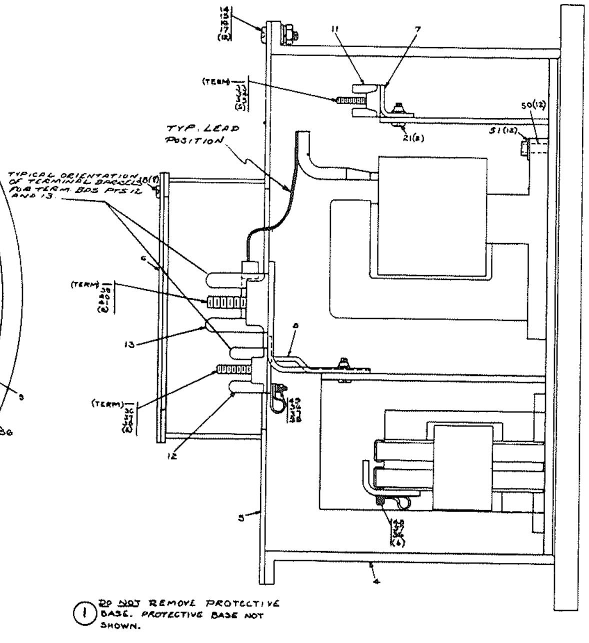
TYP CABLE CLAMP SHOWING
INSTALLATION OF PT 10

NOTE: ANCHOR ALL SMALL LEADS
WITH #33 SCOTCH.

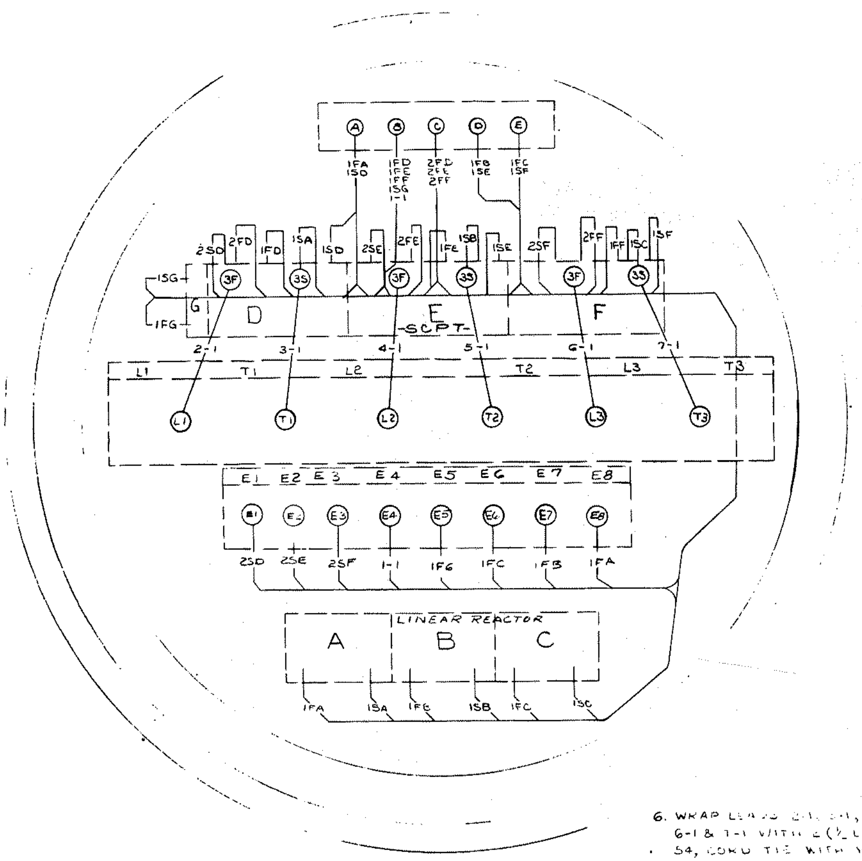




TOP VIEW - COVER REMOVED



# CONNECTION DIAGRAM



CONNECTION TABLE

| D.L. PT. NO. WIRE SIZE | D.L. PT NO AMP TERM | LEAD | FROM | TO |
|---|---|---|---|---|
| SELF | PT 29 | 1FA | REACTOR | E8 (TB) |
| | PT28 | 1FA | E8(TB) | A (TB) |
| | | 1SD | SCPT | A (TB) |
| | PT 29 | 1FB | REACTOR | E7 (TB) |
| | PT 28 | 1FB | E7(TB) | D (TB) |
| | | 1SE | SCPT | D (TB) |
| | PT 29 | 1FC | REACTOR | E6 (TB) |
| | PT 28 | 1FC | E6 (TB) | E (TB) |
| | | 1SF | SCPT | E (TB) |
| | SEE NOTE 1 | 1FD | | C (TB) |
| | | 1FE | | |
| | | 1FF | | |
| SELF | | 1SG | SCPT | C (TB) |
| PT 27 | | 1-1 | C(TB) | E4 (TB) |
| SELF | PT 57 | 2SD | SCPT | E1 (TB) |
| | PT 57 | 2SE | | E2 (TB) |
| | PT 57 | 2SF | | E3 (TB) |
| | PT31 | 2FD | | B (TB) |
| | | 2FE | | B (TB) |
| | | 2FF | | B (TB) |
| | PT 29 | 1FG | SCPT | E5 (TB) |
| | — | 1SA | REACTOR | SCPT (3SD) |
| | — | 1SB | REACTOR | SCPT (3SE) |
| SELF | — | 1SC | REACTOR | SCPT (3SF) |
| PT26 | PT55 | 2-1 | SCPT | L1 (TB) |
| | | 3-1 | | T1 (TB) |
| | | 4-1 | | L2 (TB) |
| | | 5-1 | | T2 (TB) |
| | | 6-1 | | L3 (TB) |
| PT26 | PT55 | 7-1 | SCPT | T3 (TB) |

NOTES:

1. CONNECT ALL LEADS TO PT NO 30 FOR CONNECTION AT C, PT NO 29 FOR CONNECTION AT E4.
2. ALL CONNECTIONS TO BE MADE PER MIA-58.
3.
4. ALL PART NO'S ON THIS DWG ARE LISTED ON DL 352060DM150A1.
5. ALL INSULATION TO BE REMOVED FROM PT 26.
6. WRAP LEADS 2-1, 3-1, 4-1, 5-1, 6-1 & 7-1 WITH 2 (½ LAPS) PT 54, CORD TIE WITH PT 53.
7. CORD TIE LEADS WITH PT 53. THEN WRAP HARNESS WITH PT 25.

44C350747

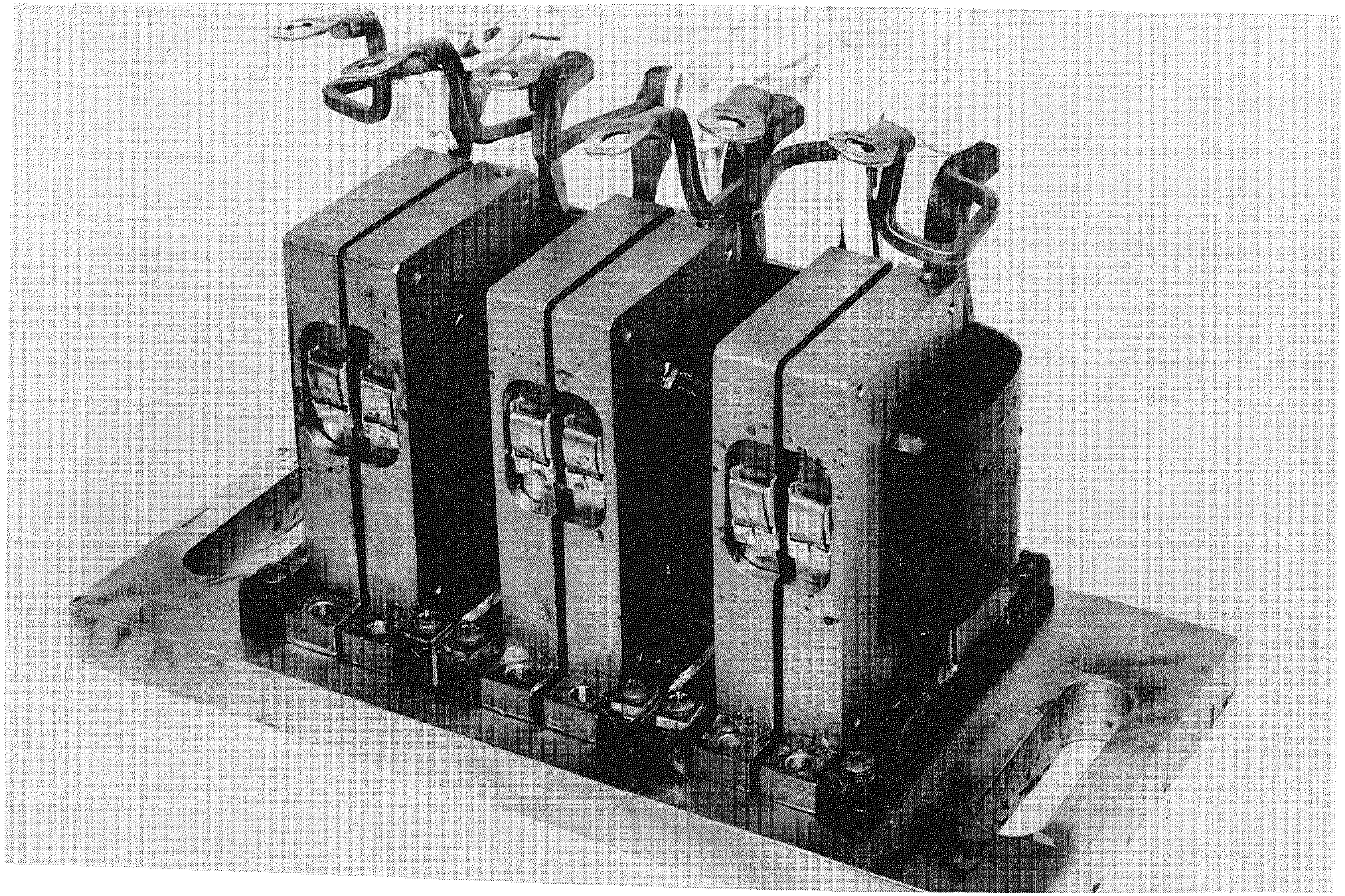
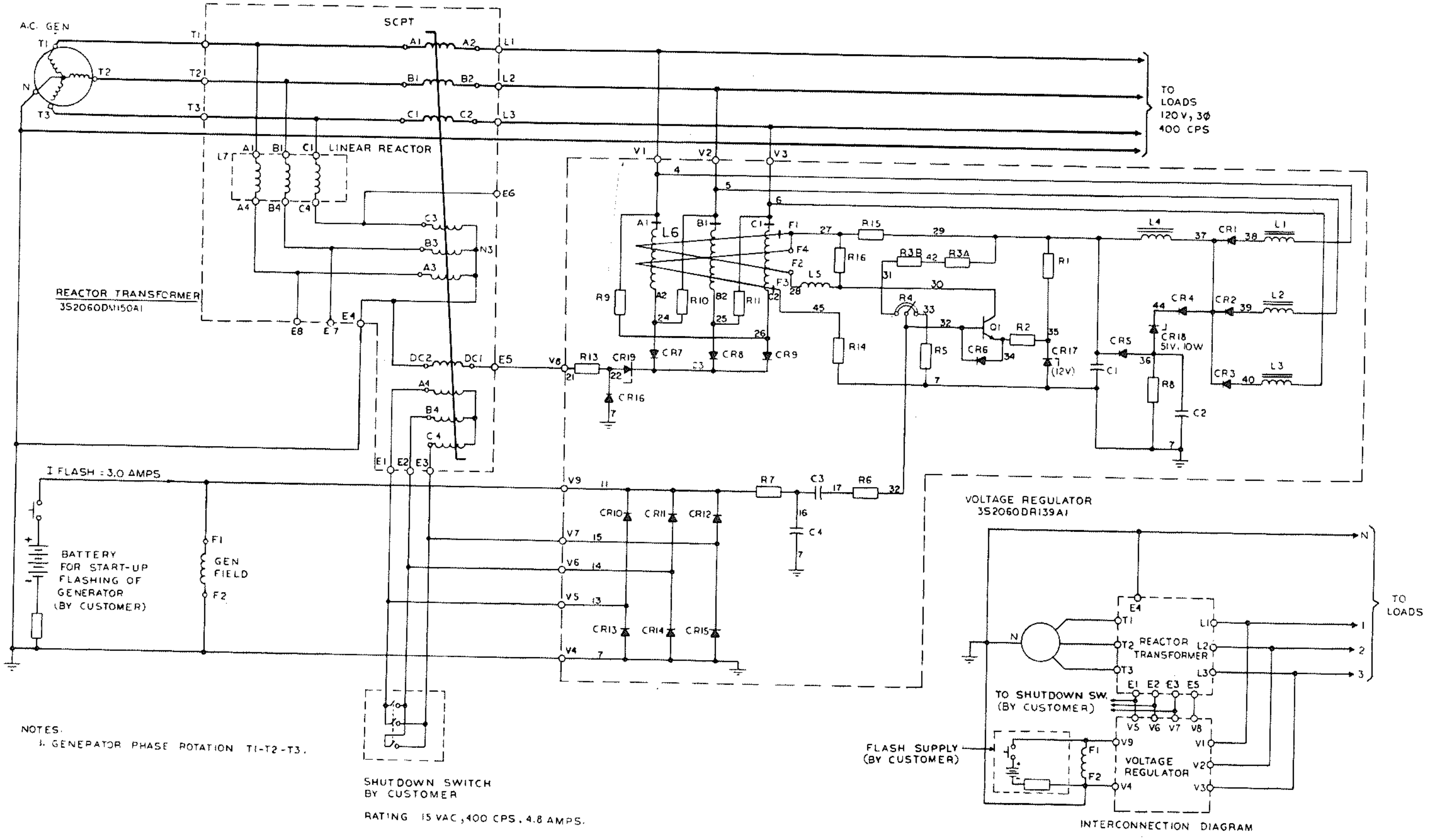


FIGURE 65

REACTOR TRANSFORMER without case



NOTES:
1. GENERATOR PHASE ROTATION T1-T2-T3.

SCHEMATIC DIAGRAM
STATIC EXCITER REGULATOR
BRAYTON CYCLE FLYABLE

DWG NO.
440242103

# APPENDIX D

## TESTS

The section contains the following items:

A. Acceptance Test Procedures

   1. Alternator research package
   2. In-house stator
   3. Engineering Breadboard Voltage Regulator-Exciter and Load Bank

B. Performance Tests

   1. Breadboard VRE open loop data
   2. Alternator research package
   3. Flyable VRE open loop data

The hardware successfully passed all acceptance tests and the data is included in this section.

The breadboard VRE was subjected to the open loop tests specified on SI-10713-13, Section 3S2060DR138A1 which is included in this section. The test procedure includes data sheets for recording the test data as well as instructions for conducting the tests.

The breadboard VRE and the ARP alternator were subjected to the closed loop tests specified on 44A351303 which is included in this section.

The flyable units were subjected to the open loop tests specified on SI-10713-13 Section 3S2060DR139A1 which is included in this section. No closed loop tests were run on the "flyable" units.

# ACCEPTANCE TEST PROCEDURE

## BRAYTON CYCLE ALTERNATOR RESEARCH PACKAGE

### A. Objective

The test objective is to run an acceptance test on the Brayton Cycle Alternator Research Package (2CM393A1 alternator and Breadboard Voltage Regulator Exciter) as required by Pratt and Whitney Aircraft Specification 6358-A in partial fulfillment of Purchase Order No. 422752.

### B. Description

The acceptance test consists of operation with no excitation at design speed of 12,000 rpm for 30 minutes and operation at 120% of design speed, 14,400 rpm, for 10 minutes.

### C. Witnessing

The acceptance test will be witnessed by Pratt and Whitney Aircraft and NASA personnel. The Pratt and Whitney Aircraft and NASA representative will be requested to sign the acceptance test data sheets as recognition of the successful completion of the acceptance test.

### D. Instrument Calibration

Prior to initiation of the acceptance test, the following instrumentation shall be calibrated:

| Instrument | Date last Calibrated | Date next Calibrated |
|---|---|---|
| Electronic Counter | 1/31/66 | 5/1/66 |
| Bristol Temperature Recorder | 2/2/66 | 5/2/66 |

### E. Data to be Recorded

1. Total running time
2. Total acceptance test time
3. Rotational speed (rpm)
4. Vibration on anti-drive end (ADE) and drive end (DE) end shield (inches deflection). Use light beam meter.
5. Lube oil inlet temperature (°C). Both ADE and DE.
6. Lube oil outlet temperature (°C). Both ADE and DE.
7. ADE bearing temperature (°C).
8. DE bearing temperature (°C).
9. Lube oil inlet pressure (psig).
10. ADE bearing oil flow (#/min).
11. DE bearing oil flow (#/min).
12. Rotor cavity temperature (°C).
    Rotor cavity is vented to atmosphere and thus no pressure reading is required.

### F. Operating Procedure

1. Start electronic counter and Bristol Temperature Recorder instrumentation at least one half (1/2) hour before test is to start.

2. Record all thermocouple readings prior to initiation of test.

3. Initiate oil system operation and obtain steady state inlet oil operating temperature of 93.3°C (200°F). Adjust bearing oil flows as follows:

   a. ADE and DE bearing .138 Gal/min. (15 psig reference)
      Oil will be MIL-L-7808.

4. Record thermocouple data on continuous basis. Record speed and oil flow data every five (5) minutes.

5. Establish design speed of 12,000 rpm and maintain for 30 minutes.

6. Establish overspeed of 14,400 rpm and maintain for 10 minutes.

7. Reduce alternator speed to zero and shut down oil system.

### G. Operating Limits

1. Rotational speed - maximum overspeed, 14,500 rpm (limited by drive stand capability).

2. Bearing temperature - maximum 150°C.

3. Vibration - maximum .002".

### H. Operating Tolerances

| | |
|---|---|
| 1. Rotational Speed | ± 100 rpm |
| 2. Vibration | ± .0005" |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1864
SHEET NO. 2
DATE 2-3-66

GENERATOR MODEL NO. 2CM393A1 REGULATOR MODEL NO. ______ EXCITER MODEL NO. ______
SERIAL NO. AB-374-381 SERIAL NO. ______ SERIAL NO. ______
TITLE OF TEST ACCEPTANCE TEST SPECIFICATION ______
TEST STAND NO. 118

| | TIME | VOLTAGE ø1-N VOLTS | VOLTAGE ø2-N VOLTS | VOLTAGE ø3-N VOLTS | CURRENT ø1 AMPS | CURRENT ø2 AMPS | CURRENT ø3 AMPS | WATTS/PHASE ø1 WATTS | WATTS/PHASE ø2 WATTS | WATTS/PHASE ø3 WATTS | LOAD TOTAL KW | LOAD TOTAL KVA | LOAD POWER FACTOR | FIELD POWER Ef VOLTS | FIELD POWER Eaux VOLTS | FIELD POWER If AMPS | FIELD POWER Rf OHMS | FIELD POWER TOTAL TEMP °C | SPEED RPM | COOLING ~~AIR~~ OIL ΔP IN $H_2O$ | COOLING ~~AIR~~ OIL ~~AIR~~ FLOW #/MIN | COOLING OIL TEMP IN °C | COOLING OIL TEMP OUT °C | GENERATOR AMBIENT ~~ALT FEET~~ | GENERATOR AMBIENT °C | GENERATOR AMBIENT °C | REGULATOR AMBIENT ~~ALT FEET~~ | REGULATOR AMBIENT AIR TEMP °C | DE | ADE | Rotor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | TOTAL | | | | | | | | | | | | | VIB | VIB | | | | | | STATOR | LUBE | LUBE | ADE LUBE | ADE LUBE | DE | ADE | LUBE OIL | BRG | BRG | CAVITY |
| RUNNING | ACCEPT | | | | | | | | | | | | | D.E. | ADE | | | | | | FLOW | OIL | OIL | OIL | OIL | BRG. | BRG | INLET | FLOW | FLOW | TEMP |
| TIME | TEST | | | | | | | | | | | | | IN. | IN. | | | | | | GPM | IN | OUT | IN | OUT | TEMP | TEMP | PSIG | * | * | °C |
| | TIME | | | | | | | | | | | | | | | | | | | | | #3 | #4 | #5 | #6 | #9 | #7 | | | | #8 |
| | 4:10 | | | | | | | | | | | | | | | | | | 0 | | 1.38 | 88 | 87 | 88 | 78 | 80 | 85 | 12.2 | 5.3 | 5.7 | 80 |
| | 4:26 | start | | | | | | | | | | | | .001 | .0015 | | | | 12000 | | 1.38 | 87 | 87 | 87 | 78 | 82 | 84 | 11.6 | 5.7 | 5.7 | 82 |
| | 4:31 | | | | | | | | | | | | | | | | | | 12003 | | 1.38 | 87 | 90 | 87 | 80 | 90 | 86 | 11.3 | 5.7 | 5.7 | 83 |
| | 4:36 | | | | | | | | | | | | | | | | | | 12011 | | 1.38 | 87 | 91 | 87 | 80 | 91 | 86 | 11.4 | 5.7 | 5.7 | [illegible] |
| | 4:41 | | | | | | | | | | | | | .0008 | .0015 | | | | 12013 | | 1.38 | 87 | 91 | 87 | 80 | 91 | 86 | 11.6 | 5.7 | 5.7 | [illegible] |
| | 4:46 | | | | | | | | | | | | | | | | | | 11996 | | 1.38 | 86 | 91 | 87 | 80 | 91 | 86 | 11.6 | 5.7 | 5.7 | [illegible] |
| | 4:51 | | | | | | | | | | | | | | | | | | 12012 | | 1.38 | 86 | 91 | 87 | 80 | 91 | 86 | 11.5 | 5.7 | 5.7 | 85 |
| | 4:56 | Finish | | | | | | | | | | | | | | | | | 12005 | | 1.38 | 86 | 90 | 86 | 79 | 91 | 86 | 11.4 | 5.7 | 5.7 | [illegible] |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 4:58 | start | | | | | | | | | | | | .001 | .002 | | | | 14596 | | 1.38 | 86 | 91 | 86 | 81 | 92 | 87 | 11.3 | 5.7 | 5.7 | [illegible] |
| | 5:03 | | | | | | | | | | | | | | | | | | [illegible] | | 1.38 | 86 | 91 | 86 | 80 | 93 | 87 | 11.4 | 5.7 | 5.7 | [illegible] |
| | 5:08 | | | | | | | | | | | | | .001 | .002 | | | | 14480 | | 1.38 | 86 | 91 | 86 | 79 | 93 | 87 | 11.3 | 5.7 | 5.7 | [illegible] |
| 46 [illegible] | 5:12 | stop | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 123 [illegible] | 6:35 | shut off oil system. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | METER NO. | | | | | | | | | | | | | | | | | | 3398 | | | 726 | 726 | 726 | 726 | 726 | 726 | | | | [illegible] |
| | [illegible] | | | | | | | | | | | | | | | | | | 1-18-66<br>5-18-66 | | | 2-2-66<br>5-2-66 | 2-2-66<br>5-2-66 | 2-2-66<br>5-2-66 | 2-2-66<br>5-2-66 | 2-2-66<br>5-2-66 | 2-2-66<br>5-2-66 | | | | [illegible] |

Witnessed by

[illegible] Feb 3, 1966
Martin E. Palmer Jr. Feb. 3, 1966
[illegible] U.S.A.F. Feb 3, 1966
L. J. Yerge Feb 3, 1966

COLD ~~ROTOR~~ FLD RESISTANCE 227 Ω @ 25 °C
COLD STATOR RESISTANCE .0382 Ω @ 25 °C
COLD RILS. RESISTANCE ______ Ω @ ____ °C

NOTES * See Calibration curve #L-3084 for #/Min.

TESTED BY Vasilik

# ACCEPTANCE TEST PROCEDURE

## BRAYTON CYCLE IN-HOUSE STATOR

### A. Objective

The test objective is to run an acceptance test on the Brayton Cycle In-House Stator as required by Pratt and Whitney Aircraft Specification 6374.

### B. Description and Requirement

The test acceptance consists of operation described in Section I. The tests specified below are intended to demonstrate the satisfactory integrity of the alternator.

### C. Witnessing

The acceptance test will be witnessed by Pratt and Whitney Aircraft. The Pratt and Whitney Aircraft representative will be requested to sign the acceptance test data sheets as recognition of the successful completion of the acceptance test.

### D. Instrument Calibration and Test Equipment

All instruments and equipment shall be calibrated as necessary to insure that the required degree of accuracy is maintained.

### E. Data to be Recorded

| | | Accuracy |
|---|---|---|
| 1. | Time of Day | |
| 2. | Total running time | |
| 3. | Total acceptance test time | |
| 4. | Rotational speed (rpm) | ±100 rpm |
| 5. | Gas pressure within the alternator cavity | ±0.1 psi |
| 6. | Vibration on anti-drive end (ADE) and drive end (DE) end shield (inches deflection). Use light beam meter. | ±0.0005 inches |
| 7. | Lube oil inlet temperature (°F). Both ADE and DE | ±2°F |
| 8. | Lube oil outlet temperature (°F). Both ADE and DE | ±2°F |
| 9. | ADE bearing temperature (°F) | ±2°F |
| 10. | DE bearing temperature (°F) | ±2°F |
| 11. | Stator temperature (10 thermocouples) (°F) | ±2°F |
| 12. | Lube oil inlet pressure (psig). | ±0.1 psi |
| 13. | Stator coolant temperature (4 thermocouples) (°F) | ±2°F |
| 14. | ADE bearing oil flow (#/min) | ±2% |
| 15. | DE bearing oil flow (#/min) | ±2% |

|  |  |  |
|---|---|---|
| 16. | Alternator power output | ±2% |
| 17. | Alternator voltage output per phase | ±2% |
| 18. | Alternator current output per phase | ±2% |
| 19. | Field input voltage | ±2% |
| 20. | Field current | ±2% |

## F. Test Conditions

1. The stator liquid coolant inlet temperature shall be 200°F ±20°F.

2. During all testings, the rotor shall be maintained at the designated speed of 12,000 rpm ±300 rpm.

3. The alternator cavity pressure shall be maintained at 10.5 psia ±0.5 psi using air for all tests except as specifically noted.

## G. Operating Limits

1. Bearing temperature - maximum - 150°C. (302°F)

2. Vibration maximum - .002" (double amplitude)

3. Stator winding temperature - 180°C maximum. (356°F).

## H. Pre-Test Operating Procedure

1. Start electronic counter and Bristol Temperature recorder instrumentation at least one half (1/2) hour before test is to start.

2. Record all thermocouple readings prior to initiation of tests.

3. Initiate oil system operation and obtain steady state inlet oil operating temperature of 93.3°C (200°F). Adjust oil flows as follows:

   ADE and DE bearing .138 gal/min (15 psig ref) oil will be 7808.

   Stator 1.38 gal/min. (3 psig ref) oil will be 7808.

4. Record thermocouple data on a continuous basis. Record speed and oil flow data every ten (10) minutes.

5. Establish design speed of 12,000 rpm and no load. Maintain this condition until all temperature stabilizes. Record speed, temperature, and oil flow.

6. Begin testing as described in section I.

## I. Test Procedure

1. After temperature has stabilized at no-load, operate the alternator

at 15 KVA, 0.8 (lagging) power factor, 12,000 rpm, three (3) phase until all temperatures have stabilized.

2. Short three (3) phases for a period of 5 seconds maximum, after all temperatures have been stabilized as stated in paragraph 1. Record all data.

3. Return the alternator to the condition stated in paragraph 1, after conducting the test described in paragraph 2, and stabilize. When the alternator is stabilized, short one (1) phase for a period of 5 seconds maximum. Record all data.

4. Re-stabilize the alternator at no-load, 12,000 rpm. After stabilizing, operate the alternator from zero to 12 KWE, three (3) phase, 0.8 (lagging) and unity power factor in increments of 2 KWE (0, 2, 4, 6 - 12 KWE). Stabilize stator and bearing temperature at each load point and record all data.

5. Return alternator to no load condition 12,000 rpm, and stabilize. Reduce cavity pressure to 7.2 psia. Operate alternator from zero to 6 KWE, three (3) phase, 0.8 (lagging) and unity power factor, in increments of 2 KWE (0, 2, 4, 6 KWE). Stabilize stator and bearing temperature at each load point and record all data.

6. Re-stabilize alternator at the no load condition, then operate at 3.33 KVA, unity power factor, with the load connected from one phase to neutral and the other two phases open for a period of ten (10) minutes, continuous. Record data.

7. Return alternator to no-load, no excitation. Stabilize all stator and bearing temperatures. Record all data.

J. Post Test Procedure

Shut down alternator and record all data.

K. Acceptance

The test shall be considered as having been satisfactorily completed when no changes to the configuration have been made except as authorized by P&WA, and the following conditions have been met:

a. Vibration at the bearing mounts does not exceed 0.002 inch double amplitude.
b. There is no indication of contact or seizure between the rotor and stationary parts.
c. The stator liquid coolant temperature rise shall not exceed 8°C (15°F).
d. The stator temperature shall not exceed 180°C (356°F).
e. The alternator, voltage regulator-exciter and load bank demonstrate satisfactory electrical integrity.
f. Abnormal operation of the alternator, voltage regulator-exciter and load bank all be specifically noted on the test log.

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 27
DATE 5-5-66

GENERATOR MODEL NO. 2CM393A1
SERIAL NO. AB-374-285
REGULATOR MODEL NO. ENGR B.B.
SERIAL NO.
EXCITER MODEL NO.
SERIAL NO.
TEST STAND NO. 118
TITLE OF TEST ACCEPTANCE TEST
SPECIFICATION

| TIME | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING ~~AIR~~ OIL | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | φ1-N VOLTS | φ2-N VOLTS | φ3-N VOLTS | φ1 AMPS | φ2 AMPS | φ3 AMPS | φ1 WATTS | φ2 WATTS | φ3 WATTS | TOTAL KW | TOTAL KVA | POWER FACTOR | EF VOLTS | EAUX VOLTS | IF AMPS | RF OHMS | TOTAL TEMP °C | RPM | ~~ΔP~~ ~~IN H2O~~ | AIR FLOW #/MIN | TEMP IN °C | TEMP OUT °C | ALT FEET | AIR TEMP °C | FRAME TEMP °C | ALT FEET | AIR TEMP °C |
| | | | | ← | K= | 20 | → | | | | | | | | | | | | STATOR | | | STATOR | | | BEARINGS | | |
| | | | | | | | | | | | | | | | | | | | GPM | | | OIL IN | | PSIA* | OIL D.E. | ADE | PSIG |
| AM | | | | | | | | | | | | | | | | | | | | | | PSIG | IN-HG | PSIA | GPM | GPM | |
| 10:45 | | | | | | | | | | | | | | | | | | 0 | 1.38 | 93 | 93 | 1.50 | 9.6 | 10.0 | .138 | .138 | 12.2 |
| 11:00 | 120 | 120 | 120 | | | | | | | | | | 10.6 | | 2.55 | | | 12000 | 1.38 | 93 | 92 | 1.50 | 9.6 | 10.0 | .138 | .138 | 12.2 |
| 11:15 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.55 | | | 12000 | 1.38 | 93 | 93 | 1.50 | 9.6 | 10.0 | .138 | .138 | 12.2 |
| 11:25 | 120 | 120 | 120 | | | | | | | | | | 11.0 | | 2.55 | | | 12000 | 1.38 | 93 | 93 | 1.50 | 9.6 | 10.0 | .138 | .138 | 12.2 |
| 11:35 | 120 | 120 | 120 | | | | | | | | | | 11.1 | | 2.58 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| 11:45 | 180 | 120 | 120 | | | | | | | | | | 11.1 | | 2.58 | | | 12000 | 1.38 | 95 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12:30 | 120 | 120 | 120 | | | | | | | | | | 11.1 | | 2.60 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| 12:40 | 120 | 120 | 120 | | | | | | | | | | 11.1 | | 2.60 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| 12:50 | 120 | 120 | 120 | | | | | | | | | | 11.1 | | 2.60 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| 1:00 | 120 | 120 | 120 | | | | | | | | | | 11.1 | | 2.60 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1:15 | 120 | 119.5 | 120 | 2.08 | 2.08 | 208 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 24.7 | | 5.70 | | | 12000 | 1.38 | 93 | 93 | 1.48 | 9.6 | 10.0 | .138 | .138 | 12.5 |
| 1:35 | 120 | 119.5 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.2 | | 5.70 | | | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 12.5 |
| 1:55 | 120 | 119.0 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.2 | | 5.70 | | | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 12.5 |
| 2:16 | 120 | 119.5 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.2 | | 5.70 | | | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 12.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | ← | K= | 40 | → | | | | | | | | | | | | | | | | | | | | |
| 3φ SC. | | | | 4.34 | 4.27 | 4.39 | | | | | | | — | | 14.9 | | | 12200 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 12.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| METER NO. | ← | 3648 | → | 1354 | 3210 | 3583 | 1469 | 1003 | 325 | | | | 3521 | | 425 | | | | | | | | | | | | |
| CALIB DATE | | 5-22 | | 5-8 | 5-29 | 5-22 | 5-22 | 5-29 | 5-25 | | | | 5-22 | | 5-22 | | | | | | | | | | | | |

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD R.M.G. RESISTANCE Ω @ °C

NOTES: SPEED & OIL FLOW DATA RECORDED EVERY 20 MIN INSTEAD OF 10 MIN.

VIBRATION DE = .0005" ADE = .0008" @ NL & FL

* 10.5 psia should be 9.7 psia

TESTED BY FARABAUGH
V.T. [illegible] for 5/5/66
D Cipriani

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

GENERATOR MODEL NUMBER 2CM393A1
TEST NUMBER 1856
SERIAL NUMBER AB-374-285
SHEET NUMBER 27A
TITLE OF TEST ACCEPTANCE
DATE 5-5-66

Ronald Cohen 5/5/66

| | DE OIL IN | BRG OIL OUT | ADE OIL IN | BRG OIL OUT | DE BRG | | ADE BRG | | FRAME I.D. | STATOR CORE O.D. | STATOR TOOTH | D.E. END TURN | | FRAME I.D. | 180° BUS | | STATOR TOOTH | ADE END TURN | STATOR PSIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | #11 | #13 | #15 | #1 | #3 | #6 | #8 | #10 | #12 | #14 | |
| 10:45 | 87 | 87 | 88 | 80 | 81 | 82 | 82 | 83 | 89 | 89 | 89 | 90 | 90 | 87 | 88 | 90 | 90 | 90 | 10.0 |
| 11:00 | 87 | 93 | 89 | 90 | 93 | 90 | 96 | 90 | 90 | 94 | 90 | 96 | 94 | 90 | 90 | 92 | 94 | 94 | 10.0 |
| 11:15 | 87 | 93 | 89 | 93 | 90 | 90 | 90 | 90 | 94 | 93 | 94 | 97 | 97 | 91 | 93 | 94 | 96 | 96 | 10.0 |
| 11:35 | 88 | 94 | 89 | — | 94 | 91 | 90 | 90 | 90 | 93 | 94 | 99 | 99 | 93 | 94 | 96 | 97 | 97 | 10.0 |
| | | | | | | | | | | | | | | | | | | | |
| 12:30 | 88 | 93 | 88 | — | 94 | 91 | 90 | 90 | 91 | 93 | 96 | 99 | 99 | 93 | 96 | 97 | 97 | 97 | 10.0 |
| 12: | 88 | 93 | 88 | - | 93 | 90 | 90 | 90 | 91 | 93 | 96 | 100 | 99 | 93 | 96 | 97 | 97 | 97 | 10.0 |
| 12:50 | 88 | 93 | 88 | - | 93 | 90 | 90 | 90 | 91 | 93 | 96 | 100 | 99 | 93 | 96 | 97 | 97 | 97 | 10.0 |
| 1:00 | 88 | 93 | 88 | - | 93 | 90 | 90 | 90 | 91 | 93 | 96 | 100 | 99 | 93 | 96 | 97 | 97 | 97 | 10.0 |
| | | | | | | | | | | | | | | | | | | | |
| 1:15 | 88 | 96 | 88 | - | 96 | 93 | 91 | 91 | 94 | 97 | 101 | 116 | 114 | 103 | 108 | 109 | 106 | 111 | 10.0 |
| 1:35 | 88 | 97.5 | 88 | - | 99 | 96 | 93 | 92 | 99 | 102 | 108 | 121 | 121 | 113 | 117 | 120 | 114 | 118 | 10.5 |
| 1:55 | 88 | 96 | 87 | - | 99 | 94 | 93 | 93 | 99 | 102 | 108 | 123 | 121 | 114 | 117 | 121 | 115 | 118 | 10.5 |
| 2:15 | 87 | 95 | 87 | — | 99 | 94 | 93 | 93 | 99 | 102 | 108 | 123 | 123 | 114 | 117 | 121 | 115 | 118 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
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| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 28
DATE 5-5-66

GENERATOR MODEL NO. 2CM393A1
SERIAL NO. AB-374-285
REGULATOR MODEL NO. ENGR. B.B.
SERIAL NO.
EXCITER MODEL NO.
SERIAL NO.
TEST STAND NO. 118
TITLE OF TEST ACCEPTANCE
SPECIFICATION

| TIME | VOLTAGE |  |  | CURRENT |  |  | WATTS/PHASE |  |  | LOAD |  |  | FIELD POWER |  |  |  |  | SPEED | COOLING ~~AIR~~ OIL |  |  |  | GENERATOR AMBIENT |  |  | REGULATOR AMBIENT |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | ø1-N VOLTS | ø2-N VOLTS | ø3-N VOLTS | ø1 AMPS | ø2 AMPS | ø3 AMPS | ø1 WATTS | ø2 WATTS | ø3 WATTS | TOTAL KW | TOTAL KVA | POWER FACTOR | EF VOLTS | EAUX VOLTS | IF AMPS | RF OHMS | TOTAL TEMP °C | RPM | ~~ΔP~~ IN ~~H2O~~ | AIR FLOW #/MIN | TEMP IN °C | TEMP OUT °C | ALT FEET | AIR TEMP °C | FRAME TEMP °C | ALT FEET | AIR TEMP °C |
|  |  |  |  | ← K=20 → |  |  |  |  |  |  |  |  |  |  |  |  |  |  | STATOR |  |  | STATOR |  |  | BEARINGS |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | GPM |  |  | OIL IN | IN-Hg | * | OIL DE | OIL ODE | PSIG |
| PM |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | PSIG |  | PSIA | GPM | GPM |  |
| 2:45 | 120 | 119.5 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 26.1 |  | 5.70 |  |  | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 3:05 | 120 | 119.5 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.2 |  | 5.70 |  |  | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 3:25 | 120 | 119.5 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.2 |  | 5.70 |  |  | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | K=20 | K=40 | ← K=20 → |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ① | 102.5 | 0 | 96 | 1.80 | 6.48 | 1.79 | 141 | 0 | 127 |  |  |  | 45.0 |  | 10.6 |  |  | 12000 | 1.38 | 93 | 96 | 1.48 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4:10 | 120 | 119.9 | 119.9 |  |  |  |  |  |  |  |  |  | 10.9 |  | 2.57 |  |  | 12000 | 1.38 | 93 | 93 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 4:30 | 120.1 | 120.0 | 120.0 |  |  |  |  |  |  |  |  |  | 10.9 |  | 2.57 |  |  | 12000 | 1.38 | 93 | 93 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 4:50 | 120.1 | 120.0 | 120.0 |  |  |  |  |  |  |  |  |  | 10.9 |  | 2.58 |  |  | 12000 | 1.38 | 93 | 92 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 17.5 |
| 5:10 | 120.1 | 120.0 | 120.0 |  |  |  |  |  |  |  |  |  | 10.9 |  | 2.58 |  |  | 12000 | 1.38 | 93 | 92 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 17.2 |
| 5:30 | 120.1 | 120.0 | 120.0 |  |  |  |  |  |  |  |  |  | 10.9 |  | 2.58 |  |  | 12000 | 1.38 | 93 | 92 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 17.0 |
|  |  |  |  | ← K=4 → |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5:50 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 12.8 |  | 3.05 | 4.19 |  | 12000 | 1.38 | 93 | 92 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 16.8 |
| 6:10 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 13.0 |  | 3.08 | 4.22 |  | 12000 | 1.38 | 93 | 92 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 16.6 |
| 6:30 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 13.0 |  | 3.08 | 4.22 |  | 12000 | 1.38 | 94 | 93.5 | 1.45 | 10.2 | ~~10.5~~ | .138 | .138 | 15.5 |
| ':50 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 13.0 |  | 3.08 | 4.22 |  | 12000 | 1.38 | 94 | 93 | 1.41 | 10.2 | ~~10.5~~ | .138 | .138 | 17.0 |
| 7:10 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 13.0 |  | 3.08 | 4.22 |  | 12000 | 1.38 | 93 | 93 | 1.41 | 10.2 | ~~10.5~~ | .138 | .138 | 16.6 |
| 7:30 | 120.1 | 120.0 | 120.0 | 1.74 | 1.74 | 1.74 | 167 | 167 | 167 | 2.0 | 2.505 | .80 | 13.0 |  | 3.08 | 4.22 |  | 12000 | 1.38 | 93 | 92 | 1.41 | 10.2 | ~~10.5~~ | .138 | .138 | 16.4 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7:50 | 120.1 | 119.9 | 120.0 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.0 |  | 3.54 | 4.24 |  | 12000 | 1.38 | 93 | 93 | 1.41 | 10.2 | ~~10.5~~ | .138 | .138 | 17.0 |
| 8:10 | 120.1 | 119.9 | 120.0 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.0 |  | 3.54 | 4.24 |  | 12000 | 1.38 | 92 | 92 | 1.44 | 10.2 | ~~10.5~~ | .138 | .138 | 17.1 |
| METER NO. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CALIB DATE |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

5/6/66

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD RMG. RESISTANCE Ω @ °C

NOTES: ① ø2 TO GROUND S.C.
* 10.5 psia should be 9.7 psia

TESTED BY FARABAUGH
V.V. 5/6/66
5/6/66

## AIRCRAFT GENERATOR TEST DATA SHEET

### ERIE PLANT, BUILDING 17F

GENERATOR MODEL NUMBER 2C[illegible]
TEST NUMBER 1856
SERIAL NUMBER AB-374-285
SHEET NUMBER 28A
TITLE OF TEST ACCEPTANCE
DATE [illegible]

WB Spencer 5/6/66

| | DE OIL IN | BRG OIL OUT | ADE OIL IN | BRG OIL OUT | DE BRG | | ADE BRG | | FRAME I.D. | STATOR CORE O.D. | STATOR TOOTH | D.E. END TURN | | FRAME I.D. | 180° BUS | | STATOR TOOTH | ADE END TURN | STATOR PSIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| PM | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | #11 | #13 | #15 | #1 | #3 | #2 | #8 | #10 | #12 | #14 | |
| 2:45 | 87 | 97 | 88 | – | 99 | 96 | 94 | 94 | 99 | 102 | 108 | 123 | 121 | 113 | 117 | 121 | 115 | 118 | 10.5 |
| 3:05 | 87 | [illegible] | 88 | - | 99 | [illegible] | 94 | 94 | 99 | 102 | 108 | 123 | 123 | 115 | 118 | 121 | 115 | 118 | 10.5 |
| 3:25 | 87 | 97 | 88 | - | 100 | 96 | [illegible] | [illegible] | 100 | 103 | 107 | [illegible] | 123 | 115 | 118 | 121 | 117 | 120 | |
| 4:10 | 87 | 94 | 87 | – | 95 | 92 | 90 | 90 | 93 | 94 | 96 | 101 | 101 | 95 | 97 | 99 | 99 | 100 | 10.5 |
| 4:30 | 87 | 94 | 87 | 81 | 94 | 91 | 90 | 90 | 92 | 94 | 95 | 101 | 100 | 94 | 96 | 98 | 98 | 99 | 10.5 |
| 4:50 | 86 | 93 | 86 | 80 | 93 | 90 | 89 | 89 | 91 | 93 | 94 | 99 | 99 | 93 | 94 | 96 | 97 | 98 | 10.5 |
| 5:1 | 87 | 94 | 87 | 81 | 94 | 91 | 90 | 90 | 92 | 93 | 95 | 99 | 99 | 92 | 94 | 96 | 97 | 97 | 10.5 |
| 5:30 | 86 | 93 | 86 | 80 | 93 | 91 | 89 | 89 | 92 | 93 | 95 | 99 | 99 | 92 | 94 | 96 | 96 | 97 | 10.5 |
| 5:50 | 85 | 93 | 86 | 78 | 93 | 90 | 88 | 88 | 91 | 93 | 95 | 101 | 100 | 92 | 94 | 96 | 97 | 97 | 10.5 |
| 6:10 | 86 | 93 | 86 | 80 | 93 | 91 | 89 | 89 | 92 | 93 | 95 | 100 | 100 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| 6:30 | 86 | 94 | 87 | 79 | 95 | 92 | 90 | 90 | 93 | 95 | 96 | 101 | 101 | 94 | 95 | 98 | 98 | 99 | 10.5 |
| 6:50 | 87 | 94 | 87 | 79 | 94 | 92 | 90 | 90 | 92 | 94 | 96 | 100 | 100 | 93 | 95 | 97 | 97 | 98 | 10.5 |
| 7:10 | 87 | 94 | 87 | 78 | 95 | 92 | 90 | 90 | 93 | 95 | 97 | 101 | – | 94 | 95 | 97 | 97 | 98 | 10.5 |
| 7:30 | 86 | 93 | 86 | 79 | 94 | 92 | 89 | 89 | 92 | 94 | 96 | 101 | – | 93 | 94 | 96 | 96 | 98 | 10.5 |
| 7:50 | 86 | 94 | 87 | 81 | 95 | 92 | 90 | 90 | 93 | 94 | 97 | 101 | - | 94 | 96 | 98 | 98 | 99 | 10.5 |
| 8:10 | 86 | 94 | 86 | 79 | 95 | 92 | 90 | 90 | 92 | 94 | 97 | 101 | - | 94 | 96 | 98 | 98 | 99 | 10.5 |
| 8: | 87 | 94 | 87 | 81 | 95 | 93 | 91 | 91 | 93 | 95 | 97 | 102 | - | 94 | 96 | 98 | 98 | 100 | 10.5 |
| 8:50 | 87 | 95 | 88 | 81 | 96 | 93 | 91 | 91 | 94 | 95 | 98 | 103 | - | 95 | 97 | 99 | 99 | 100 | 10.5 |
| 9:10 | 87 | 95 | 87 | 82 | 96 | 93 | 91 | 91 | 94 | 96 | 99 | 106 | – | 97 | 100 | 102 | 101 | 103 | 10.5 |
| 9:30 | 88 | 96 | 88 | 82 | 97 | 94 | 92 | 92 | 95 | 97 | 100 | 106 | – | 98 | 101 | 103 | 102 | 104 | 10.5 |
| 9:50 | 86 | 94 | 86 | 81 | 95 | 92 | 90 | 90 | 94 | 96 | 99 | 105 | – | 97 | 100 | 102 | 101 | 102 | 10.5 |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 29
DATE 5-5-66

GENERATOR MODEL NO. 2CM393A1
SERIAL NO. AB-274-285
REGULATOR MODEL NO. Eng'g B.B.
SERIAL NO.
EXCITER MODEL NO.
SERIAL NO.
TEST STAND NO. 118
TITLE OF TEST Acceptance
SPECIFICATION

| | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING ~~AIR~~ oil | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | ø1-N | ø2-N | ø3-N | ø1 | ø2 | ø3 | ø1 | ø2 | ø3 | TOTAL KW | TOTAL KVA | POWER FACTOR | EF | EAUX | IF | RF | TOTAL TEMP | RPM | ~~ΔP~~ | ~~AIR FLOW~~ | TEMP IN | TEMP OUT | ALT | AIR TEMP | FRAME TEMP | ALT | AIR TEMP |
| | VOLTS | VOLTS | VOLTS | AMPS | AMPS | AMPS | WATTS | WATTS | WATTS | | | | VOLTS | VOLTS | AMPS | OHMS | °C | | ~~IN H$_2$O~~ | ~~#/MIN~~ | °C | °C | FEET | °C | °C | FEET | °C |
| | | | | ← | | K=4 | | | → | | | | | | | | | | stator | | | | stator | | Bearings | | |
| P.M. | | | | | | | | | | | | | | | | | | | GPM | PSIG | | | in-Hg | PSIA* | D.E GPM | ADE GPM | PSIG |
| 8:30 | 120.1 | 119.9 | 120.0 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.0 | | 3.54 | 4.24 | | 12000 | 1.38 | 1.44 | 93 | 93 | 10.2 | ~~10.5~~ | .138 | .138 | 17.4 |
| 8:50 | 120.1 | 119.9 | 120.0 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.0 | | 3.54 | 4.24 | | 12000 | 1.38 | 1.41 | 93 | 93 | 10.2 | ~~10.5~~ | .138 | .138 | 17.4 |
| | | | | ← | | K=10 | | | → | | | | | | | | | | | | | | | | | | |
| 9:10 | 120.2 | 119.8 | 120.3 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.4 | | 4.10 | 4.25 | | 12000 | 1.38 | 1.41 | 93 | 93 | 10.2 | ~~10.5~~ | .138 | .138 | 17.3 |
| 9:30 | 120.1 | 119.7 | 120.2 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.3 | | 4.08 | 4.24 | | 12000 | 1.38 | 1.41 | 94 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 17.6 |
| 9:50 | 120.1 | 119.7 | 120.2 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.3 | | 4.08 | 4.24 | | 12000 | 1.38 | 1.44 | 92 | 93 | 10.2 | ~~10.5~~ | .138 | .138 | 16.8 |
| 10:10 | 120.1 | 119.7 | 120.2 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.2 | | 4.08 | 4.24 | | 12000 | 1.38 | 1.44 | 92 | 92 | 10.2 | ~~10.5~~ | .138 | .138 | 16.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10:30 | 120.1 | 119.6 | 120.3 | 2.78 | 2.78 | 2.78 | 266 | 266 | 266 | 8.0 | 10.0 | .80 | 19.9 | | 4.64 | 4.29 | | 12000 | 1.38 | 1.41 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 16.2 |
| 10:50 | 120.1 | 119.6 | 120.3 | 2.78 | 2.78 | 2.78 | 266 | 266 | 266 | 8.0 | 10.0 | .80 | 19.9 | | 4.63 | 4.30 | | 12000 | 1.38 | 1.41 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 16.2 |
| 11:10 | 120.1 | 119.7 | 120.2 | 2.78 | 2.78 | 2.78 | 266 | 266 | 266 | 8.0 | 10.0 | .80 | 19.9 | | 4.63 | 4.30 | | 12000 | 1.38 | 1.41 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 16.1 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11:30 | 120.1 | 119.8 | 120.2 | 3.47 | 3.47 | 3.47 | 333 | 333 | 333 | 10.0 | 12.5 | .80 | 22.6 | | 5.20 | 4.34 | | 12000 | 1.38 | 1.41 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 15.5 |
| 11:50 | 120.1 | 119.8 | 120.2 | 3.47 | 3.47 | 3.47 | 333 | 333 | 333 | 10.0 | 12.5 | .80 | 22.8 | | 5.25 | 4.34 | | 12000 | 1.38 | 1.34 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | 15.2 |
| 12:10 | 120.1 | 119.8 | 120.2 | 3.47 | 3.47 | 3.47 | 333 | 333 | 335 | 10.0 | 12.5 | .80 | 22.8 | | 5.25 | 4.34 | | 12000 | 1.38 | 1.31 | 94 | 96 | 10.2 | ~~10.5~~ | .138 | .138 | 15.2 |
| 12:30 | 120.1 | 119.8 | 120.2 | 3.47 | 3.47 | 3.47 | 333 | 333 | 333 | 10.0 | 12.5 | .80 | 22.8 | | 5.25 | 4.34 | | 12000 | 1.38 | 1.31 | 94 | 96 | 10.2 | ~~10.5~~ | .138 | .138 | 15.2 |
| | | | | ← | | K=20 | | | → | | | | | | | | | | | | | | | | | | |
| 1:00 | 120.2 | 119.8 | 120.5 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.6 | | 5.8 | 4.41 | | 12000 | 1.38 | 1.30 | 94 | 96 | 10.2 | ~~10.5~~ | .138 | .138 | 13.2 |
| 1:20 | 120.2 | 119.8 | 120.5 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.4 | | 5.82 | 4.36 | | 12000 | 1.38 | 1.30 | 93 | 94 | 10.2 | ~~10.5~~ | .138 | .138 | |
| 1:40 | 120.2 | 119.8 | 120.4 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.6 | | 5.8 | 4.41 | | 12000 | 1.38 | 1.25 | 96 | 99 | 10.2 | ~~10.5~~ | .138 | .138 | 12.0 |
| 2:00 | 120.2 | 119.8 | 120.4 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 12.0 | 15.0 | .80 | 25.6 | | 5.8 | 4.41 | | 12000 | 1.38 | 1.25 | 93 | 96 | 10.2 | ~~10.5~~ | .138 | .138 | 12.0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| METER NO. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | | | | | | | | | |

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD R.M.G. RESISTANCE ____ Ω @ ____ °C

NOTES: * 10.5 psia should be 9.7 psia

TESTED BY Vasilik
V.T. Timinger 5/6/66
D Cypriani 5/6/66

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

G. .ERATOR MODEL NUMBER 2C111393H1 TEST NUMBER 1856
SERIAL NUMBER AB-374-285 SHEET NUMBER 29A
TITLE OF TEST Acceptance DATE 5-5-66

NB Spencer 5/6/66

| | D.E. OIL IN | BRG. OIL OUT | ADE OIL IN | BRG OIL OUT | D.E BRG | | ADE BRG | | Frame I.D | STATOR CORE O.D. | Stator Tooth | D.E. END TURN | | FRAME I.D. | 180° BUS | | STATOR Tooth | ADE END TURN | stator PSIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P.M. | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| | #3 | 11 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 15 | 1 | 3 | 6 | 8 | 10 | 12 | 14 | |
| 10:10 | 85 | 94 | 86 | 80 | 95 | 92 | 90 | 90 | 92 | 95 | 98 | 105 | – | 96 | 99 | 102 | 101 | 102 | 10.5 |
| 10:30 | 86 | 95 | 86 | 79 | 96 | 92 | 91 | 91 | 95 | 97 | 101 | 109 | – | 100 | 103 | 107 | 104 | 107 | 10.5 |
| 10:50 | 86 | 95 | 87 | 83 | 97 | 94 | 91 | 92 | 95 | 98 | 102 | 110 | – | 101 | 104 | 108 | 105 | 107 | 10.5 |
| 11:10 | 86 | 96 | 87 | 81 | 97 | 94 | 92 | 92 | 96 | 98 | 102 | 110 | – | 101 | 104 | 108 | 105 | 107 | 10.5 |
| 11:30 | 86 | 96 | 86 | 80 | 98 | 95 | 92 | 93 | 97 | 100 | 105 | 114 | – | 105 | 109 | 113 | 108 | 112 | 10.5 |
| 11:50 | 87 | 96 | 87 | 84 | 99 | 96 | 93 | 93 | 97 | 101 | 105 | 116 | – | 105 | 109 | 114 | 110 | 115 | 10.5 |
| 12: | 87 | 97 | 87 | 85 | 99 | 96 | 93 | 93 | 99 | 102 | 105 | 116 | – | 106 | 111 | 114 | 111 | 114 | 10.5 |
| 12:30 | 87 | 97 | 87 | 84 | 99 | 96 | 93 | 93 | 99 | 101 | 105 | 116 | – | 106 | 111 | 114 | 110 | 114 | 10.5 |
| 1:00 | 86 | 98 | 87 | 81 | 99 | 96 | 93 | 93 | 99 | 102 | 108 | 122 | – | 111 | 116 | 120 | 114 | 117 | 10.5 |
| 1:20 | 84 | 96 | 84 | 84 | 99 | 93 | 91 | 91 | 96 | 102 | 105 | 120 | – | 108 | 114 | 119 | 111 | 114 | 10.5 |
| :40 | 87 | 99 | 87 | 84 | 99 | 96 | 96 | 96 | 102 | 102 | 108 | 123 | – | 111 | 117 | 120 | 114 | 117 | 10.5 |
| :00 | 84 | 96 | 84 | 84 | 99 | 96 | 93 | 93 | 99 | 102 | 108 | 120 | – | 111 | 116 | 120 | 114 | 117 | 10.5 |
| 4:30 | 90 | 96 | 90 | 81 | 96 | 93 | 93 | 93 | 96 | 96 | 99 | 102 | – | 94 | 96 | 99 | 99 | 99 | 7.2 |
| 4:50 | 87 | 93 | 87 | 83 | 93 | 90 | 90 | 93 | 93 | 93 | 96 | 93 | – | 93 | 96 | 98 | 98 | 98 | 7.2 |
| 5:10 | 87 | 93 | 87 | 78 | 93 | 90 | 90 | 90 | 90 | 93 | 96 | 99 | – | 90 | 93 | 96 | 96 | 96 | 7.2 |
| 5:20 | 86 | 93 | 87 | 78 | 93 | 90 | 90 | 90 | 90 | 93 | 96 | 99 | – | 90 | 93 | 96 | 96 | 96 | 7.2 |
| 5 | 86 | 93 | 88 | 78 | 93 | 90 | 90 | 90 | 93 | 93 | 92 | 99 | – | 90 | 93 | 96 | 96 | 96 | 7.2 |
| 6:10 | 86 | 93 | 88 | 79 | 93 | 91 | 90 | 90 | 93 | 93 | 96 | 99 | – | 90 | 93 | 92 | 96 | 96 | 7.2 |
| 6:30 | 87 | 93 | 88 | 81 | 93 | 90 | 90 | 90 | 93 | 93 | 96 | 99 | – | 93 | 96 | 96 | 96 | 96 | 7.2 |
| 6:50 | 87 | 93 | 87 | 78 | 93 | 90 | 90 | 90 | 93 | 93 | 96 | 102 | – | 93 | 96 | 99 | 99 | 99 | 7.2 |
| 7:10 | 86 | 93 | 87 | 78 | 93 | 90 | 90 | 90 | 93 | 93 | 96 | 102 | – | 95 | 98 | 99 | 99 | 99 | 7.2 |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 30
DATE 5/6/66

GENERATOR MODEL NO. 2CM393H1 REGULATOR MODEL NO. Eng'g B.B. EXCITER MODEL NO.
SERIAL NO. HB-374-285 SERIAL NO. SERIAL NO.
TEST STAND NO. 118
TITLE OF TEST Acceptance SPECIFICATION

| TIME | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING ~~AIR~~ oil | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ø1-N | Ø2-N | Ø3-N | Ø1 | Ø2 | Ø3 | Ø1 | Ø2 | Ø3 | TOTAL | TOTAL | POWER | EF | EAUX | IF | RF | TOTAL TEMP | RPM | ΔP | AIR FLOW | TEMP IN | TEMP OUT | ALT | AIR TEMP | FRAME TEMP | ALT | AIR TEMP | |
| | VOLTS | VOLTS | VOLTS | AMPS | AMPS | AMPS | WATTS | WATTS | WATTS | KW | KVA | FACTOR | VOLTS | VOLTS | AMPS | OHMS | °C | | IN H₂O | #/MIN | °C | °C | FEET | °C | °C | FEET | °C | |
| | | | | | | | ← K=4 → | | | | | | | | | | | | Stator | | | | Stator | | Bearings | | | |
| | | | | | | | | | | | | | | | | | | | GPM | PSIG | | | in-hg | PSIA | D.E GPM | A.E GPM | PSIG | |
| 4:30 | 119.9 | 119.9 | 119.9 | | | | | | | | | | 11.1 | | 2.6 | 4.26 | | 12000 | 1.38 | 1.34 | 96 | 96 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| 4:50 | 120 | 119.9 | 119.9 | | | | | | | | | | 11.0 | | 2.6 | 4.23 | | 12000 | 1.38 | 1.45 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 5:10 | 120 | 120 | 119.9 | | | | | | | | | | 11.0 | | 2.6 | 4.23 | | 12000 | 1.38 | 1.45 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5:20 | 120.2 | 120 | 120.1 | 1.37 | 1.37 | 1.39 | 167 | 167 | 167 | 2.0 | 1.98 | 1.0 | 11.4 | | 2.71 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.2 | |
| 5:40 | 120.2 | 120 | 120.1 | 1.37 | 1.37 | 1.38 | 167 | 167 | 167 | 2.0 | 1.98 | 1.0 | 11.4 | | 2.71 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.2 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5:50 | 120.1 | 120 | 120.0 | 2.73 | 2.74 | 2.76 | 334 | 334 | 334 | 4.0 | 3.94 | 1.0 | 12.0 | | 2.85 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.2 | |
| 6:10 | 120.1 | 120.0 | 120.0 | 2.78 | 2.75 | 2.79 | 334 | 334 | 334 | 4.0 | 3.98 | 1.0 | 12.0 | | 2.85 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.2 | |
| 6:30 | 120.1 | 120.0 | 120.0 | 2.74 | 2.75 | 2.79 | 334 | 334 | 334 | 4.0 | 3.98 | 1.0 | 12.0 | | 2.85 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.1 | |
| | | | | | | | ← K=10 → | | | | | | | | | | | | | | | | | | | | | |
| 6:50 | 120.1 | 119.9 | 120.1 | 1.65 | 1.64 | 1.66 | 200 | 200 | 200 | 6.0 | 5.95 | 1.0 | 12.6 | | 3.0 | 4.20 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 20.5 | |
| 7:10 | 120.1 | 119.8 | 120.0 | 1.65 | 1.64 | 1.66 | 200 | 200 | 200 | 6.0 | 5.95 | 1.0 | 12.7 | | 3.0 | 4.20 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| 7:30 | 120.1 | 119.8 | 120.0 | 1.65 | 1.64 | 1.66 | 200 | 200 | 200 | 6.0 | 5.95 | 1.0 | 12.7 | | 3.0 | 4.20 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8:00 | 120 | 119.8 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.5 | | 4.12 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| 8:20 | 120 | 119.8 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.5 | | 4.12 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| 8:40 | 120 | 119.8 | 120 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 6.0 | 7.5 | .80 | 17.5 | | 4.12 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9: | | | | | | | ← K=4 → | | | | | | | | | | | | | | | | | | | | | |
| 9:00 | 120 | 119.8 | 120 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.3 | | 3.60 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 9:20 | 120 | 119.8 | 120 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.2 | | 3.60 | 4.22 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 9:40 | 120 | 119.8 | 120 | 3.47 | 3.47 | 3.47 | 334 | 334 | 334 | 4.0 | 5.0 | .80 | 15.2 | | 3.60 | 4.22 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | ① |
| METER NO. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD P.M.G. RESISTANCE Ω @ °C

NOTES: ① VIB. = .0005" DE .001 ADE

TESTED BY Brzozowski.
FARABAUGH
O.V. [illegible] 5/6/66
D [illegible] 5/6/66

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

GENERATOR MODEL NUMBER 2CM393A1
TEST NUMBER 1856
SERIAL NUMBER AB-374-285
SHEET NUMBER 30H
TITLE OF TEST Acceptance
DATE 5/6/66

STAND #118

W B Spencer 5/6/66

| Ti | D.E OIL IN | BRG OIL OUT | ADE OIL IN | BRG OIL OUT | D.E BRG | | ADE BRG | | FRAME I.D. | STATOR CORE O.D. | STATOR TOOTH | D.E. END TURN | | FRAME I.D. | 180° BUS | | STATOR TOOTH | ADE END TURN | STATOR [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| | #3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 15 | 1 | 3 | 6 | 8 | 10 | 12 | 14 | |
| 7:30 | 86 | 93 | 87 | 79 | 93 | 90 | 90 | 90 | 93 | 93 | 96 | 102 | 96 | 96 | 99 | 99 | 99 | 99 | 7.2 |
| | | | | | | | | | | | | | | | | | | | |
| 8:00 | 86 | 95 | 88 | 78 | 95 | 91 | 90 | 90 | 93 | 95 | 98 | 104 | 96 | 96 | 99 | 101 | 101 | 102 | 7.2 |
| 8:20 | 86 | 95 | 87 | 78 | 95 | 91 | 90 | 90 | 93 | 95 | 98 | 105 | 96 | 97 | 99 | 102 | 99 | 102 | 7.2 |
| 8:40 | 86 | 95 | 87 | 78 | 95 | 91 | 90 | 90 | 93 | 95 | 98 | 105 | 96 | 97 | 99 | 102 | 99 | 102 | 7.2 |
| | | | | | | | | | | | | | | | | | | | |
| 9: | 87 | 95 | 87 | 81 | 95 | 92 | 90 | 90 | 93 | 94 | 97 | 102 | 95 | 97 | 99 | 99 | 99 | 100 | 7.2 |
| 9:20 | 87 | 95 | 87 | 80 | 95 | 92 | 90 | 90 | 93 | 94 | 96 | 102 | – | 94 | 97 | 99 | 99 | 99 | 7.2 |
| 9:40 | 87 | 94 | 87 | 81 | 94 | 92 | 90 | 90 | 93 | 94 | 96 | 102 | - | 94 | 96 | 99 | [illegible] | [illegible] | 7.2 |
| | | | | | | | | | | | | | | | | | | | |
| 10:15 | 86 | 93 | 86 | 81 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 99 | - | 93 | 96 | 98 | 98 | 99 | 7.2 |
| 10:30 | 86 | 93 | 86 | 80 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 99 | - | 92 | 94 | 96 | 97 | 97 | 7.2 |
| 10:45 | 86 | 93 | 86 | 81 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 99 | - | 92 | 94 | 96 | 97 | 97 | 7.2 |
| | | | | | | | | | | | | | | | | | | | |
| 11:00 | 86 | 93 | 87 | 81 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 97 | 97 | 90 | 93 | 94 | 95 | 96 | 7.2 |
| 11:15 | 86 | 93 | 87 | 80 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 97 | 97 | 90 | 93 | 94 | 95 | 96 | 7.2 |
| 11:[illegible] | 86 | 93 | 87 | 80 | 94 | 91 | 90 | 90 | 91 | 93 | 95 | 97 | - | 90 | 93 | 94 | 95 | 96 | 7.2 |
| | | | | | | | | | | | | | | | | | | | |
| 11:40 | 87 | 94 | 87 | 81 | 94 | 91 | 90 | 90 | 92 | 94 | 95 | 99 | - | 91 | 93 | 95 | 96 | 97 | 10.5 |
| 11:55 | 87 | 94 | 87 | 81 | 94 | 91 | 90 | 90 | 92 | 95 | 95 | 99 | - | 91 | 93 | 95 | 96 | 97 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 31
DATE 5-6-66

GENERATOR MODEL NO. 2CM393A1
SERIAL NO. AB-004-285
REGULATOR MODEL NO. ENG'R. A.B.
SERIAL NO.
EXCITER MODEL NO.
SERIAL NO.
TEST STAND NO. 8
TITLE OF TEST ACCEPTANCE
SPECIFICATION

| TIME | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING AIR | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ø1-N | Ø2-N | Ø3-N | Ø1 | Ø2 | Ø3 | Ø1 | Ø2 | Ø3 | TOTAL KW | TOTAL KVA | POWER FACTOR | EF | EAUX | IF | RF | TOTAL TEMP | RPM | ΔP | AIR FLOW | TEMP IN | TEMP OUT | ALT | AIR TEMP | FRAME TEMP | ALT | AIR TEMP | |
| | VOLTS | VOLTS | VOLTS | AMPS | AMPS | AMPS | WATTS | WATTS | WATTS | | | | VOLTS | VOLTS | AMPS | OHMS | °C | | IN $H_2O$ | #/MIN | °C | °C | FEET | °C | °C | FEET | °C | |
| | | | | ← K=4 → | | | | | | | | | | | | | | | STATOR | | | | STATOR | | BEARINGS | | | |
| | | | | | | | | | | | | | | | | | | | GPM | PSIG | | | IN-HG | PSIA | DE GPM | ADE GPM | PSIG | |
| 10:15 | 120 | 119.8 | 120 | 1.73 | 1.73 | 1.73 | 167 | 167 | 167 | 2.0 | 2.5 | .80 | 12.8 | | 3.02 | 4.23 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 10:30 | 120 | 119.8 | 120 | 1.73 | 1.73 | 1.73 | 167 | 167 | 167 | 2.0 | 2.5 | .80 | 12.8 | | 3.02 | 4.23 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 10:45 | 120 | 119.8 | 120 | 1.73 | 1.73 | 1.73 | 167 | 167 | 167 | 2.0 | 2.5 | .80 | 12.8 | | 3.02 | 4.23 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11:00 | 120 | 120 | 120 | | | | | | | | | | 11.0 | | 2.60 | 4.22 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 11:15 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| 11:30 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 15.3 | 7.2 | .138 | .138 | 21.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11:40 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| 11:55 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | 4.21 | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12:02 | 119 | 118.5 | 122 | 2.32 | – | – | 277 | – | – | | | | 11.2 | | 2.61 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12:15 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| 12:35 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| 12:55 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.5 | |
| 1:10 | 120 | 120 | 120 | | | | | | | | | | 10.9 | | 2.59 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.0 | |
| | | | | ← K=10 → | | | | | | | | | | | | | | | | | | | | | | | | |
| 1:13 | 116.0 | 114.8 | 125.5 | 2.87 | – | – | 334 | – | – | 3.34 | 3.33 | 1.0 | 11.6 | | 2.75 | | | 12000 | 1.38 | 1.50 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 21.0 | VIB=.0025"DE .0012ADE |
| 1:23 | 115.9 | 114.9 | 125.7 | 2.88 | – | – | 336 | – | – | 3.36 | 3.32 | 1.0 | 11.7 | | 2.75 | | | 12000 | 1.38 | 1.55 | 92 | 92 | 8.5 | 10.5 | .138 | .138 | 10.5 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| METER NO. | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

5/6/66

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD P.M.G. RESISTANCE Ω @ °C

NOTES: Authorized 45 min instead of 1 hr. Stabilization - W.R. Spencer

TESTED BY FARABAUGH
V.V. Trump 5/6/66
D Cyriani 5/6/66

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

G. .ERATOR MODEL NUMBER 2CM373A1
SERIAL NUMBER AB-374-285
TITLE OF TEST [illegible]

TEST NUMBER 1856
SHEET NUMBER 31 A
DATE 5-6-66

WD Spencer 5/6/66

| | D.E. OIL IN | BRG OIL OUT | ADE OIL IN | BRG OIL OUT | D.E. BRG | | ADE BRG | | FRAME I.D. | STATOR CORE O.D. | STATOR TOOTH | DE END TURN | | FRAME I.D. | 180° BUS | | STATOR TOOTH | ADE END TURN | STATOR PSIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | #11 | #13 | #15 | #1 | #3 | #6 | #9 | #10 | #12 | #14 | |
| 12:15 | 87 | 94 | 87 | 81 | 94 | 92 | 91 | 91 | 93 | 94 | 96 | 99 | - | 91 | 92 | 96 | 96 | 97 | 10.5 |
| 12:35 | 87 | 94 | 87 | 80 | 94 | 92 | 91 | 91 | 93 | 94 | 96 | 99 | - | 91 | 92 | 96 | 96 | 97 | 10.5 |
| 12:55 | 87 | 94 | 87 | 80 | 94 | 92 | 91 | 91 | 93 | 94 | 96 | [illegible] | - | 91 | 92 | 96 | [illegible] | [illegible] | 10.5 |
| 1:10 | 87 | 94 | 88 | 81 | 94 | 93 | 91 | 91 | 93 | 94 | 96 | 99 | - | 91 | 92 | 96 | 96 | 97 | 10.5 |
| 1:23 | 88 | 93 | 88 | 81 | 94 | 91 | 90 | 90 | 93 | 94 | 97 | 102 | - | 94 | 96 | 97 | 97 | 97 | 10.5 |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 32
DATE 5-6-66

GENERATOR MODEL NO. 2CM393A1
SERIAL NO. AB-3[illegible]-285
REGULATOR MODEL NO. ENG'R B.B.
SERIAL NO.
EXCITER MODEL NO.
SERIAL NO.
TEST STAND NO. 118
TITLE OF TEST ACCEPTANCE
SPECIFICATION

| TIME | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING AIR | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ø1-N | Ø2-N | Ø3-N | Ø1 | Ø2 | Ø3 | Ø1 | Ø2 | Ø3 | TOTAL KW | TOTAL KVA | POWER FACTOR | EF | EAUX | IF | RF | TOTAL TEMP | RPM | ΔP | AIR FLOW | TEMP IN | TEMP OUT | ALT | AIR TEMP | FRAME TEMP | ALT | AIR TEMP |
| | VOLTS | VOLTS | VOLTS | AMPS | AMPS | AMPS | WATTS | WATTS | WATTS | | | | VOLTS | VOLTS | AMPS | OHMS | °C | | IN $H_2O$ | #/MIN | °C | °C | FEET | °C | °C | FEET | °C |
| | | | | ← K=20 → | | | | | | | | | | | | | | | STATOR | | | | STATOR | | BEARINGS | | |
| | | | | | | | | | | | | | | | | | | | GPM | PSIG | | | VAC. IN-HG | PSIA | DE GPM | ADE GPM | PSIG |
| 2:00 | 120 | 119.5 | 120 | 2.03 | [illegible] | 2.22 | [illegible] | 200 | [illegible] | 12.0 | 15.0 | .80 | 25.2 | | 5.78 | 4.37 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 2:15 | 120 | 119.5 | 120 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 12.0 | 15.0 | .80 | 25.4 | | 5.78 | 4.39 | | 12000 | 1.38 | 1.50 | 93 | 98 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2:30 | 120 | 119.5 | 120 | 1.66 | 1.66 | 1.66 | 200 | 200 | 200 | 12.0 | 11.95 | 1.0 | 16.3 | | 3.75 | 4.34 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 2:45 | 120 | 119.5 | 120 | 1.66 | 1.66 | 1.66 | 200 | 200 | 200 | 12.0 | 11.95 | 1.0 | 16.1 | | 3.75 | 4.30 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 3:00 | 120 | 119.5 | 120 | 1.66 | 1.66 | 1.66 | 200 | 200 | 200 | 12.0 | 11.95 | 1.0 | 16.1 | | 3.75 | 4.30 | | 12000 | 1.38 | 1.50 | 92 | 93 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| | | | | ← K=10 → | | | | | | | | | | | | | | | | | | | | | | | |
| 3:15 | 120 | 119.8 | 120 | 2.76 | 2.75 | 2.78 | 333 | 333 | 333 | 10.0 | 10.0 | 1.0 | 14.7 | | 3.45 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 3:30 | 120 | 119.8 | 120 | 2.76 | 2.75 | 2.78 | 333 | 333 | 333 | 10.0 | 10.0 | 1.0 | 14.7 | | 3.45 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 3:45 | 120 | 119.8 | 120 | [illegible] | 2.75 | 2.75 | 333 | 333 | 333 | [illegible] | [illegible] | [illegible] | 14.7 | | 3.45 | 4.26 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4:00 | 120 | 120 | 120 | 2.22 | 2.18 | 2.24 | 267 | 267 | 267 | 8.0 | 7.98 | 1.0 | 13.6 | | 3.20 | 4.25 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 4:15 | 120 | 120 | 120 | 2.22 | 2.18 | 2.24 | 267 | 267 | 267 | 8.0 | 7.98 | 1.0 | 13.6 | | 3.20 | 4.25 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 4:30 | 120 | 120 | 120 | 2.22 | 2.18 | 2.24 | 267 | 267 | 267 | 8.0 | 7.98 | 1.0 | 13.6 | | 3.20 | 4.25 | | 12000 | 1.38 | 1.50 | 93 | 94 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4:45 | 120 | 119.9 | 120 | 1.66 | 1.64 | 1.67 | 200 | 200 | 200 | 6.0 | 5.98 | 1.0 | 12.5 | | 2.91 | 4.28 | | 12000 | 1.38 | 1.50 | 95 | 95 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 5:00 | 120.1 | 120.0 | 120.1 | 1.65 | 1.64 | 1.67 | 200 | 200 | 200 | 6.0 | 5.97 | 1.0 | 12.5 | | 2.94 | 4.25 | | 12000 | 1.38 | 1.47 | 94 | 94 | 8.5 | 10.5 | .138 | .138 | 17.4 |
| 5:15 | 120.1 | 120.0 | 120.1 | 1.65 | 1.64 | 1.67 | 200 | 200 | 200 | 6.0 | 5.97 | 1.0 | 12.5 | | 2.94 | 4.25 | | 12000 | 1.38 | 1.44 | 92 | 92 | 8.5 | 10.5 | .138 | .138 | 17.2 |
| METER NO. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | | | | | | | | | |

5/6/66

COLD ROTOR RESISTANCE 3.26 Ω @ 25 °C
COLD STATOR RESISTANCE .039 Ω @ 25 °C
COLD R.M.S. RESISTANCE Ω @ °C

NOTES:

TESTED BY FARABAUGH
W.T. [illegible] Jr. 5/6/66
D Cipriani 5/6/66

(10-01)

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

NERATOR MODEL NUMBER 2CM393A1
TEST NUMBER 1856
SERIAL NUMBER AB-374-285
SHEET NUMBER 32A
TITLE OF TEST ACCEPTANCE
DATE 5-6-66

WB Spencer 5/6/66

| | DE OIL IN | BRG OIL OUT | ADE OIL IN | BRG OIL OUT | DE BRG | | ADE BRG | | FRAME I.D. | STATOR CORE O.D. | STATOR TOOTH | DE END TURN | | FRAME I.D. | 180° BUS | | STATOR TOOTH | ADE END TURN | STATOR PSIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | |
| | #3 | #4 | #5 | #6. | #7 | #8 | #9 | #10 | #11 | #13 | #15 | #1 | #3 | #6 | #8 | #10 | #12 | #14 | |
| 2:00 | 86 | 96 | 87 | 81 | 97 | 95 | 93 | 93 | 97 | 100 | 105 | 118 | 118 | 108 | 113 | 117 | 111 | 114 | 10.5 |
| 2:15 | 87 | 96 | 87 | 84 | 99 | 95 | 94 | 94 | 99 | 101 | 107 | 121 | 121 | 111 | 116 | 120 | 113 | 117 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 2:30 | 87 | 96 | 87 | 82 | 98 | 94 | 93 | 94 | 97 | 100 | 105 | 116 | - | 108 | 111 | 115 | 111 | 113 | 10.5 |
| 2:45 | 87 | 96 | 87 | 82 | 98 | 94 | 92 | 93 | 96 | 99 | 103 | 114 | 114 | 105 | 108 | 113 | 107 | 110 | 10.5 |
| 3:00 | 86 | 96 | 86 | 81 | 96 | 93 | 92 | 92 | 96 | 98 | 102 | 110 | - | 104 | 107 | 113 | 107 | 109 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 3:1 | 87 | 96 | 87 | 80 | 96 | 93 | 92 | 92 | 96 | 97 | 101 | 109 | | 101 | 104 | 107 | 101 | 107 | 10.5 |
| 3:80 | 87 | 96 | 87 | 81 | 96 | 93 | 92 | 92 | 96 | 97 | 101 | 108 | 108 | 101 | 104 | 107 | 102 | 107 | 10.5 |
| 3:45 | 87 | 96 | 87 | 81 | 96 | 93 | 92 | 92 | 96 | 97 | 101 | 108 | 108 | 101 | 104 | 107 | 102 | 107 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 4:00 | 87 | 96 | 87 | 80 | 96 | 92 | 91 | 91 | 94 | 97 | 99 | 106 | — | 99 | 100 | 105 | 102 | 105 | 10.5 |
| 4:15 | 87 | 96 | 87 | 81 | 96 | 93 | 91 | 91 | 94 | 97 | 99 | 106 | 106 | 97 | 100 | 103 | 102 | 103 | 10.5 |
| 4:30 | 87 | 96 | 87 | 82 | 96 | 93 | 91 | 91 | 95 | 97 | 99 | 106 | - | 97 | 100 | 103 | 102 | 103 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 4:45 | 88 | 96 | 88 | 80 | 96 | 93 | 92 | 92 | 96 | 97 | 99 | 105 | - | 97 | 99 | 102 | 101 | 102 | 10.5 |
| 5:00 | 87 | 95 | 88 | 80 | 96 | 93 | 92 | 92 | 95 | 96 | 99 | 104 | - | 96 | 99 | 101 | 101 | 102 | 10.5 |
| 5:1 | 85 | 94 | 87 | 80 | 95 | 92 | 90 | 90 | 93 | 95 | 97 | 102 | - | 95 | 98 | 100 | 99 | 101 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO. 1856
SHEET NO. 33
DATE 5-6-66

GENERATOR MODEL NO. 2CM393H1
SERIAL NO. AB-374-285
TITLE OF TEST Acceptance

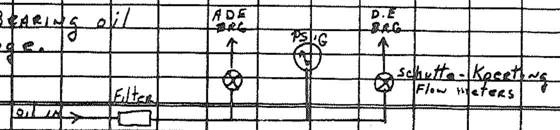
REGULATOR MODEL NO. Eng'r B.B.
SERIAL NO.
SPECIFICATION

EXCITER MODEL NO.
SERIAL NO.

TEST STAND NO. 118

| TIME | VOLTAGE Ø1-N VOLTS | VOLTAGE Ø2-N VOLTS | VOLTAGE Ø3-N VOLTS | CURRENT Ø1 AMPS | CURRENT Ø2 AMPS | CURRENT Ø3 AMPS | WATTS/PHASE Ø1 WATTS | WATTS/PHASE Ø2 WATTS | WATTS/PHASE Ø3 WATTS | LOAD TOTAL KW | LOAD TOTAL KVA | LOAD POWER FACTOR | FIELD POWER Ef VOLTS | FIELD POWER Eaux VOLTS | FIELD POWER If AMPS | FIELD POWER Rf OHMS | FIELD POWER TOTAL TEMP °C | SPEED RPM | COOLING AIR ΔP IN $H_2O$ | COOLING AIR AIR FLOW #/MIN | COOLING AIR TEMP IN °C | COOLING AIR TEMP OUT °C | GENERATOR AMBIENT ALT FEET | GENERATOR AMBIENT AIR TEMP °C | GENERATOR AMBIENT FRAME TEMP °C | REGULATOR AMBIENT ALT FEET | REGULATOR AMBIENT AIR TEMP °C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3rd | | | | ← K=4 | | | | | → | | | | | | | | | | Stator | | | | Stator | | Bearings | | |
| | | | | | | | | | | | | | | | | | | | GPM | PSIG | | | IN-Hg | PSIA | DE GPM | ADE GPM | PSIG |
| 5.30 | 120.1 | 120.0 | 120.0 | 2.76 | 2.74 | 2.79 | 334 | 334 | 334 | 4.0 | 3.98 | 1.0 | 12.0 | | 2.82 | 4.25 | | 12000 | 1.38 | 1.41 | 92 | 92 | 8.5 | 10.5 | .138 | .138 | 17.0 |
| 5.45 | 120.2 | 120.1 | 120.1 | 2.75 | 2.75 | 2.79 | 334 | 334 | 334 | 4.0 | 3.99 | 1.0 | 12.0 | | 2.82 | 4.25 | | 12000 | 1.38 | 1.44 | 92 | 92 | 8.5 | 10.5 | .138 | .138 | 17.3 |
| 6.00 | 120.2 | 120.1 | 120.1 | 2.75 | 2.75 | 2.79 | 334 | 334 | 334 | 4.0 | 3.99 | 1.0 | 12.0 | | 2.82 | 4.25 | | 12000 | 1.38 | 1.44 | 92 | 92 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 6:15 | 120.2 | 120.0 | 120.1 | 1.37 | 1.36 | 1.41 | 167 | 167 | 167 | 2.0 | 1.99 | 1.0 | 11.2 | | 2.69 | 4.20 | | 12000 | 1.38 | 1.44 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 6:30 | 120.2 | 120.0 | 120.1 | 1.37 | 1.36 | 1.41 | 167 | 167 | 167 | 2.0 | 1.99 | 1.0 | 11.4 | | 2.69 | 4.24 | | 12000 | 1.38 | 1.44 | 93 | 93 | 8.5 | 10.5 | .138 | .138 | 18.5 |
| 6:45 | 120.2 | 120.0 | 120.1 | 1.37 | 1.36 | 1.41 | 167 | 167 | 167 | 2.0 | 1.99 | 1.0 | 11.4 | | 2.69 | 4.24 | | 12000 | 1.38 | 1.44 | 94 | 93 | 8.5 | 10.5 | .138 | .138 | 18.1 |
| .00 | 120.0 | 120.0 | 120.0 | | | | | | | | | | 11.0 | | 2.59 | | | 12000 | 1.38 | 1.44 | 94 | 93 | 8.5 | 10.5 | .138 | .138 | 18.1 |
| 7:15 | 120.0 | 120.0 | 120.0 | | | | | | | | | | 11.0 | | 2.59 | | | 12000 | 1.38 | 1.44 | 94 | 93 | 8.5 | 10.5 | .138 | .138 | 18.1 |
| 7:30 | 120.1 | 120.0 | 120.0 | | | | | | | | | | 11.0 | | 2.59 | | | 12000 | 1.38 | 1.44 | 94 | 93 | 8.5 | 10.5 | .138 | .138 | 18.1 |
| 7:45 | | | | | | | | | | | | | 0 | | 0 | | | 12000 | 1.38 | 1.44 | 93 | 91 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 8:00 | | | | | | | | | | | | | 0 | | 0 | | | 12000 | 1.38 | 1.50 | 93 | 91 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 8:15 | | | | | | | | | | | | | 0 | | 0 | | | 12000 | 1.38 | 1.50 | 93 | 91 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 8:17 | 0 | 0 | 0 | 0 | 0.05 | 0.20 | 0 | 1.00 | 1.00 | | | | 0 | | 0 | | | 0 | 1.38 | 1.50 | 93 | 91 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| 8:30 | | | | | | | | | | | | | 0 | | 0 | | | 0 | 1.38 | 1.50 | 93 | 91 | 8.5 | 10.5 | .138 | .138 | 18.0 |
| METER NO. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: Location of Bearing oil Pressure Gauge.



Total Acceptance Running Time = 33.25 Hrs.

COLD ROTOR RESISTANCE [illegible] Ω @ 25 °C
COLD STATOR RESISTANCE .031 Ω @ 25 °C
COLD RMG. RESISTANCE Ω @ °C

NOTES:

TESTED BY Vasilik
5/6/66
5/6/66

DC-786 (10-61)

# AIRCRAFT GENERATOR TEST DATA SHEET

## ERIE PLANT, BUILDING 17F

ERATOR MODEL NUMBER 2CM393A1
TEST NUMBER 1856
SERIAL NUMBER AB-374-285
SHEET NUMBER 33A
TITLE OF TEST Acceptance
DATE 5-6-66

NB Spence 5/6/66

| PM | D.E. | BRG | ADE | BRG | DE | | ADE | | Frame | Stator | Stator | D.E | | Frame | 180° | | Stator | ADE | Stator |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OIL IN | OIL OUT | OIL IN | OIL OUT | BRG | | BRG | | ID | CORE OD | Tooth | END TURN | | I.D. | Bus | | Tooth | End TURN | PSIA |
| | | | | | | | | | #1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| | #3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 15 | 1 | 3 | 6 | 8 | 10 | 12 | 14 | |
| 5:30 | 85 | 93 | 86 | 82 | 94 | 91 | 89 | 89 | 92 | 93 | 95 | 100 | - | 93 | 95 | 98 | 97 | 98 | 10.5 |
| 5:45 | 85 | 93 | 86 | 78 | 93 | 91 | 89 | 89 | 92 | 93 | 95 | 99 | - | 92 | 94 | 96 | 96 | 98 | 10.5 |
| 6:00 | 85 | 93 | 86 | 77 | 94 | 91 | 89 | 89 | 92 | 93 | 95 | 100 | 100 | 92 | 94 | 97 | 97 | 98 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 6:15 | 87 | 94 | 87 | 80 | 94 | 92 | 90 | 90 | 92 | 94 | 95 | 100 | 99 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| 6:30 | 87 | 94 | 88 | 80 | 94 | 92 | 90 | 90 | 93 | 94 | 95 | 100 | 99 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| 6:45 | 87 | 94 | 87 | 80 | 94 | 92 | 90 | 90 | 93 | 94 | 95 | 100 | 100 | 92 | 95 | 97 | 98 | 98 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 7:00 | 87 | 94 | 87 | 80 | 94 | 92 | 90 | 90 | 92 | 94 | 95 | 100 | 99 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| 7:15 | 87 | 94 | 87 | 77 | 94 | 92 | 90 | 90 | 93 | 94 | 96 | 100 | 99 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| 7:30 | 86 | 94 | 87 | 80 | 94 | 92 | 90 | 90 | 92 | 94 | 95 | 99 | 99 | 92 | 94 | 96 | 97 | 98 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 7:45 | 86 | 92 | 86 | 76 | 92 | 89 | 87 | 87 | 89 | 90 | 90 | 94 | 94 | 89 | 91 | 93 | 93 | 94 | 10.5 |
| 8:00 | 86 | 92 | 86 | 79 | 91 | 89 | 87 | 87 | 89 | 89 | 90 | 93 | 92 | 87 | 89 | 91 | 92 | 92 | 10.5 |
| 8:15 | 86 | 92 | 86 | 76 | 91 | 89 | 87 | 87 | 89 | 89 | 90 | 93 | 92 | 87 | 89 | 90 | 91 | 92 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| 8:[illegible] | 86 | 87 | 86 | 75 | 87 | 86 | 86 | 86 | 88 | 89 | 89 | 92 | 92 | 87 | 89 | 90 | 91 | 91 | 10.5 |
| 8:[illegible]0 | 87 | 87 | 87 | 72 | 81 | 82 | 84 | 84 | 88 | 88 | 88 | 90 | 90 | 86 | 88 | 89 | 89 | 89 | 10.5 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| METER NO. | | | | | | | | | | | | | | | | | | | |
| CALIB DATE | | | | | | | | | | | | | | | | | | | |

# ACCEPTANCE TEST PROCEDURE

## BRAYTON CYCLE LOAD BANK AND ENGINEERING BREADBOARD VOLTAGE REGULATOR-EXCITER

### A. Objective

The test objective is to run an acceptance test on the Brayton Cycle Load Bank and Engineering breadboard voltage regulator exciter as required by Pratt and Whitney Aircraft Specification 6374.

### B. Description and Requirement

The test acceptance consists of operation described in section I. The tests specified below are intended to demonstrate the satisfactory integrity of the load bank and Engineering breadboard voltage regulator exciter.

### C. Witnessing

The acceptance test will be witnessed by Pratt and Whitney Aircraft. The Pratt and Whitney Aircraft representative will be requested to sign the acceptance test data sheets as recognition of the successful completion of the acceptance test.

### D. Instrument Calibration and Test Equipment

All instruments and equipment shall be calibrated as necessary to insure that the required degree of accuracy is maintained.

### E. Data to be Recorded

| | Accuracy |
|---|---|
| 1. Time of day | |
| 2. Total running time | |
| 3. Total acceptance test time | |
| 4. Rotational speed (rpm) | ±100 rpm |
| 5. ADE bearing temperature (°F) | ±2°F |
| 6. DE bearing temperature (°F) | ±2°F |
| 7. Stator temperature (5 thermocouples)(°F) | ±2°F |
| 8. Stator coolant temperature (2 thermocouples) (°F) | ±2°F |
| 9. Alternator power output | ±2% |
| 10. Alternator voltage output per phase | ±2% |
| 11. Alternator current output per phase | ±2% |
| 12. Field input voltage | ±2% |
| 13. Field current | ±2% |

### F. Test Conditions

1. The stator liquid coolant inlet temperature shall be tap water temperature.

2. During all testings the rotor shall be maintained at the designated speed of 12,000 rpm ±300 rpm.

G. Operating Limits

1. Bearing temperature - maximum - 100°C (212°F)

2. Vibration maximum - .002" (double amplitude)

3. Stator winding temperature - 180°C maximum. (356°F)

H. Pre-Test Operating Procedure

1. Start electronic counter and Bristol Temperature Recorder instrumentation at least on half (1/2) hour before test is to start.

2. Record all thermocouple readings prior to initiation of tests.

3. Record thermocouple data on a continuous basis.

I. Test Procedure

1. Operate the alternator at 15 KVA, 0.8 (lagging) power factor, 12,000 RPM, three (3) phase. Record all data.

2. Short three (3) phases for a period of 5 seconds maximum. Record all data.

3. Return the alternator to the condition stated in paragraph 1, after conducting the test described in paragraph 2, and then short one (1) phase for a period of 5 seconds maximum. Record all data.

4. Return the alternator to no-load, 12,000 RPM. Operate the alternator from zero to 12 KWE, three (3) phase, 0.8 (lagging) and unity power factor in increments of 2 KWE (0, 2, 4, 6 - 12 KWE). Record all data.

5. Return alternator to the no load condition, then operate at 3.33 KVA, unity power factor, with the load connected from one phase to neutral and the other two phases open for a period of ten (10) minutes, continuous. Record data.

6. Return alternator to no-load, no excitation. Record all data.

J. Post Test Procedure

Shut down alternator and record all data.

K. Acceptance

The test shall be considered as having been satisfactorily completed when no changes to the configuration have been made except as authorized by P&WA, and the following conditions have been met:

1. The voltage regulator-exciter and load bank demonstrate satisfactory electrical integrity.
2. Abnormal operation of the voltage regulator-exciter and load bank shall be specifically noted on the test log.

**GENERAL ELECTRIC**

TEST NO. ____
SHEET NO. 1
DATE 11/15/66

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

GENERATOR MODEL NO. 2CM393B1 REGULATOR MODEL NO. ENG. BREADBOARD EXCITER MODEL NO. ENG. BREADBOARD
SERIAL NO. ____ SERIAL NO. — SERIAL NO. — TEST STAND NO. ____
TITLE OF TEST Brayton Cycle Load Bank Acceptance Test
Avitron Load Bank, Model T80 SPECIFICATION P&WA 6374

| | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING AIR | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | Ø1-N | Ø2-N | Ø3-N | Ø1 | Ø2 | Ø3 | Ø1 | Ø2 | Ø3 | TOTAL KW | TOTAL KVA | POWER FACTOR | EF | EAUX | IF | RF | TOTAL TEMP | RPM | ΔP | AIR FLOW | TEMP IN | TEMP OUT | ALT | AIR TEMP | FRAME TEMP | ALT | AIR TEMP | |
| | VOLTS | VOLTS | VOLTS | AMPS | AMPS | AMPS | WATTS | WATTS | WATTS | | | | VOLTS | VOLTS | AMPS | OHMS | °C | | IN $H_2O$ | #/MIN | °C | °C | FEET | °C | °C | FEET | °C | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | Test 4 |
| [illegible] | 120 | 120 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.2 | | 2.6 | 3.2 | | 12000 | | | | | | | | | | Unity PF |
| | | | | | K=1 | | | K=2 | | | | | | | | | | | | | | | | | | | | |
| 10:02 | 120 | 120 | 120 | 5.5 | 5.5 | 5.55 | 320 | 327 | 326 | 2 | 2 | 1 | 8.7 | | 2.72 | 3.2 | | 12000 | | | | | | | | | | |
| | | | | | K=2 | | | K=4 | | | | | | | | | | | | | | | | | | | | |
| 10:05 | 120 | 122 | 122 | 5.5 | 5.5 | 5.5 | 330 | 325 | 325 | 4 | 4 | 1 | 9.2 | | 2.[illegible]7 | 3.2 | | 12000 | | | | | | | | | | |
| | | | | | K=5 | | | K=10 | | | | | | | | | | | | | | | | | | | | |
| 10:[illegible] | [illegible] | 120 | 120 | 3.5 | 3.3 | 3.3 | 197 | 195 | 195 | 6 | 6 | 1 | 9.7 | | 3.0 | 3.2 | | 12000 | | | | | | | | | | |
| 10:12 | 1[illegible]0 | 122 | 122 | 4.5 | 4.5 | 4.5 | 270 | 265 | 265 | 8 | 8 | 1 | 0 | | 0 | 0 | | | | | | | | | | | | |
| [illegible] 14 | [illegible] | 123 | 123 | 5.5 | 5.5 | 5.5 | [illegible] | 325 | [illegible] | 10 | 10 | 1 | 11.35 | | 3.48 | 3.26 | | 12000 | | | | | | | | | | |
| 10:[illegible] | [illegible] | 125 | 122 | 6.7 | 6.7 | 6.7 | 395 | 400 | 392 | 12 | 12 | 1 | 12.6 | | 3.83 | 3.28 | | 12000 | | | | | | | | | | |
| | | | | | K=1 | | | K=2 | | | | | | | | | | | | | | | | | | | | |
| 10:29 | 120 | 122 | 122 | 6.95 | 6.93 | 6.93 | 335 | 332 | 333 | 2 | 2.5 | .8 | 10.0 | | 3.08 | 3.2 | | 12000 | | | | | | | | | | Test 4 |
| | | | | | K=2 | | | K=4 | | | | | | | | | | | | | | | | | | | | 0.8 PF |
| 10:34 | 120 | 122 | 122 | 6.95 | 6.95 | 6.95 | 332 | 332 | 332 | 4 | 5 | .8 | 11.7 | | 3.58 | 3.26 | | 12000 | | | | | | | | | | |
| | | | | | K=5 | | | K=10 | | | | | | | | | | | | | | | | | | | | |
| 10:40 | 120 | 122 | 122 | 4.2 | 4.2 | 4.2 | 200 | 200 | 200 | 6 | 7.6 | .8 | 13.0 | | 4.0 | 3.25 | | 12000 | | | | | | | | | | |
| 10:44 | 120 | 122 | 122 | 5.55 | 5.55 | 5.55 | 265 | 265 | 265 | 8 | 10 | .8 | 15.1 | | 4.6 | 3.28 | | 12000 | | | | | | | | | | |
| ~~10:48~~ | ~~122~~ | ~~122~~ | ~~122~~ | ~~6.95~~ | ~~6.95~~ | ~~6.95~~ | ~~337~~ | ~~332~~ | ~~332~~ | | | | | | | | | | | | | | | | | | | |
| 10:56 | 122 | 122 | 122 | 6.95 | 6.95 | 6.95 | 332 | 332 | 332 | 10 | 12.7 | .8 | 17.0 | | 5.2 | 3.26 | | 12000 | | | | | | | | | | |
| 10:58 | 120 | 122 | 122 | 8.55 | 8.35 | 8.35 | 400 | 400 | 400 | 12 | 15 | .8 | [illegible].7 | | 5.9 | 3.28 | | 12000 | | | | | | | | | | (Test 2) |
| 10:59 | 120 | 122 | 122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.5 | | 2.6 | 3.26 | | 12000 | | | | | | | | | | No Load |
| | | | | | K=5 | | | K=10 | | | | | | | | | | | | | | | | | | | | |
| 3:10 | 120 | 122 | 122 | 6.7 | 6.7 | 6.7 | 398 | 400 | 395 | 12 | 12 | 1 | 12.4 | | 3.85 | 3.2 | | 12000 | | | | | | | | | | Unity PF |
| 3:30 | 0 | 0 | 0 | 210 | 210 | 210 | — | — | — | 0 | 0 | 0 | 61.0 | | 19.4 | 3.14 | | 12000 | | | | | | | | | (4 [illegible]) | Short Circuit All [illegible] |
| METER NO. | | | | | K=1 | #635 | | | | | | | 1816 | | 228 | | | | | | | | | | | | | |
| CAL D | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Witnessed by N.K. [illegible] 11/15/66
[illegible] 11/15/66
[illegible] 11/15/66

COLD ROTOR RESISTANCE ____ Ω @ ____ °C
COLD STATOR RESISTANCE ____ Ω @ ____ °C
COLD P.M.G. RESISTANCE ____ Ω @ ____ °C

NOTES: DC VOLTMETER SERIAL NO. 1816 (FOR BRAYTON CYCLE GEN. FLD. VOLTAGE)
DC AMMETER SERIAL NO. 226 ( " " " " " CURRENT)
AC AMMETER SERIAL NO 635 ( " " " " Ø3 CURRENT)

TESTED BY D. Foley
M. E. O'Neil

DC-706 (10-61)

**GENERAL ELECTRIC**

# AIRCRAFT GENERATOR TEST DATA SHEET

ERIE PLANT BLDG. 17F

TEST NO.
SHEET NO. 2
DATE 11-15-66

GENERATOR MODEL NO. 2CM393B1 REGULATOR MODEL NO. ENG. BREADBOARD EXCITER MODEL NO. ENG. BREADBOARD
SERIAL NO. SERIAL NO. — SERIAL NO. — TEST STAND NO.
TITLE OF TEST Brayton Cycle Load Bank Acceptance Test All from Load Bank Model TFO. SPECIFICATION RHWA 6374

| TIME | VOLTAGE | | | CURRENT | | | WATTS/PHASE | | | LOAD | | | FIELD POWER | | | | | SPEED | COOLING AIR | | | | GENERATOR AMBIENT | | | REGULATOR AMBIENT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ø1-N VOLTS | Ø2-N VOLTS | Ø3-N VOLTS | Ø1 AMPS | Ø2 AMPS | Ø3 AMPS | Ø1 WATTS | Ø2 WATTS | Ø3 WATTS | TOTAL KW | TOTAL KVA | POWER FACTOR | EF VOLTS | EAUX VOLTS | IF AMPS | RF OHMS | TOTAL TEMP °C | RPM | ΔP IN $H_2O$ | AIR FLOW #/MIN | TEMP IN °C | TEMP OUT °C | ALT FEET | AIR TEMP °C | FRAME TEMP °C | ALT FEET | AIR TEMP °C | |
| | | | | | K=1 | | | | | | | | | | | | | | | | | | | | | | | PHASE 3 |
| 4.05 | 118 | 115 | 0 | — | — | 320 | — | — | — | 0 | 0 | 0 | 450 | | 13.9 | 3.2 | | 12000 | (START | 15KVA) | | (.8 POWER | | FACTOR) | | | | ONE PHASE TO NEUTRAL |
| | | | | | 185 | | | K=10 | | | | | | | | | | | | | | | | | | | | |
| 4.20 | 125 | 120 | 117 | 0 | 0 | 555 | 0 | 0 | 320 | 3.3 | 3.3 | 1 | 8.2V | | 2.7A | 3 | | 12000 | (UNITY | POWER | FACTOR) | | (HOLD | 4 min) | | | | Unbal Load Ø1=0 Ø2=0 Ø3= [illegible] |
| 4.25 | 120 | 120 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.0 | | 2.5 | 3.2 | | 12000 | | | | | | | | | | No Load Final |
| METER NO. | | | | | | 635 | | | | | | | 1816 | | 228 | | | | | | | | | | | | | |
| CAL'N D | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Witnessed by
W. H. [illegible] 11/15/66
[illegible] 11/15/66
L. J. [illegible] 11/15/66

COLD ROTOR RESISTANCE ______ Ω @ ____ °C
COLD STATOR RESISTANCE ______ Ω @ ____ °C
COLD RMG. RESISTANCE ______ Ω @ ____ °C

NOTES:

TESTED BY D. Foley
M. E. O'Neil

DC-786 (10-61)

GENERAL ELECTRIC

# STANDING INSTRUCTIONS

SI 10713 SECT. 13
SECTION 3S2060DR138A1
CONT ON SHEET 2 SH NO. 1

## TEST PROCEDURE FOR VOLTAGE REGULATOR-EXCITER 3S2060DR138A1. CUSTOMER BREADBOARD

1. Reference Drawings — Elementary 44D241414
   Connection 44F242243

2. Meters and Equipment
   - a. Line-Neutral Voltage 0-150V A.C.
   - b. Mag-Amp Control Current 0-15 MA. D.C.
   - c. SCPT Control Current 0-2 Amps D.C.
   - d. Field Current 0-10 Amps D.C.
   - e. A. C. Hipot Tester
   - f. Fluke Differential D. C. Voltmeter
   - g. Analyzer
   - h. Inductive 1.0 Hy. Plus Resistive Field Load (Total 5.0 Ω D.C. Resistance) 500 Watts
   - i. Brush Recorder
   - j. Decade Resistor Box
   - k. D.C. Hipot Tester

3. Wire Check
   - a. Completely wire check VR-E per Elementary 44D241414 and connection diagram 44F242243.

4. Hipot
   - a. Connect all outside terminals together, shorting all rectifiers, all terminals of transistors and all capacitors.
   - b. Hipot from all terminals to ground at 1800 volts D.C., current limited, for 1 minute.
   - c. Hipot from all terminals to ground at 1250 volts rms, 60 cps for 1 minute.
   - d. Remove all shorting wires.

5. Voltage Checks
   - a. Open all wires on TB2-1, TB2-3, TB2-5.
   - b. Connect VR-E as shown in test 6, sheet 2.
   - c. With 120V L-N applied set R4 so that $I_c$ reads 7.5 ma.
   - d. With 120 volts applied line-neutral (ave. of 3$\phi$) make the following voltage measurements using a Fluke Differential voltmeter. (CONT. ON SHEET 2)

5. **Voltage Checks - con't**

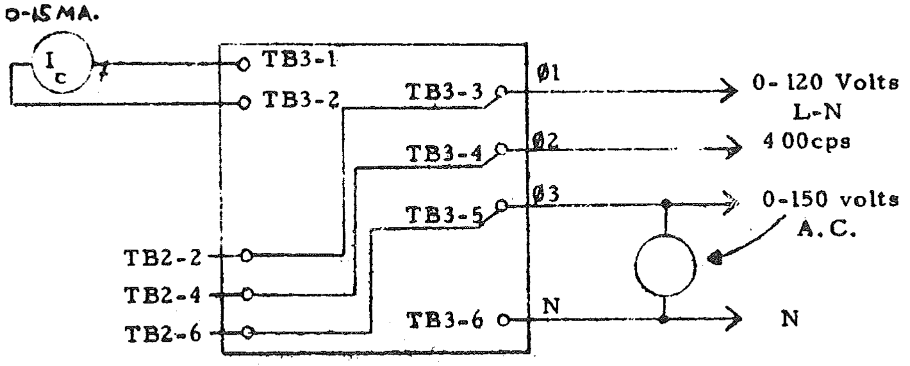
e. Record values measured in Table 1, Sheet 7

| VOLTAGE | MEASURE | | NOMINAL VALUE |
|---|---|---|---|
| | From Circuit # (+) | To Circuit # (-) | |
| CR17 | 35 | 7 | 12V |
| CR18 | 44 | 36 | 36V |
| R14 | 45 | 7 | 31V |
| Q1 BASE-GND. | 33 | 7 | 13V |
| CR19 | 23 | 22 | 24V |
| C1 | 29 | 7 | 134V |
| C2 | 36 | 7 | 128V |
| | | | |
| | | | |

6. **Mag-Amp Gain Test**

a. Connect VR-E as shown below. Break circuit 23 and insert 0-2 amp D.C. meter or use Hewlett-Packard D.C. Clip-On Ammeter.

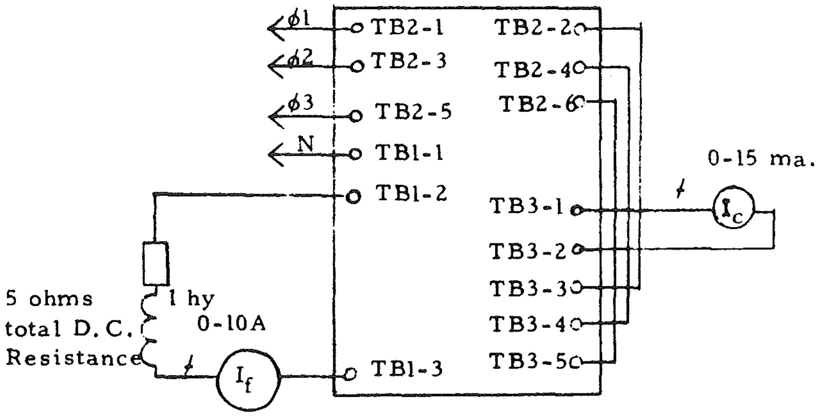
b. Remove jumper between TB3-1 and TB3-2 and insert meter $I_c$.



6. Mag-Amp Gain Test Con't
   c. Maintaining 120 volts line-neutral approximately, vary pot R4 so that Mag-Amp $I_c$ varies from 6-10 ma. and record values on sheet 8, Table 3 and plot results on Figure 1, Sheet 8.
   d. Re-set pot R4 so that $I_c$ reads 7.5. ma.

7. Sensitivity Test
   a. Leave panel connected as above and vary line-neutral voltage from 117-124 volts L-N (average of 3ϕ) and record resulting values of mag-amp $I_c$ on Sheet 10 , Table 4.
   b. Plot results on Figure 2, Sheet 9.
   c. Re-connect wires on TB2-1, TB2-3, TB2-5.

8. Exciter Gain Tests - No Load
   a. Connect VR-E as shown below.
   b. Leave 0-2 Amp Meter in circuit 23 as used in previous test.



   c. Maintaining VL-N at 120V (average of 3ϕ), vary pot R4 so that Mag-amp load current varies from 0-1.4 amps and record resulting values of I field on Sheet 10 , Table 5.
   d. Plot results on Figure 3, Sheet 11.
   e. Re-set pot R4 so that Mag-amp $I_c$ reads 7.5 ma.

9. <u>Over Voltage Tests</u>

a. With panel connected as above, set VL-N to 120 volts (average of $3\phi$) and measure voltage from circuit 29 (+) to circuit 7 (-). This voltage should be 134 + or - 1.0 volts D. C. Record Vcl ON SHEET 12.

b. Measure and record voltage across C2. Vc2 ON SHEET 12. Should be 127V.

c. Open power supply wire to TB2-1. Increase L-N voltage on other two phases until Vcl returns to value recorded above. Record VL-N required to do this ON SHEET 12.

d. Use Fluke Differential Voltmeter to measure these voltages.

10. <u>GCR Tests</u>

a. Apply 28 volts D.C. to TB1-4 and TB1-5. <u>Do Not Apply Any Other Power To Panel.</u>

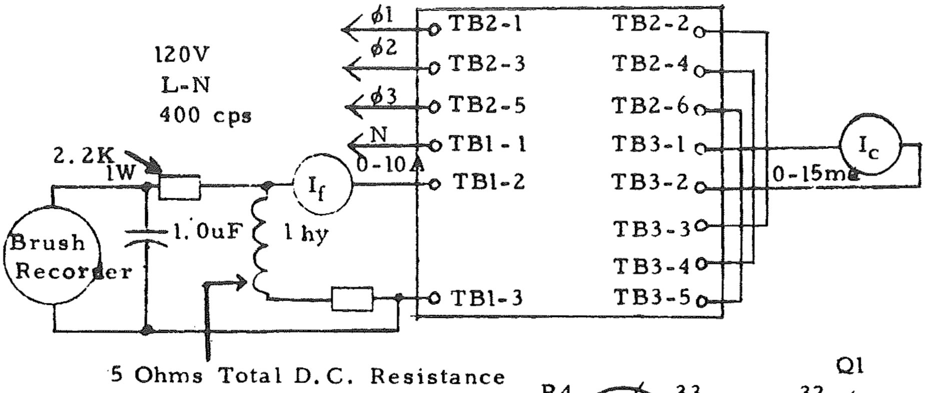
b. Record data in Table 2, Sheet 7.

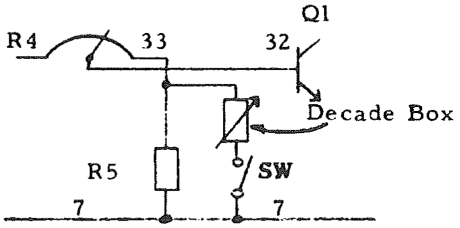
c. Measure resistance across the following points:

| From Circuit # | To Circuit # | Resistance Should Be |
|---|---|---|
| 8 | 7 | 0 ohms |
| 9 | 7 | 0 ohms |
| 10 | 7 | 0 ohms |
| | | |

11. Transient Tests

a. Connect VR-E as shown below





b. Apply 120V L-N (ave) and adjust pot R4 so $I_{field}$ is approximately 1.70 amps.

c. Disconnect power and connect a decade resistor box and switch in series across R5 (from circuit 33 to ground). Switch in Off position. (AS SHOWN IN SKETCH ABOVE.)

d. Adjust decade resistor box initially TO 69K.ohms. Readjust per (e) below

e. Turn switch to on position and check $I_{field}$. Should be 3.5-4.0 amps With brush recorder and filter connected as above and 120 volts L-N applied, turn switch (connected in series with decade box across R5) On, then Off, and record the transient time.

f. Submit curves obtained with other test data.

g. Turn power Off and disconnect switch and decade resistor box from panel.

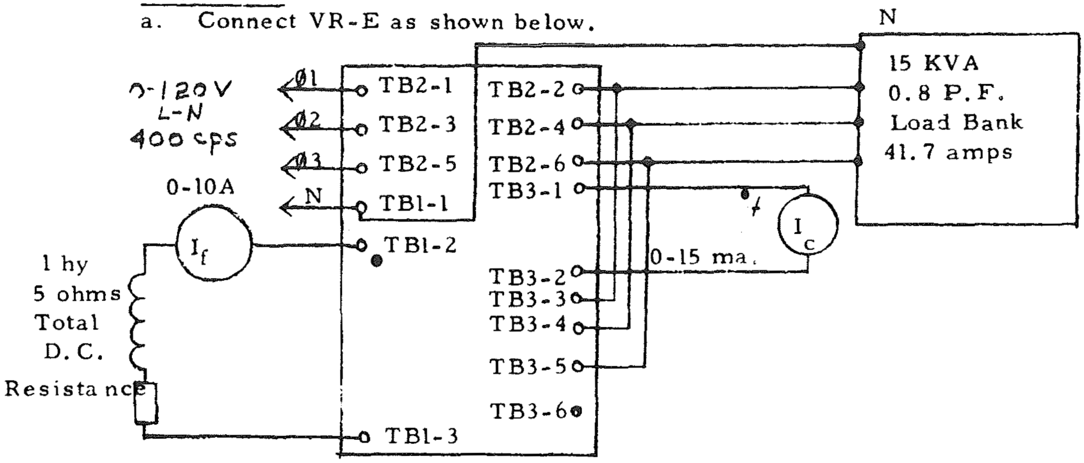
h. Re-apply power (120 volts L-N, Ave.) and adjust pot R4 so that Mag-Amp $I_c$ is 7.5 ma.

i. Set Brush Recorder so pen moves approximately 20 Div. and run recorder at 5mm/sec.

j. CURVE SHOULD BE APPROXIMATELY AS SHOWN IN SKETCH 1 ON SheeT 14.

12. Load Tests

a. Connect VR-E as shown below.



b. Maintaining VL-N at 120 volts, vary pot R4 so that Mag-Amp load current varies from 0-1.4 amps and record results in Table 7, Sheet 12.

c. Plot results in Figure 4, Sheet 13.

d. Re-set pot R4 so that Mag-Amp $I_c$ is 7.5 ma.

## DATA SHEETS

1. Wire Check O.K. . (Check if O.K.)
2. Hipot O.K. . (Check if O.K.)
3. Voltage Checks

TABLE 1

| VOLTAGE | MEASURE From Ckts No (+) | MEASURE To Ckts. No. (-) | NOMINAL VALUE | MEASURED VALUE |
|---|---|---|---|---|
| CR17 | 35 | 7 | 12V | 11.69 |
| CR18 | 44 | 36 | 36V | 33.60 |
| R14 | 45 | 7 | 31 V | 30.78 |
| Q1 Base-Grd. | 32 | 7 | 13 V | 13.04 |
| CR19 | 23 | 22 | 24V | 24.98 |
| C1 | 29 | 7 | 134V | 134.80 |
| C2 | 36 | 7 | 128V | 128.10 |
| | | | | |

4. GCR Test Results

TABLE 2

| FROM CIRCUIT NO. | TO CIRCUIT NO. | MEASURED RESISTANCE |
|---|---|---|
| 8 | 7 | 0 |
| 9 | 7 | 0 |
| 10 | 7 | 0 |

SERIAL NUMBER 5888351

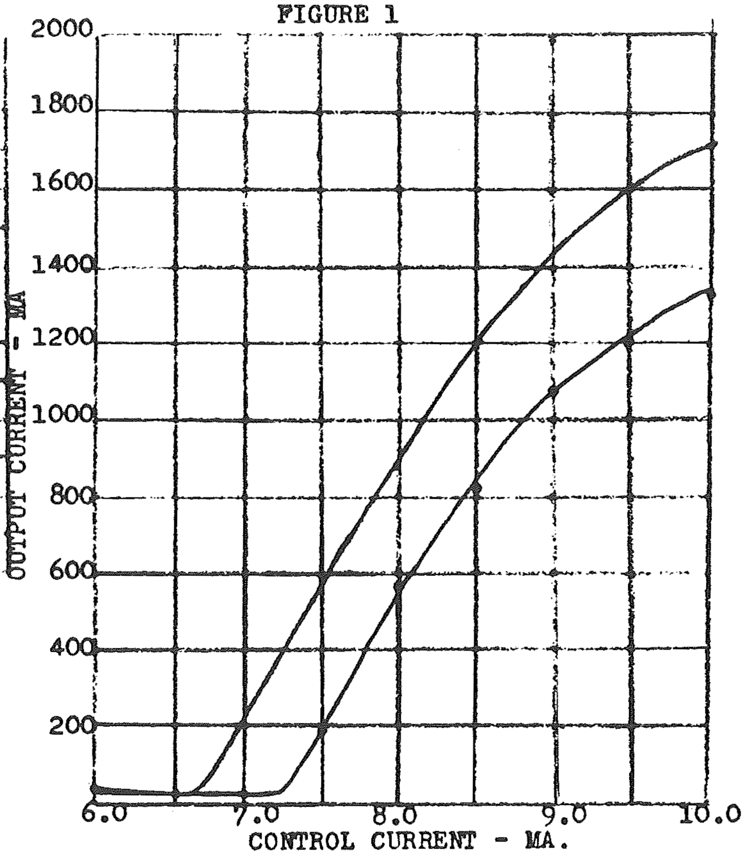
DATA SHEETS

5. Mag-Amp Gain Test Results

TABLE 3

| Control Current-MA. | Output Current-MA. |
|---|---|
| 6.0 | 35 |
| 6.5 | 22 |
| 7.0 | 20 |
| 7.5 | 190 |
| 8.0 | 575 |
| 8.5 | 820 |
| 9.0 | 1070 |
| 9.5 | 1200 |
| 10.0 | 1335 |
| | |
| | |
| | |

FIGURE 1



MAG-AMP CHARACTERISTIC CURVE

Slope of curve between 200 and 1000 MA. to be 400 to 700 ma/ma.
Minimum $I_{out}$ to be 70 ma. or less.

SERIAL NUMBER 5888351

$GAIN = \frac{1.0 - .2}{8.85 - 7.5} = \frac{.8}{1.35} = 590$ ma/ma.

DATA SHEETS

6. Sensitivity Test Results

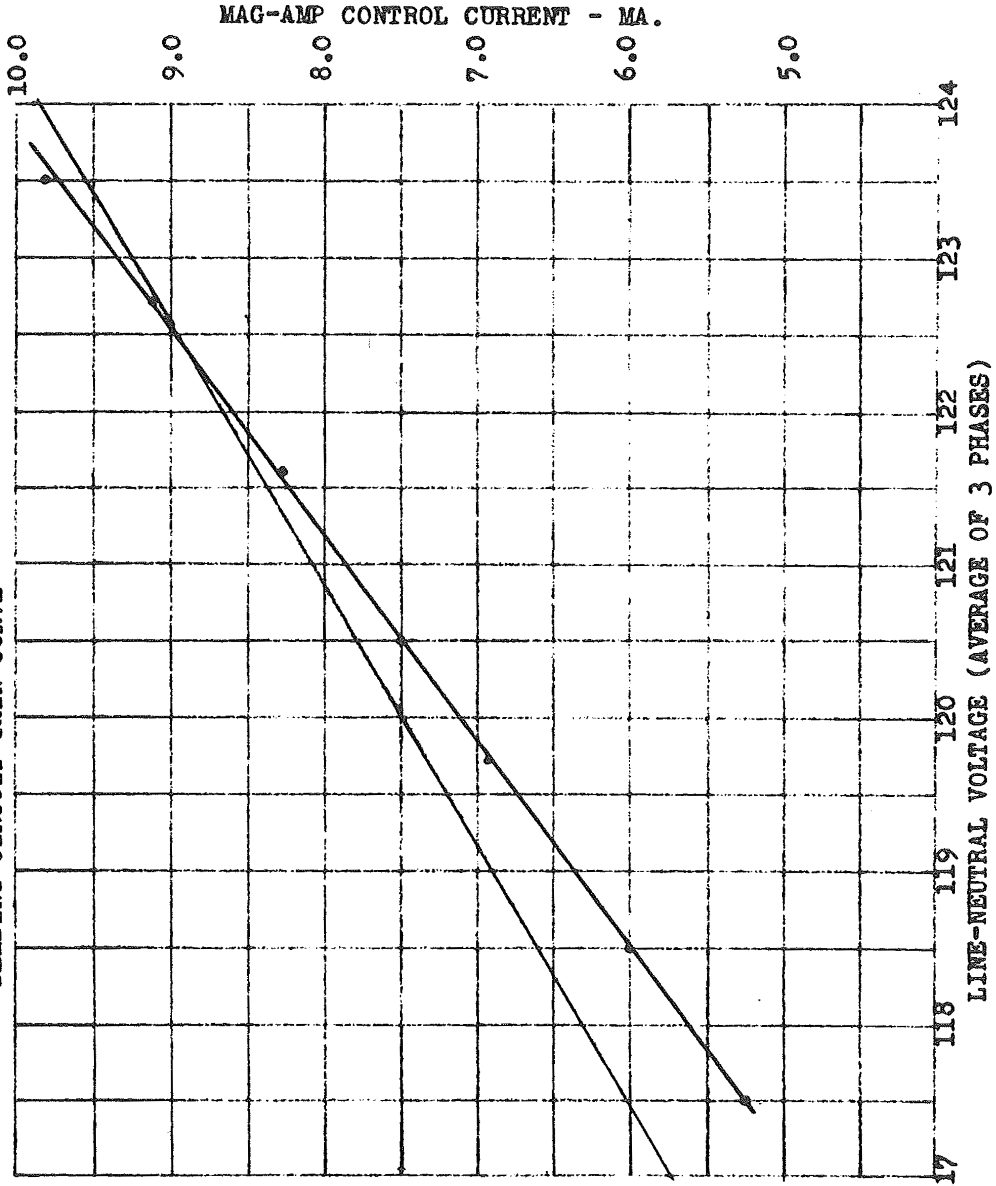


FIGURE 2
SENSING CIRCUIT GAIN CURVE

SERIAL NUMBER 5888351

## DATA SHEETS

Sensitivity Test Results (Con't.)

TABLE 4

| Line-Neutral Voltage | | | Average Voltage | Mag-Amp Control Current MA. |
|---|---|---|---|---|
| ϕ1-N | ϕ2-N | ϕ3-N | | |
| 117.40 | 118.0 | 117.0 | 117.46 | 5.25 |
| 118.50 | 118.8 | 118.0 | 118.43 | 6.00 |
| 119.90 | 120.2 | 119.0 | 119.70 | 6.90 |
| 120.70 | 120.8 | 120.0 | 120.50 | 7.50 |
| 121.60 | 122.2 | 121.0 | 121.60 | 8.30 |
| 123.10 | 123.20 | 122.0 | 122.76 | 9.15 |
| 123.40 | 124.20 | 123.00 | 123.50 | 9.80 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

7. Exciter Gain Test - No Load

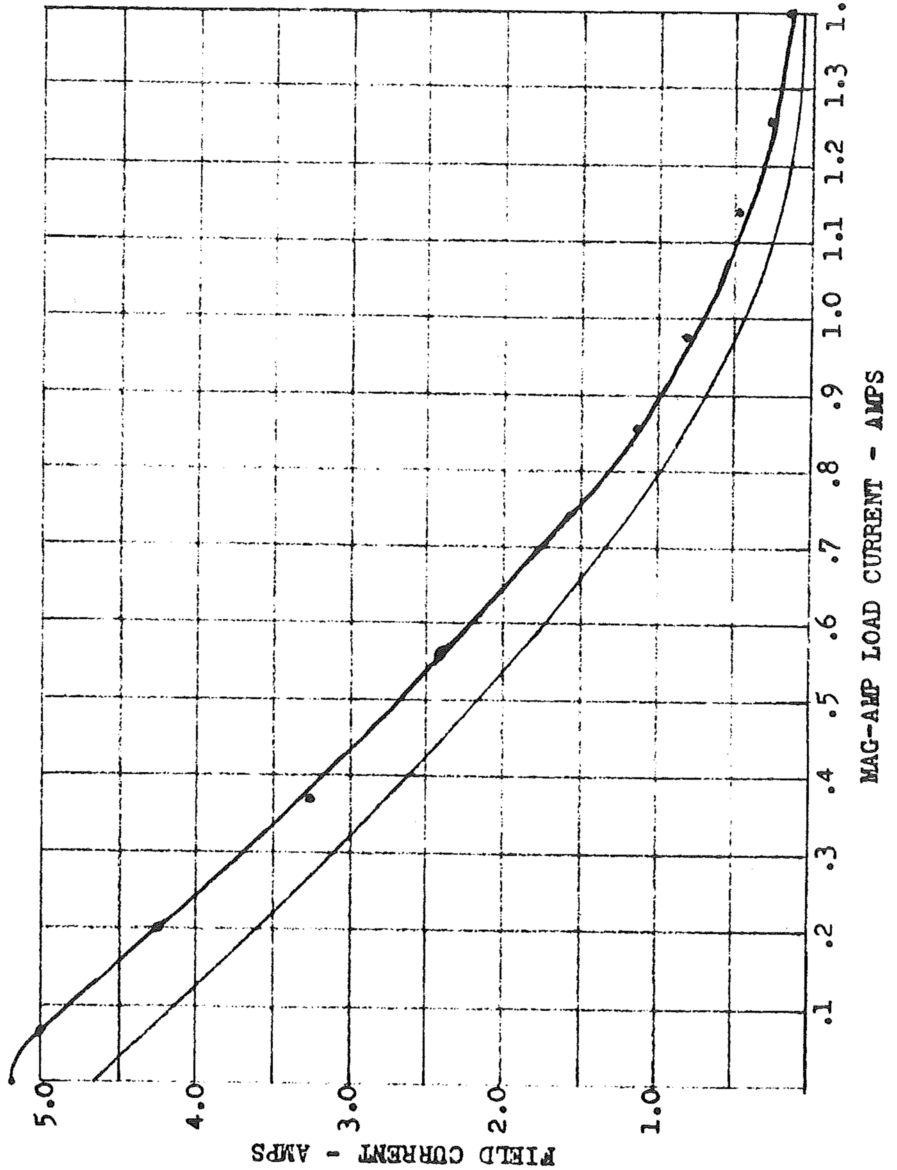
TABLE 5

| Mag-Amp Load (AMPS) Current | Field (AMPS) Current |
|---|---|
| 0 | 5.2 |
| .07 | 5.0 |
| .20 | 4.26 |
| .37 | 3.29 |
| .56 | 2.40 |
| .72 | 1.72 |
| .86 | 1.16 |
| .98 | .83 |
| 1.14 | .48 |
| 1.26 | .35 |
| 1.35 | .26 |
| 1.40 | .24 |

SERIAL NUMBER 5888351

## DATA SHEETS

### Exciter Gain Test Results - No Load (Con't)



EXCITER NO-LOAD CHARACTERISTIC CURVE

FIGURE 3

SERIAL NUMBER 5888351

## DATA SHEETS

8. Overvoltage Test Results

TABLE 6

| VL-N | | | Average VOLTAGE | Vc1 | Vc2 |
|---|---|---|---|---|---|
| ø1-N | ø2-N | ø3-N | | | |
| 120.4 | 120.6 | 120.0 | 120.3 | 135.31 | 128.43 |
| OPEN | 127.3 | 128.7 | 128.0 | 135.31 | 136.12 |
| | | | | | |

9. Exciter Load Test Results

TABLE 7

| VL-N | | | Inductive Load Amps | Resistive Load Amps | Mag-Amp Load (AMPS) Current | Field (AMPS) Current |
|---|---|---|---|---|---|---|
| ø1-N | ø2-N | ø3-N | | | | |
| 120.0 | 120.4 | 119.8 | 21.20 | 32.0 | 0 | 8.15 |
| ↑ | ↑ | ↑ | ↑ | ↑ | .07 | 7.85 |
| | | | | | .20 | 7.05 |
| | | | | | .34 | 6.15 |
| | | | | | .62 | 4.55 |
| | | | | | .82 | 3.55 |
| | | | | | 1.10 | 2.10 |
| | | | | | 1.20 | 1.60 |
| ↓ | ↓ | ↓ | ↓ | ↓ | 1.30 | 1.30 |
| 120.0 | 120.4 | 119.8 | 21.2 | 32.0 | 1.40 | .80 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

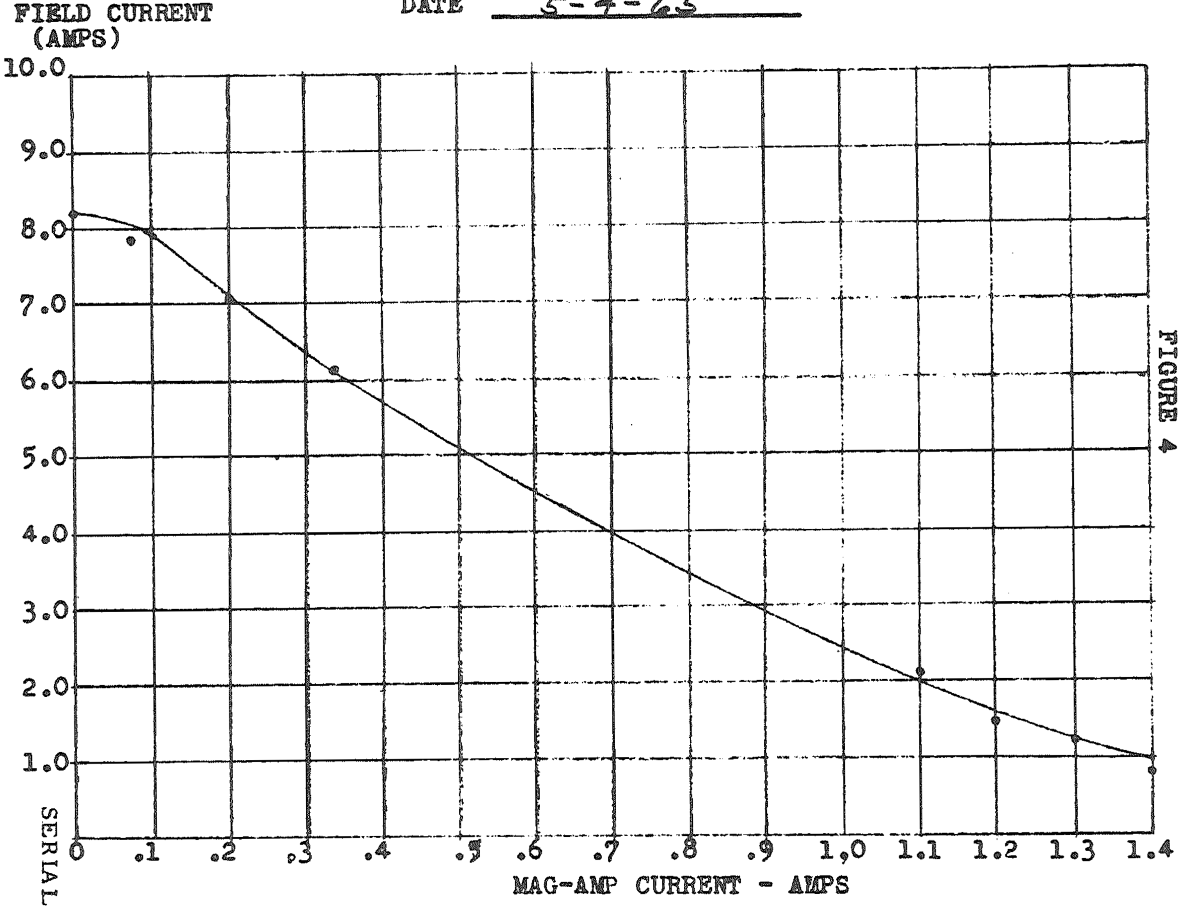
SERIAL NUMBER 5888351

DATA SHEETS

Exciter Load Test Results (Con't.)

FIGURE 4

SERIAL NO. 5888351
TESTED BY C.F. CONNER
DATE 5-4-65



EXCITER FULL-LOAD CHARACTERISTIC CURVE

SERIAL NUMBER

G ERAL ELECTRIC

# STANDING INSTRUCTIONS

SI 10713 SECT. 13
SECTION 35R0630R 23A1
CONT ON SHEET FL SH NO. 14

SKETCH 1

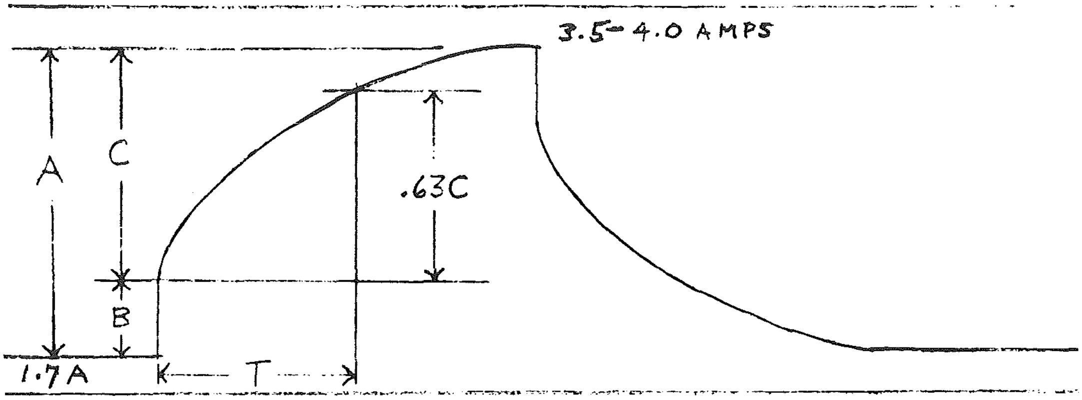


TABLE 8

| A | B | B/A | C | ..3C | T (SEC.) |
|---|---|---|---|---|---|
| 24.5 | 3.0 | .122 | 21.5 | 13.5 | 2.5 |
|  |  |  |  |  |  |

a.) B/A SHOULD BE .10 To .15 .

b.) T SHOULD BE 1.5 To 3.5 .

SERIAL NUMBER 5888351
TESTED BY C. F. Conner
DATE May 4, 1965

## Index

## Revisions

| Rev. No. | AN No. | Approvals | | | Pages Revised | Date Issued |
|---|---|---|---|---|---|---|
| | | EDE | PE | Q.C.E. | | |
| A | 66-285 | | | S. W. Coler | 2,5,6,8,11,12 | Feb. 9, 1966 |
| | | | | | | |
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TEST PROCEDURE

### 1.0 Scope

This specification drawing describes the tests to be conducted on the Brayton Cycle Breadboard VRE with the alternator for the Alternator Research Package.

### 2.0 Description of Equipment

The Brayton Cycle Breadboard VRE supplies all excitation for and regulates the output voltage of an oil cooled, brushless, homopolar alternator rated at 15 KVA, 080 p.f., 120/208 volts RMS, 3 phase, 41.7 amperes, 400 cps. Maximum regulator output is approximately 60 volts DC during a 3 phase short circuit.

The regulator senses the average of the three RMS line to neutral voltages and controls the alternator field current so as to maintain this average constant at 120 V.

### 3.0 Applicable Drawings

Elementary 44D241414
Outline 44D241419
Assembly 44E250497
Connection 44F242243

### 4.0 Test Equipment

### 4.1 Drive Stand

The drive stand must be capable of delivering 24 KW at 12,000 rpm. It must be capable of driving the alternator at no load at 320-480 cps.

### 4.2 Load Bank

The load bank must be capable of absorbing the following loads.

0-30 KVA load 0.80 p.f., 3 ø, 120/208 V, 400 cps
0-8 KVA, 1.0 p.f., 1 ø, 120 V, 400 cps at same time as 3 ø unity p.f. load Ⓐ
3 ø short circuit 170a, 5 sec.
0-12.5 KW, 1.0 p.f., 3ø, 120 V Ⓐ

### 4.3 Alternator

These tests are to be run with the alternator for the Alternator Research Package.

### 4.4 Coolant Supply for Alternator

(See alternator outline drawing for requirement)

### 4.5 Regulator Cooling

No coolant is required for the regulator. Regulator is to be mounted on a rack with at least 1 foot clearance above and below. Back of rack is to be open.

4.6 Field Flashing Equipment

An appropriate battery, rectifier, switch and resistor are required for flashing.

5.0 Instrumentation

Instruments shall be calibrated not earlier than one month before use.

5.1 Line Voltage

a) AC voltmeter 0-75/150 volts, ± 1% accuracy, calibrated at 400 cps. Use GE type P3 or equivalent.

Use appropriate switch to record all three line-neutral voltages using same meter.

5.2 Line Current

0-5 amps RMS, 400 cps, ± 1% accuracy. (3 required)
Use with approximately 15:1 ratio current transformer, 400 cps ± 1% accuracy (3 req'd)
For short circuit use approximately 60:1 ratio CT's and ammeters equipped with holding device to hold at maximum reading.

5.3 Field Current

DC ammeter 0-15 amps, ± 1% accuracy.

5.4 Field Volts

DC voltmeter 0-75 volts, ± 1% ACCURACY.

5.5 Frequency

320-480 cps ± 1 cps accuracy.
Use Berkley counter model 5510 or equivalent.

5.6 KW Load

Use single phase wattmeter with 150 V, 5a coils. (3 required) Calibrate at 400 cps to ± 2% accuracy. Use three approximately 15:1 ratio CT's specified for ammeters.

5.7 Transient Response

Recorder frequency response 20 cps minimum and auxiliary circuitry connected as shown in 16.0. One-half division accuracy. Use Brush Recorder Mark II or equivalent. (See Calibration Note 14.1)

5.8 Exciter Control Current

0-2 amps DC ± 2%.

5.9 Field Flashing

0-5a DC, ± 5%.

5.10 Voltage Modulation

Avtron Model T53 Amplitude Modulation Meter or equivalent

6.0 Test Records

6.1 Record VRE Model Number and Serial Number on all data sheets.

6.2 Record serial numbers of all meters and instruments on sheets in section 18.0.

6.3 Record all test data on sheets in section 19.0.

7.0 Test Conditions

Tests will be made in laboratory at Erie, Pennsylvania. Ambient temperature will be 25 ± 15°C.

8.0 Initial Tests

8.0.1 Connect equipment as shown in section 17.0. Completely check all wiring.

8.0.2 With alternator running at 400 cps no load, close SW-FLASH momentarily. (field current should be approximately 3.0a).

8.0.3 Alternator voltage should be approximately 120 V L-N. If not, shut down immediately and check for cause.

8.0.4 If voltage is approximately 120 V L-N, vary voltage setting slightly to see that voltage changes and that CW rotation increases line voltage.

8.1 Emergency Shutdown Test

With alternator running at no load, rated voltage, energize GCR. Alternator voltage should go to zero.

Deenergize GCR and flash alternator again if necessary. Alternator voltage should return to rated.

8.2 High-Phase Takeover

With alternator running at no load, rated voltage, open one sensing lead to regulator. Voltage should go to 108% ± 2% on highest phase. Reconnect the open phase.

9.0 Range of Adjustment and Adjustment Increments

9.1 At no load set line-neutral voltage to 114 volts. Demonstrate that voltage can be set at 114.3 and 114.6 volts.

9.2 Set line-neutral voltage at 120 volts. Demonstrate that line voltage can be set at 119.7 at 120.3 volts.

9.3 Set line voltage at 126 volts. Demonstrate that line voltage can be set at 125.7 and 125.4 volts.

10.0 **Regulation Test (Including overload)**

10.1 Run VRE and alternator at no load with frequency set at 400 ± 1 cps.

10.2 Set voltage at 120 ± 0.5 V. Lock and do not readjust for balance of tests. Maintain loads below at 0.78 - .82 p.f., 3 phase, balanced. Record the three-line voltages, frequency, three-line currents, three wattmeter readings, VRE control current, alternator field current and voltage for each of the following loads

| | |
|---|---|
| a) No load | e) 75% load |
| b) 10% load | f) 100% load |
| c) 30% load | g) 150% load (2 minutes max.) |
| d) 50% load | h) 200% load (5 seconds max.) |

11.0 **Frequency Effect**

11.1 Set frequency at 320 cps with alternator at no load. Record frequency, the three line-to-line voltages, field voltage, field current and control current.

11.2 Repeat at 360 cps, 400 cps, 440 cps and 480 cps.

12.0 **Voltage Modulation**

12.1 With alternator at rated speed and voltage, no load, measure the voltage modulation.

12.2 Repeat at rated speed, voltage, load and power factor.

12.3 Repeat at rated speed, voltage and power factor at half load.

13.0 **Unbalance Load Test**

13.1 **Initial load - no load**

13.1.1 Run alternator at no load, rated voltage and rated frequency.

13.1.2 Apply a single phase line-to-neutral load equal to 1/6 rated current (6.9 amps) at unity p.f.
Record the three line-to-neutral voltage, 3 line currents, 3 wattmeter readings, field voltage, field current and frequency.

13.1.3 Repeat for a single phase line-to-neutral load equal to 1/3 rated current (13.9 amps) at unity p.f.

13.1.4 Repeat for a single phase line-to-neutral load equal to 2/3 rated current (27.8) at unity p.f.

13.2 **Initial load - one third rated**

13.2.1 Run alternator at 1/3 rated current, unity p.f., three-phase load (13.9a) at rated voltage and frequency. Ⓐ

13.2.2 Repeat 13.1.2 (1/6 load)

13.2.3 Repeat 13.1.3 (1/3 load)

13.2.4 Repeat 13.1.4 (2/3 load)

### 13.3 Initial Load- two-thirds rated

13.3.1 Run alternator at 2/3 rated current, unity p.f., three-phase load (27.8a) at rated voltage and frequency. Ⓐ

13.3.2 Repeat 13.1.2 (1/6 load)

13.3.3 Repeat 13.1.3 (1/3 load)

### 13.4 Initial Load - five-sixths rated

13.4.1 Run alternator at 5/6 rated current, unity p.f., three-phase load (34.7a) at rated voltage and frequency. Ⓐ

13.4.2 Repeat 13.1.2 (1/6 load)

### 14.0 Transient Tests (Recovery time and voltage rise)

14.1 Connect recorder as shown in 16.0
Calibrate chart by recording voltage with voltage set at 114,120 and 126 V.

14.2 With the alternator initially at no load and rated speed, apply rated load at rated power factor. Record the transient. Also record, on data sheet, frequency, three-line voltages, three-line currents, three wattmeter readings, field voltage, field current and control current before and after transient. Record chart speed and voltage calibration from 14.1.

14.3 Repeat for load removal.

14.4 Repeat 14.2 except apply 2.0 per unit load at rated power factor.

14.5 Repeat 14.4 for load removal

### 15.0 Short Circuit Tests

15.1 Run alternator for 1 hour at full load or until field is at rated full load temperature. With alternator initially at no load, apply a three-phase short circuit. Hold short circuit for five seconds.

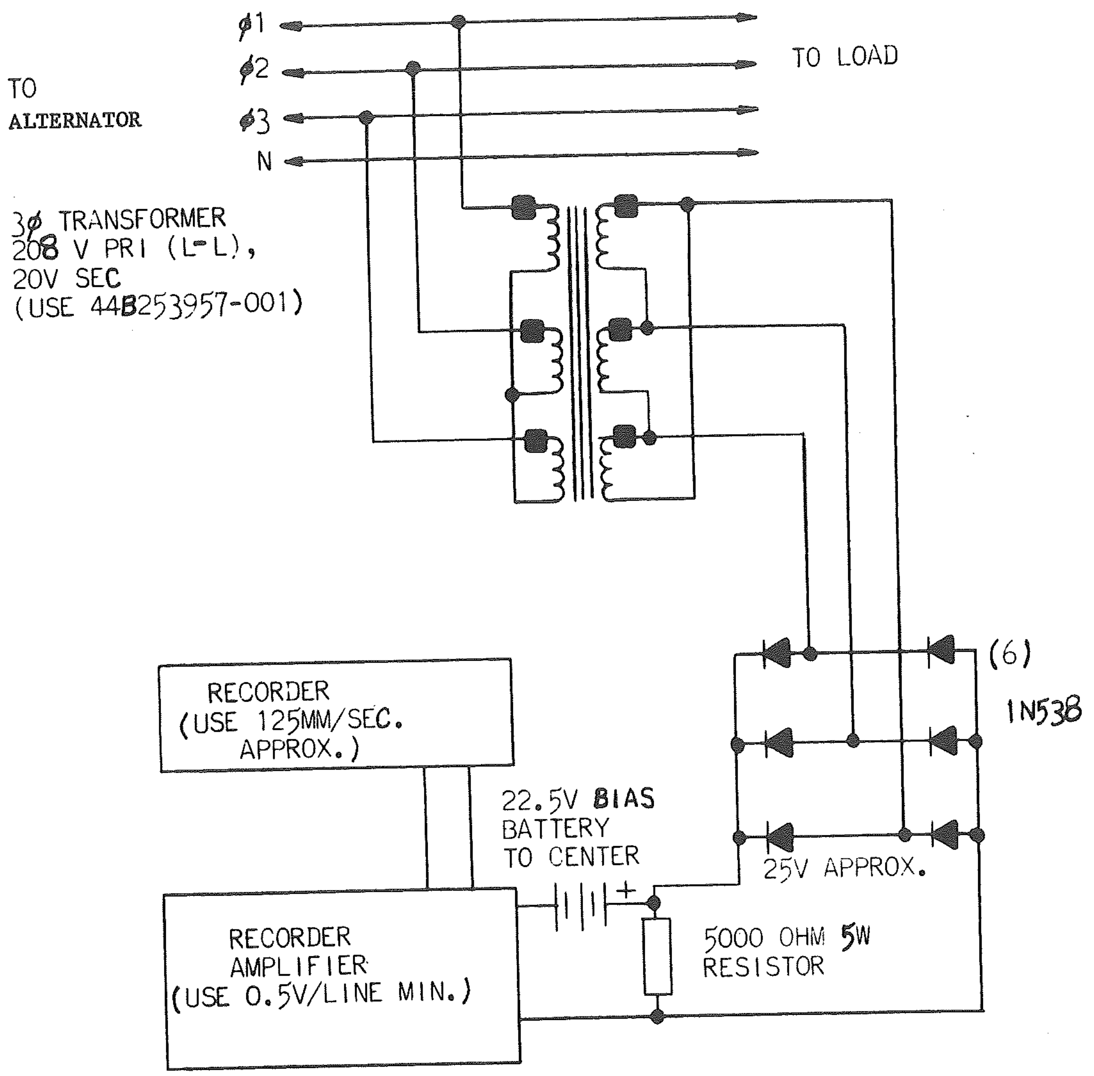
Record the following on a data sheet before and during the short circuit.

a) Three line-to-line voltages.
b) Three-line currents., using ammeters with holding device and special CT's.
c) Alternator field current.
d) Alternator field voltage.
e) VRE control current.
f) Frequency

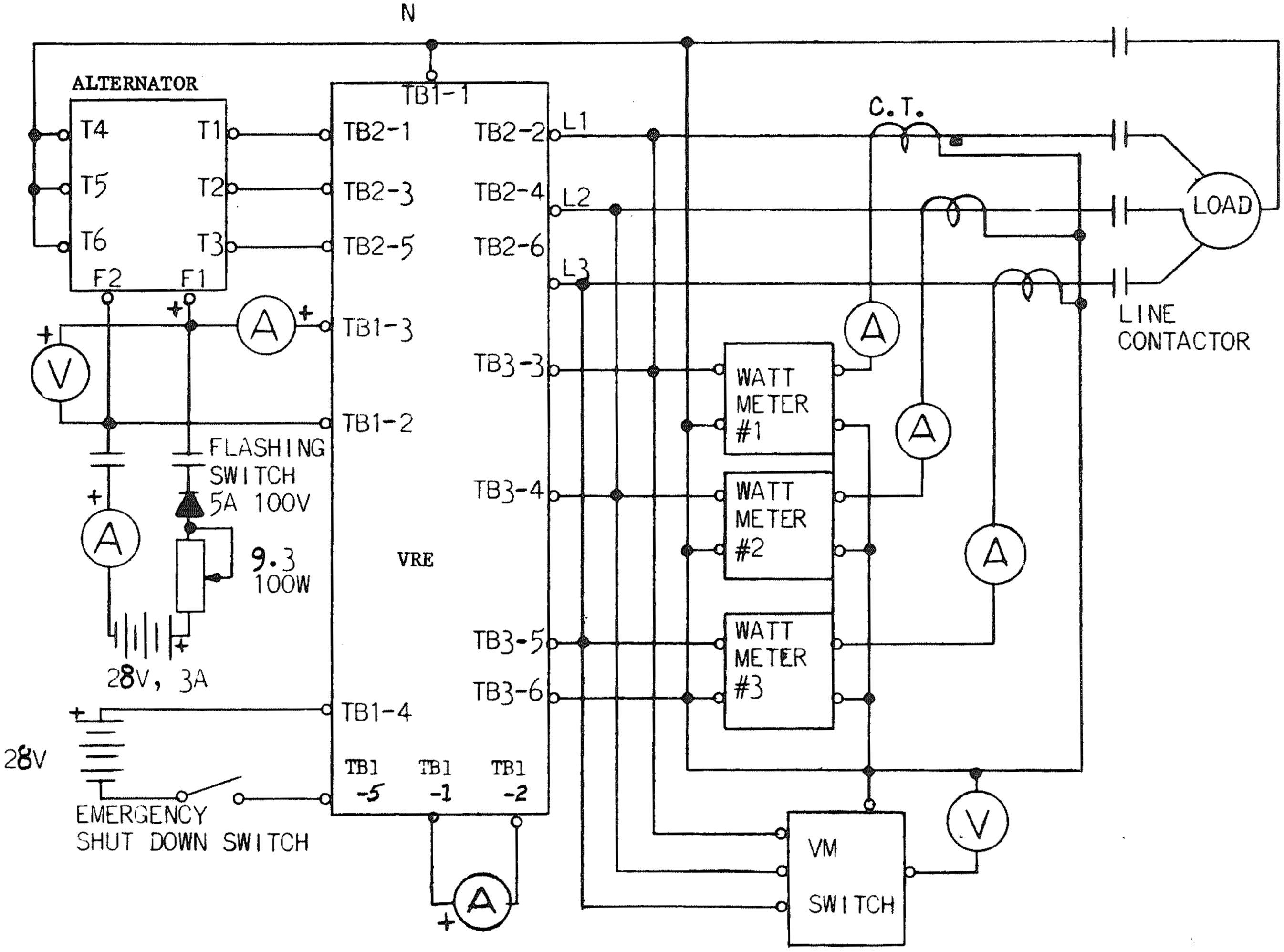
15.2 Repeat for one phase, line-to-neutral short circuit on phase 1-N, 2-N, 3-N.

15.3 Repeat for one phase, line-to-line short circuits on phase 1-2, 2-3, 3-1.

## 16.0 RECORDER CIRCUIT



## 17.0 CONNECTION DIAGRAM



REMOVE JUMPER BETWEEN TB1 AND TB1-2 AND CONNECT
AMMETER AS SHOWN

## 18.0 Instrument List

| MEASUREMENT | | METER | RANGE | SERIAL NO. | CALIBRATION DATE |
|---|---|---|---|---|---|
| Line Voltage | | AC Volts | 0-150 | 964 | 1/18/66 |
| Line Current | (1) | AC Amps | 0-5 | 410 | 11/22/65 |
| | (2) | AC Amps | 0-5 | 1353 | 11/22/65 |
| | (3) | AC Amps | 0-5 | 135 | 12/30/65 |
| Field Voltage | | DC Volts | 0-75 | 12 | 1/10/66 |
| Field Current | | DC Amps | 0-15 | 228 | 1/7/66 |
| Frequency | | | | 1927 | 1/15/66 |
| Wattmeter | (1) | — | 100V 5a | 437 | 1/3/66 |
| | (2) | — | " | 403 | 1/3/66 |
| | (3) | — | " | 637 | 1/3/66 |
| Recorder/Amplifier | | BRUSH MARK II | (A2763) | 4122 | Calibrate before use |
| Control Current | | DC Amps | ~~0-2~~ 0-1.5 | 3372 | 11/24/65 |
| Flashing Current | | DC Amps | 0-5 | NOT USED | — |
| Voltage Modulation | | AVTRON T33 | 0-1/5% | 3293 | 9/1/65 |
| Current Transformer | (1) | | (Ratio) | A238249 | — |
| | (2) | | 20:1 & 4:1 | A439202 | — |
| | (3) | | | C901380 | — |

SEE SHEET 9A FOR CT'S & AMMETERS
USED IN SHORT CIRCUIT TESTS.

**Contract No. NAS3-6013**

VRE **Model No.** 3S2060 DR138A1

VRE **Serial No.** 5888351

**Tested By** VASILIK & DWYER **Date** 2-2-66

## 18.0 Instrument List

| MEASUREMENT | METER | RANGE | SERIAL NO. | CALIBRATION DATE |
|---|---|---|---|---|
| Line Voltage | AC Volts | 0-150 | | |
| Line Current (1) | AC Amps | 0-5 | 1352 | 1/17/66 |
| (2) | AC Amps | 0-5 | 3596 | 12/30/65 |
| (3) | AC Amps | 0-5 | 305 | 1/17/66 |
| Field Voltage | DC Volts | 0-75 | | |
| Field Current | DC Amps | 0-15 | | |
| Frequency | | | | |
| Wattmeter (1) | | | | |
| (2) | | | | |
| (3) | | | | |
| Recorder/Amplifier | | | | |
| Control Current | DC Amps | 0-2 | | |
| Flashing Current | DC Amps | 0-5 | | |
| Voltage Modulation | | | | |
| Current Transformer (1) | | 60:1 (Ratio) | 7199241 | — |
| (2) | | 60:1 | F218334 | — |
| (3) | | 60:1 | F198877 | — |

FOR SHORT CIRCUIT TESTS ONLY
(OTHER METERS SAME AS ON PREV. SHEET)

Contract No. NAS3-6013

VRE Model No. 35 2060 DR 138A1

VRE Serial No. 5668351

Tested By Dryer Date 2-2-66

## 19.0 Data Sheets

### 19.1 **Initial Test (8.0)**

60V@ 4950 RPM w/o FLASH
120V@ 8530 RPM w/o FLASH

**Flashing** ✓ check if okay

C W rotation of Volt Adj increases voltage ✓ check if okay

### 19.2 Emergency Shutdown (8.1)

Shuts down when GCR is energized ✓ check if okay
Recovers after GCR is de-energized ✓ check if okay
Is flashing circuit required? No yes or no

### 19.3 High Phase Takeover(8.2)

| Condition | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | $V_{AVE}$ |
|---|---|---|---|---|
| All sensing leads connected | 119.9 | 119.9 | 119.8 | 119.9 |
| One sensing lead open | 0 | 131.0 | 131.1 | 131.0 |

### 19.4 Range of Adjustment(9.0)

| Target Voltage Setting | Measured Voltages | | | |
|---|---|---|---|---|
| | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | $V_{AV}$ |
| 114.0 | 114.0 | 114.0 | 113.9 | 114.0 |
| 114.3 | 114.3 | 114.3 | 114.2 | 114.3 |
| 114.6 | 114.6 | 114.6 | 114.5 | 114.6 |
| 120.0 | 119.9 | 119.8 | 119.8 | 119.8 |
| 119.7 | 119.5 | 119.5 | 119.4 | 119.5 |
| 120.3 | 120.2 | 120.2 | 120.1 | 120.2 |
| 126.0 | 126.1 | 126.1 | 126.0 | 126.1 |
| 125.7 | 125.7 | 125.7 | 125.6 | 125.7 |
| 125.4 | 125.3 | 125.3 | 125.2 | 125.3 |

**Contract NAS3-6013**

**Model No.** 3S 2060 DR138A1

Serial No. 5888351

Tested By Vasilik + Dryer Date 2-2-66

## 19.5 Regulation - Including Overload(10.0)

| MEASURED VALUES | | | | | | | | | | | | | | CALCULATED VALUES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MULT. BY | | 1 | 1 | 1 | 4/20 | 4/20 | 4/20 | 4/20 | 4/20 | 4/20 ** | 1 | 1 | 1 | | | | | |
| %, LOAD | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | I1 | I2 | I3 | $W_1$ | $W_2$ | $W_3$ | $I_c$ | $V_f$ | $I_f$ | $V_{av}$ | $I_{av}$ | KW | KVA | p. f. |
| 0 | 400 | 119.9 | 119.9 | 119.8 | 0 | 0 | 0 | 0 | 0 | 0 | .57 | 11.2 | 2.64 | 119.9 | 0 | 0 | 0 | — |
| 10 | 400 | 119.9 | 119.9 | 119.9 | 1.04 | 1.04 | 1.04 | 100 | 100 | 100 | .56 | 12.4 | 2.91 | 119.9 | 4.16 | 1.2 | 1.5 | 0.8 |
| 30 | 400 | 120.2 | 120.2 | 120.1 | 3.12 | 3.12 | 3.12 | 300 | 300 | 300 | .57 | 14.4 | 3.39 | 120.2 | 12.49 | 3.6 | 4.5 | 0.8 |
| 50 | 400 | 120.1 | 120.1 | 120.5 | 1.04 | 1.04 | 1.04 | 100 | 100 | 100 | .57 | 17.1 | 4.00 | 120.2 | 20.8 | 6.0 | 7.5 | 0.8 |
| 75 | 400 | 119.9 | 120.1 | 120.1 | 1.56 | 1.56 | 1.56 | 150 | 150 | 150 | .57 | 21.0 | 4.88 | 120.1 | 31.2 | 9.0 | 11.25 | 0.8 |
| 100 | 400 | 120.0 | 120.0 | 120.2 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | .57 | 25.0 | 5.70 | 120.1 | 41.6 | 12.0 | 15.0 | 0.8 |
| 150* | 400 | 120.4 | 120.5 | 120.5 | 3.12 | 3.12 | 3.12 | 300 | 300 | 300 | .54 | 34.8 | 7.73 | 120.5 | 62.3 | 18.0 | 22.5 | 0.8 |
| 200✦ | 400 | 120.8 | 120.9 | 120.4 | 4.16 | 4.16 | 4.16 | 400 | 400 | 400 | .45 | 48.1 | 10.2 | 120.7 | 83.2 | 24.0 | 30.0 | 0.8 |

Ⓐ↑

* 2 Minutes Max. ✦ 5 Seconds Max. ** X 4 FOR 10,30% LOADS
X 20 FOR OTHER LOADS

Contract No. NAS3-6013
Model No. 352060 DL 138 A1
Serial No. 5888 351
Tested By VASLIK & DRYER
Date 2-2-66

## 19.6 Frequency Effect(11.0)

| RPM | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | $V_f$ | $I_f$ | $I_c$ | $V_{AV}$ |
|---|---|---|---|---|---|---|---|---|
| 9600 | 320 | 120.2 | 120.2 | 120.1 | 16.8 | 3.8 | .445 | 120.2 |
| 10800 | 360 | 120.1 | 120.0 | 120.0 | 13.0 | 2.94 | .528 | 120.0 |
| 12000 | 400 | 120.0 | 120.0 | 120.0 | 10.8 | 2.47 | .560 | 120.0 |
| 13200 | 440 | 119.9 | 119.9 | 119.8 | 9.3 | 2.12 | .580 | 119.9 |
| 14400 | 480 | 119.9 | 119.9 | 119.8 | 8.1 | 1.88 | .592 | 119.9 |

## 19.7 Voltage Modulation(12.0)

| MEASURED VALUES | | | | | | | | | | | | | | CALCULATED VALUES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MULT. BY | | 1 | 1 | 1 | 20 | 20 | 20 | 20 | 20 | 20 | 1 | 1 | | | | | | |
| % LOAD | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | I1 | I2 | I3 | $W_1$ | $W_2$ | $W_3$ | $V_f$ | $I_f$ | VOLT MOD | $V_{AV}$ | $I_{AV}$ | KW | KVA | p. f. |
| 0 | 400 | | | | 0 | 0 | 0 | 0 | 0 | 0 | | | .61 | | 0 | 0 | 0 | — |
| 100% | 400 | 120.1 | 120.1 | 120.1 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | 24.9 | 5.74 | .165 | 120.1 | 41.6 | 12 | 15 | .8 |

## 19.8 Unbalanced Load(13.0)

Ⓐ

| MEASURED VALUES | | | | | | | | | | | | | | | | CALCULATED VALUES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MULT. BY | | | 1 | 1 | 1 | 4/20 | 4/20 | 4/20 | 4/20 | 4/20 | * 4/20 | 1 | 1 | 1 | | | | | MAX | $\Delta V$ |
| 3Φ LOAD | 1Φ LOAD | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | *I1 | I2 | I3 | $W_1$ | $W_2$ | $W_3$ | $V_f$ | $I_f$ | $I_c$ | $V_{av}$ | $I_1$ | $I_2$ | $I_3$ | $\Delta V$ | $V_{av}$ (%) |
| 0 | 0 | 400 | 119.9 | 119.9 | 119.9 | 0 | 0 | 0 | 0 | 0 | 0 | 11.4 | 2.68 | .53 | 119.9 | 0 | 0 | 0 | 0 | — |
| 0 | 1/6 | 400 | 119.3 | 121.8 | 118.9 | 1.74 | 0 | 0 | 207 | 0 | 0 | 11.5 | 2.70 | .53 | 120.0 | 6.95 | 0 | 0 | 1.8 | 1.5 |
| 0 | 1/3 | 400 | 118.7 | 123.7 | 118.1 | 3.47 | 0 | 0 | 404 | 0 | 0 | 11.6 | 2.74 | .54 | 120.2 | 13.9 | 0 | 0 | 3.5 | 2.9 |
| 0 | 2/3 | 400 | 117.0 | 127.2 | 116.0 | 1.39 | 0 | 0 | 161 | 0 | 0 | 12.2 | 2.88 | .54 | 120.1 | 27.8 | 0 | 0 | 7.1 | 5.9 |
| 1/3 | 0 | 400 | 120.1 | 120.3 | 120.3 | .69 | .69 | .69 | 83 | 81 | 83 | 12.5 | 2.94 | .55 | 120.2 | 13.8 | 13.8 | 13.8 | — | — |
| 1/3 | 1/6 | 400 | 119.3 | 121.9 | 119.4 | 1.03 | .69 | .69 | 121 | 80 | 85 | 12.9 | 3.05 | .54 | 120.2 | 20.6 | 13.8 | 13.8 | 1.7 | 1.4 |
| 1/3 | 1/3 | 400 | 118.4 | 123.7 | 119.4 | 1.38 | .69 | .69 | 163 | 80 | 87 | 13.4 | 3.15 | .54 | 120.2 | 27.6 | 13.8 | 13.8 | 3.5 | 2.9 |
| 1/3 | 2/3 | 400 | 116.9 | 127.2 | 116.9 | 2.08 | .69 | .69 | 238 | 80 | 89 | 14.4 | 3.38 | .53 | 120.3 | 41.6 | 13.8 | 13.8 | 6.9 | 5.7 |
| 2/3 | 0 | 400 | 120.1 | 120.2 | 120.2 | 1.38 | 1.38 | 1.38 | 166 | 164 | 164 | 15.3 | 3.55 | .52 | 120.2 | 27.6 | 27.6 | 27.6 | — | — |
| 2/3 | 1/6 | 400 | 119.4 | 122.0 | 119.5 | 1.72 | 1.36 | 1.36 | 202 | 163 | 167 | 15.8 | 3.7 | .52 | 120.3 | 34.4 | 27.6 | 27.6 | 1.7 | 1.4 |
| 2/3 | 1/3 | 400 | 119.4 | 123.8 | 118.7 | 2.08 | 1.38 | 1.38 | 245 | 162 | 169 | 16.5 | 3.8 | .52 | 120.3 | 41.6 | 27.6 | 27.6 | 3.5 | 2.9 |
| 5/6 | 0 | 400 | 120.2 | 120.1 | 120.2 | 1.72 | 1.71 | 1.72 | 207 | 203 | 204 | 17.0 | 3.93 | .52 | 120.2 | 34.4 | 34.4 | 34.4 | — | — |
| 5/6 | 1/6 | 400 | 119.2 | 121.9 | 119.5 | 2.08 | 1.71 | 1.72 | 245 | 202 | 208 | 17.6 | 4.07 | .52 | 120.2 | 41.6 | 34.4 | 34.4 | 1.7 | 1.4 |

* MULT. BY 4 FOR ZERO 3Φ LOAD POINTS, 1/6 & 1/3 1Φ LOAD POINTS
MULT. BY 20 FOR OTHER LOAD POINTS.

Contract No. NAS3-6013
Model No. 3S2060DR136A1
Serial No. 5558351
Tested By VASILIK, DRYER Date 7-2-66

## 19.9 Transient Tests(14.0)

| | | | | | MEASURED VALUES | | | | | | | | | CALCULATED VALUES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MULT. BY | | 1 | 1 | 1 | 20 | 20 | 20 | 20 | 20 | 20 | 1 | 1 | 1 | | | | | |
| % LOAD | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | I1 | I2 | I3 | $W_1$ | $W_2$ | $W_3$ | $I_c$ | $V_f$ | $I_f$ | $V_{av}$ | Iav | KW | KVA | p. f. |
| 0 | 425 | 120.0 | 119.9 | 119.9 | 0 | 0 | 0 | 0 | 0 | 0 | .56 | 10.5 | 2.28 | 119.9 | 0 | 0 | 0 | — |
| 100 | 400 | 120.1 | 120.1 | 120.3 | 2.08 | 2.08 | 2.08 | 200 | 200 | 200 | .58 | 25.4 | 5.52 | 120.2 | 41.6 | 12.0 | 15.0 | 0.8 |
| 0 | 425 | 119.9 | 119.9 | 119.9 | 0 | 0 | 0 | 0 | 0 | 0 | .57 | 10.2 | 2.26 | 119.9 | 0 | 0 | 0 | — |
| 200* | 400 | 120.9 | 120.8 | 120.8 | 4.16 | 4.16 | 4.16 | 400 | 400 | 400 | .47 | 46.5 | 10.1 | 120.8 | 83.2 | 24.0 | 30.0 | 0.8 |
| 0 | 439 | 119.9 | 119.9 | 1198 | 0 | 0 | 0 | 0 | 0 | 0 | .56 | 10.0 | 2.19 | 119.9 | 0 | 0 | 0 | — |

*5 Seconds Maximum

| LOAD CHANGE | DIP | | RISE | | RECOVERY TIME(SEC) |
|---|---|---|---|---|---|
| | V | % | V | % | |
| 0-100 | 25.9 | 21.6 | --- | --- | 0.14 |
| 100-0 | --- | --- | 33.6 | 28.0 | 0.19 |
| 0-200 | 44.5 | 37.1 | --- | --- | 0.14 |
| 200-0 | --- | --- | 60 | 50.0 | 0.24 |

Contract No. NAS3-6013
Model No. 3S2060 DR138A1
Serial No. 5888351
Tested By VASILIK & DRYER
Date 2-2-66

## 19.10 Short Circuit Tests(15.0)

| SHORT CIRCUIT TYPE | SHORT ON LINES | MEASURED | | | | | | | | | | CALCULATED | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MULT BY | 1 | 1 | 1 | 60 | 60 | 60 | 1 | 1 | 1 | | | | |
| | | f | $V_{1N}$ | $V_{2N}$ | $V_{3N}$ | I1 | I2 | I3 | $I_c$ | $V_f$ | $I_f$ | $R_f$ | $V_{av}$ | $I_{av}$ | $I_{pu}$ |
| None | None | 400 | 119.9 | 119.9 | 119.9 | 0 | 0 | 0 | .55 | 11.1 | 2.51 | 4.43 | 119.9 | 0 | 0 |
| 13Φ | 1-2-3-N | — | — | — | — | 2.85 | 2.85 | 2.87 | — | 61.0 | 13.9 | 4.38 | — | 171 | 4.1 |
| 1ΦLN | 1N | — | — | 119.0 | 109.8 | 4.37 | 0 | 0 | — | 38.4 | 8.8 | 4.36 | — | 262 | 6.3 |
| 1ΦLN | 2N | — | 119.0 | — | 109.0 | 0 | 4.40 | 0 | .23 | 39.5 | 9.0 | 4.38 | — | 264 | 6.33 |
| 1ΦLN | 3N | — | 107.0 | 116.8 | — | 0 | 0 | 4.20 | .29 | 37.0 | 8.4 | 4.40 | — | 252 | 6.05 |
| 1ΦLL | 1-2 | — | 61.0 | 61.3 | 122.3 | 2.46 | 2.43 | 0 | — | 35.7 | 8.0 | 4.47 | — | 146.8 | 3.52 |
| 1ΦLL | 2-3 | — | 121.6 | 61.2 | 61.2 | 0 | 2.42 | 2.43 | — | 35.9 | 8.0 | 4.49 | — | 145.6 | 3.50 |
| 1ΦLL | 3-1 | — | 61.3 | 122.1 | 61.6 | 2.46 | 0 | 2.44 | .68 | 36.2 | 8.0 | 4.52 | — | 147.0 | 3.63 |
| None | None | 400 | 120.0 | 120.0 | 120.0 | 0 | 0 | 0 | .57 | 10.8 | 2.42 | 4.47 | 120.0 | 0 | 0 |

GENERAL ELECTRIC

# STANDING INSTRUCTIONS

SI 10713 SECT. 13
SECTION 3S2060DR139A1
CONT ON SHEET 2 SH NO. 1

## TEST PROCEDURE FOR VOLTAGE REGULATOR 3S2060DR139A1 AND REACTOR-TRANSFORMER 3S2060DM150A1

Run complete test before and after overpotting of modules.

1. Reference Drawings: Elementary 44D242103
   Connection 44D242107

2. Instruments and Equipment
   - a. 0-150 Volt A.C. - 1%
   - b. 0-2 Amps D.C. - 1%
   - c. ~~FlukexDifferentialx~~D. C. Voltmeter 1% 30K-ohm/volt
   - d. A.C. Hipot Tester
   - e. D.C. Hipot Tester
   - f. Hewlett-Packard D.C. Clip-On Milliammeter
   - g. 1.0 ± .1 henry Inductor
   - h. Oscilloscope
   - i. 3S2060DM150A1 Reactor-Transformer
   - j. Brush Recorder
   - k. Heat Sinks
   - l. 0-5 Amps D.C. - 1%

3. Wire Check
   - a. Completely wire check voltage regulator per elementary 44D242103 and Connection Diagram 44D242107.

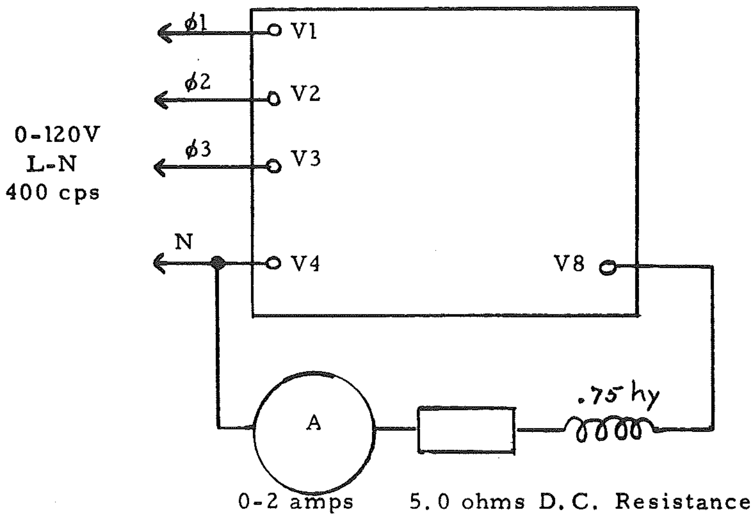
4. Hipot
   - a. Connect all terminals on terminal board together.
   - b. Jumper the following module terminals:

| From | To |
|---|---|
| Module 9, Term. 6 | Module 9, Term. 4, 5, V1 |
| Module 14, Term. 6 | Module 14, Term. 11, 16, 5, V4 |
| Module 3, Term. 1 | Module 3, Term. 2 |
| Module 12, Term. 1 | Module 12, Term. 2, 3, 6 |
| Module 12, Term. 5 | V4 |
| Module 10, Term. 2 | Module 10, Term. 1, 3 |

   - c. Hipot from outside terminals to chassis at 1800 volts d.c., current limited, for 1 minute.
   - d. Hipot from outside terminals to chassis at 1250 volts rms, 60 cps for 1 minute.
   - e. Remove all shorting wires.

5. Voltage Checks

a. Connect VR as shown below



b. Phase rotation must be φ1, φ2, φ3.

c. Apply 120V ± 1V L-N and take the following voltage measurements

d. Adjust R4 for min output at A

| Voltage | Nominal Value (± 1V) | Test Points - ( - ) | Test Points (+) |
|---|---|---|---|
| CR17 | 12V | Term. 11, Mod. 14 | Term. 6, Mod. 14 |
| C1 | 134V | Term. 1, Mod. 8 | Term. 6, Mod. 14 |
| C2 | 119V | Term. 4, Mod. 9 | Term. 6, Mod. 14 |
| R14 | 31V | Term. F3, Mod. 13 | Term. 6, Mod. 14 |
| Q1 Base GND | 13V | Term. 5, Mod. 14 | Term. 6, Mod. 14 |
| CR19 | 24V | Term. 2, Mod. 3 | Term. 1, Mod. 3 |
| ~~CR18~~ | ~~34.5V~~ | ~~Term. 6, Mod. 9~~ | ~~Term. 4, Mod. 9~~ |

d. Use High Impedance DC Voltmeter to measure these voltages.

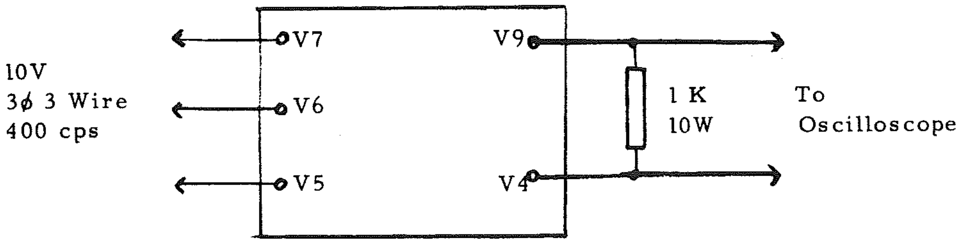
e. Record data in Table 1, Sheet 6

6. Mag-Amp Gain Tests
   a. Leave VR connected as in previous test.
   b. Connect Hewlett-Packard D.C. Clip-On Ammeter on circuit 28 or 30·to read mag-amp control current.
   c. Vary line-neutral voltage so that mag-amp $I_c$ varies from 6-10 ma. and record resulting values of mag-amp output current in Table 2, Sheet 6 .
   d. Plot curve on Figure 1, Sheet 7 .

7. Sensitivity Tests
   a. Leave VR connected as in previous test. Set $I_c$ = 7,5ma at 120V.
   b. Vary line-neutral voltage from 117-124 volts (average of 3ϕ) and record resulting values of mag-amp control current in Table 3, Sheet 9 .
   c. Plot curve on Figure 2, Sheet 18.

8. Overvoltage Tests
   a. Leave VR connected as in previous test.
   b. Apply 120 volts line-neutral (average of 3ϕ) and read D.C. voltage from Term. 1, Mod. 8 (Plus) to Term. 6, Mod. 14. (Across C1.) Record $V_c1$______________ using High Imp. VM. Should be 133 - 135V
   c. Read D.C. Voltage from Term. 4, Mod. 9 (Plus) to Term. 6, Mod. 14, (Across $C_2$). Record $V_c2$____________. Should be 118 - 120V
   d. Disconnect power and open power lead to V1.
   3. Re-apply power and raise voltage on other two lines until $V_c1$ returns to the value recorded above. Record the line voltages required to do this in Table 4, Sheet 9. Should be 130 - 138 V.

9. Field Rectifier Tests
   a. Connect as shown below



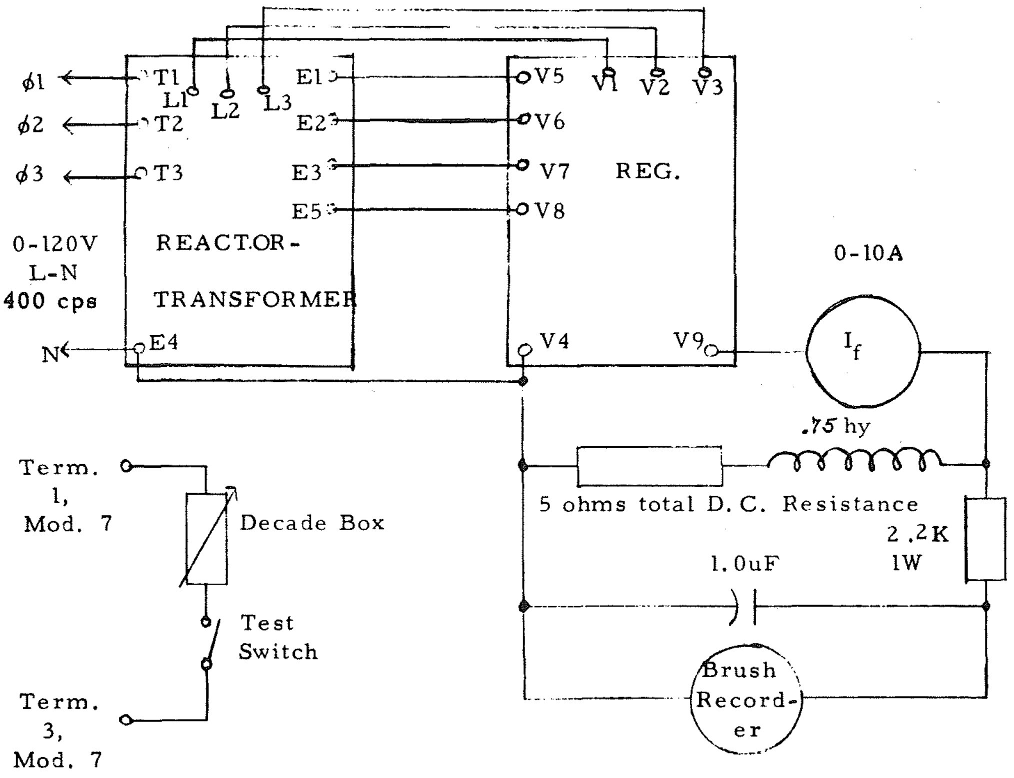
   b. Apply power as shown above. Check oscilloscope to ascertain that output wave form is three phase full wave rectified with no phases missing.

10. Transient Tests

a. Connect VR and Reactor-Transformer 3S2060DM150A1 as shown below.

~~xbxxMountxVRxonxHeatxsinkxmaintainedxatx150°Fxx~~

~~xcxxMountxReactorxTransformerxonxHeatxSinkxmaintainedxatx250°Fxx~~



d. Connect decade resistor box and switch across terminals 1 and 3 of module No. 7 as shown above. Leave switch open.

e. Apply power and adjust line-neutral voltage until $I_{field}$ is approximately 1.7 amps at 120V L-N.

f. Close Test Switch and adjust Decade Box until $I_{field}$ is 3.5-4.0 amps This should take somewhere between 65-70K.
g. Turn test switch off and check to see that $I_{field}$ returns to 1.7 amps.
h. Set Brush Recorder so pen moves approximately 20 divisions and run recorder at 5mm/second.
i. With Brush Recorder connected as shown, Turn test switch on, then off, and record the transient time. Curve obtained should be approximately as shown in Sketch 1, Sheet 10.
j. Turn power off and remove decade box and switch from circuit.

11.0 Weight

Weigh and record weight of exciter and regulator on Sheet 10.

DATA SHEETS

T63

3. Wire Check ok (Check if O.K.)
4. Hipot ok .(Check if O.K.)
5. Voltage Checks

TABLE I

| VOLTAGE | Nominal Value ± 1V | Measured Value |
|---|---|---|
| CR17 | 12V | 11.8. |
| C1 | 134V | 134.2 |
| C2 | 118V | 118.5 |
| R14 | 31V | 31.0 |
| Q1 Base -GND | 13V | 13.1 |
| CR19 | 25.5 - 29.0 | 26.7 |
| | | |

6. Mag-Amp Gain Test Results

TABLE 2

| CONTROL CURRENT (MA) | OUTPUT CURRENT (MA) |
|---|---|
| 10.0 | 12.50 |
| 9.5 | 1150 |
| 9.0 | 980 |
| 8.5 | 740 |
| 8.0 | 450 |
| 7.5 | 130 |
| 7.0 | 18 |
| 6.5 | 18 |
| 6.0 | 18 |
| | |
| | |
| | |

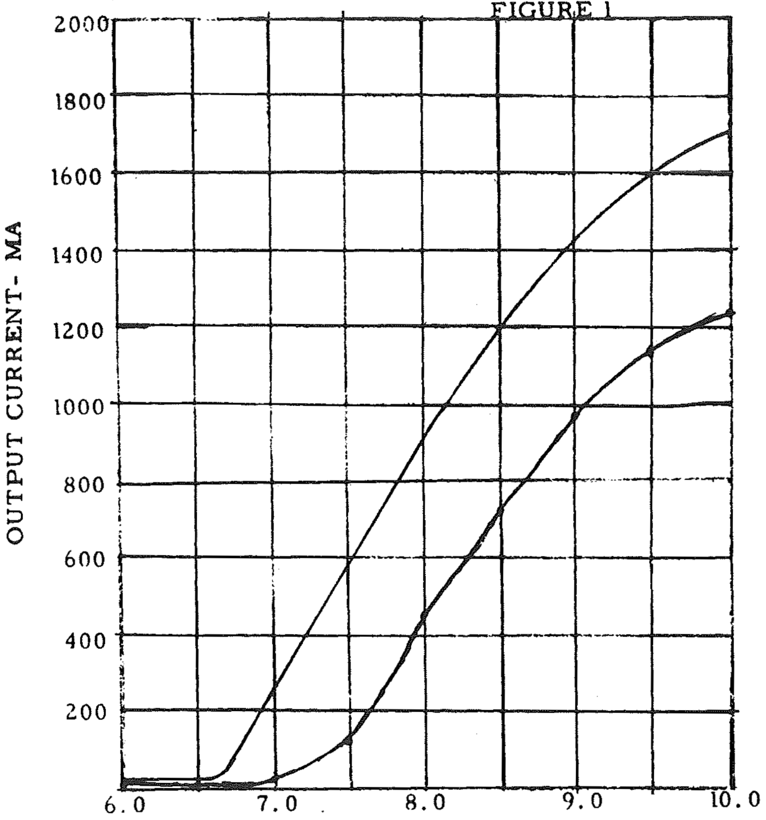
Serial No. 6270840
Tested By P.N Gianaris
Date 8-3-66

T63

## DATA SHEETS

6. Mag-Amp Gain Tests Results

FIGURE 1



MAG-AMP CHARACTERISTIC CURVE

Slope of curve between 200 and 1000 MA. to be 400 to 700 ma/ma.
Minimum $I_{out}$ to be 70 ma. or less.

Serial No. 6270840

Tested By P.N. [illegible]

Date 8-3-66

7. Sensitivity Test Results

DATA SHEETS

J63

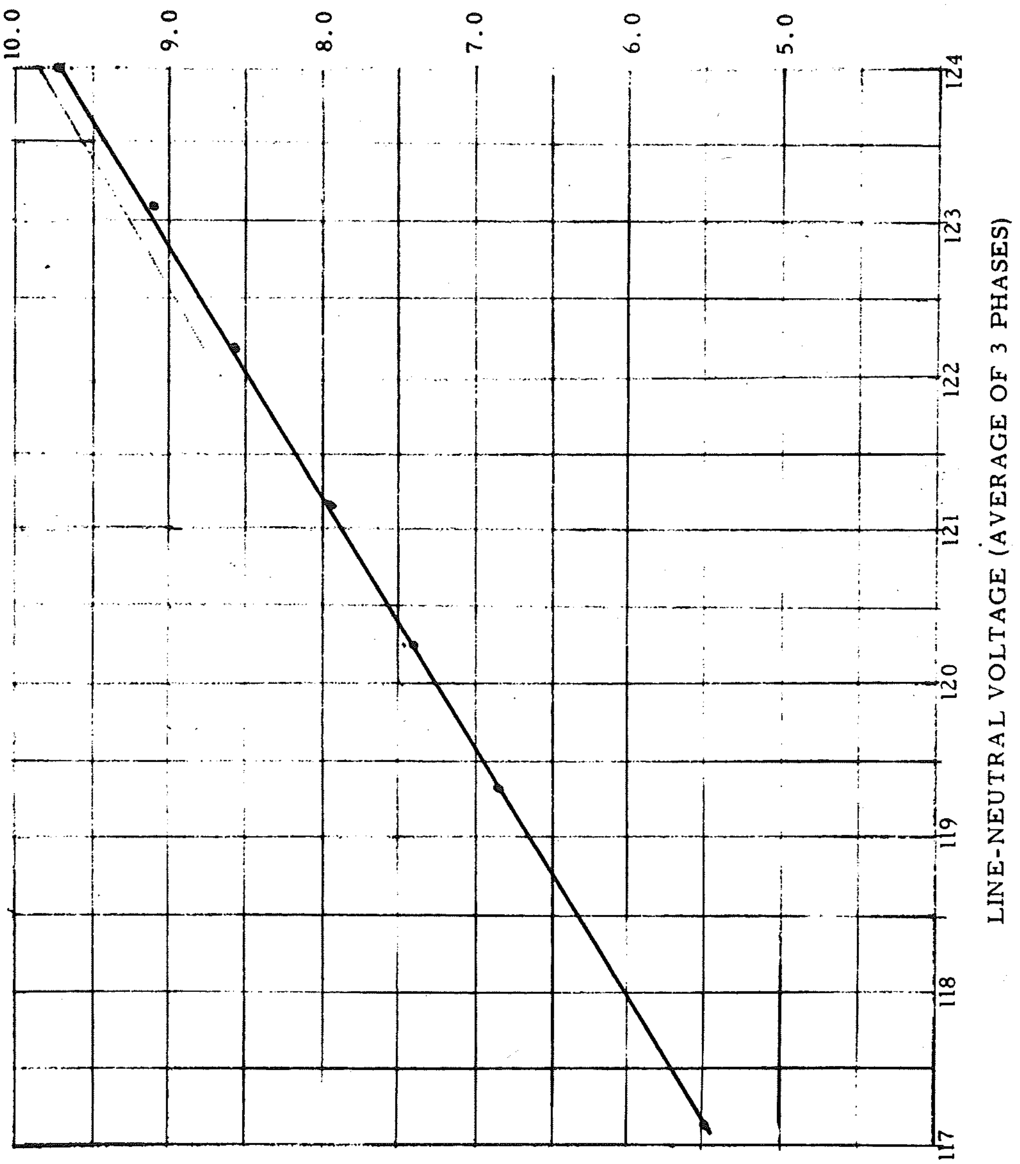


FIGURE 2
SENSING CIRCUIT GAIN CURVE

Serial No. 6270840 Tested By P.N. Giannini Date 8-4-66

DATA SHEETS

T63

7. Sensitivity Test Results (Con't)

TABLE 3

| Line-Neutral Voltage |  |  | AVERAGE VOLTAGE | MAG-AMP CONTROL CURRENT |
|---|---|---|---|---|
| φ1-N | φ2-N | φ-3-N |  |  |
| 116.5 | 117.6 | 117.6 | 117.23 | 5.5 mA |
| 117.5 | 118.8 | 118.8 | 118.36 | 6.2 mA |
| 118.4 | 119.7 | 119.8 | 119.33 | 6.8 mA |
| 119.4 | 120.6 | 120.7 | 120.26 | 7.4 mA |
| 120.3 | 121.5 | 121.8 | 121.20 | 7.95 mA |
| 121.3 | 122.5 | 122.8 | 122.20 | 8.6 mA |
| 122.4 | 123.5 | 123.8 | 123.20 | 9.2 mA |
| 123.2 | 124.5 | 124.5 | 124.06 | 9.8 mA |
| 123.5 | 124.8 | 124.9 | 124.4 | 10.0 mA |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

8. Overvoltage Test Results

TABLE 4

|  | VL-N |  |  | AVERAGE VOLTAGE | $V_{C1}$ | $V_{C2}$ |
|---|---|---|---|---|---|---|
|  | φ1-N | φ2-N | φ3-N |  |  |  |
|  | — | 136.2 | 136.6 | 136.3 | 134 |  |
|  | 136.6 | — | 137.0 | 136.5 | 134 |  |
|  | 136.0 | 136.9 | — | 136.3 | 134 |  |
| 3φ | 119.3 | 120.6 | 120.8 | 120.2 | 134.2 | 118.5 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

Serial No. 6270840

Tested By P. N. [illegible]

Date 8-3-66

DATA SHEETS

RH/KHM
8/12/66

T63

(8) Field Rectifier Test Results
Field Rectifiers OK. Check if output wave form is three phase full wave rectified with no phase missing.

9. Transient Test Results

SKETCH 1

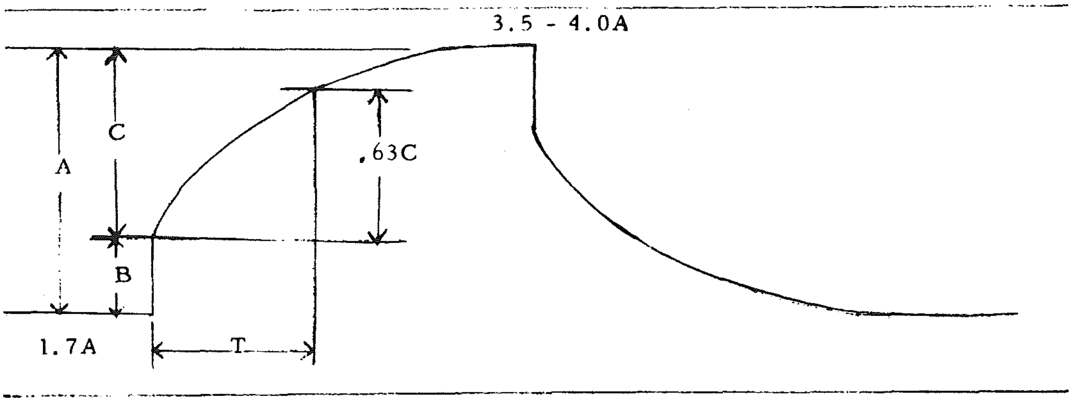


TABLE 5

| | A | B | B/A | C | .63C | T (SEC.) |
|---|---|---|---|---|---|---|
| apl. | 17.5 | 1.5 | .085 | 16.0 | 11.03 | 1.9 |
| Rem. | 17.5 | 2.0 | .088 | 15.5 | 11.03 | 1.5 |

a. B/A Should Be .05 To .09
b. T Should Be 1.4 To 3.0.
c. Off Curve Should be approximately same as on Curve.
Serial Number Regulator 6270840, Exciter 5893246
Tested By P.N. Giannaris.
Date 8-3-66.

10. Weight (with covers and all hardware).

3S2060DR139A1 57.0 Lbs. 3S2060DM150A1 45.8 Lbs

DATA SHEETS

T63

3. Wire Check OK. (Check if O.K.)
4. Hipot OK. (Check if O.K.)
5. Voltage Checks

TABLE I

| VOLTAGE | Nominal * Value ± 1V | Measured Value |
|---|---|---|
| CR17 | 12V | 11.80 |
| C1 | 134V | 134.00 |
| C2 | 118V | 117.50 |
| R14 | 31V | 31.50 |
| Q1 Base -GND | 13V | 13.10 |
| CR19 | 25.5 - 29.0 | 26.8 |
| | | |

* Except CR19

6. Mag-Amp Gain Test Results

TABLE 2

| CONTROL CURRENT (MA) | OUTPUT CURRENT (MA) |
|---|---|
| 10 | 1295 |
| 9.5 | 1200 |
| 9.0 | 1070 |
| 8.5 | 880 |
| 8.0 | 620 |
| 7.5 | 350 |
| 7.0 | 80 |
| 6.5 | 19 |
| 6.0 | 20 |
| | |
| | |
| | |

Serial No. 6270841

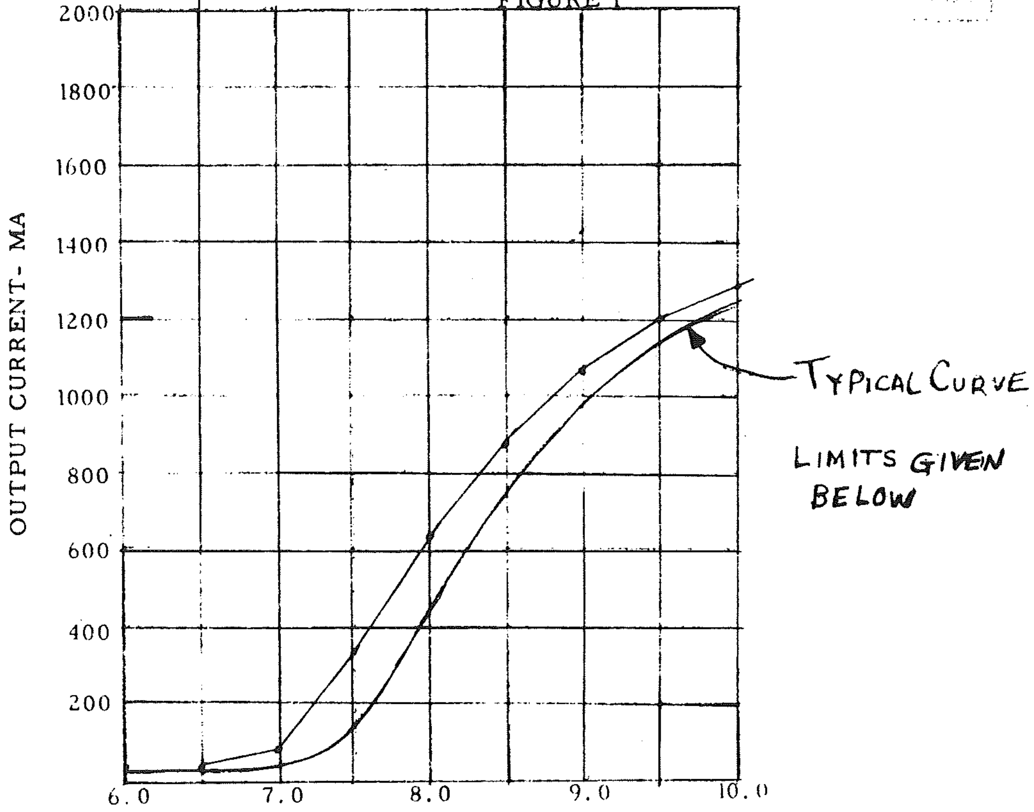
Tested By P.N Giannaris

Date 10-20-66

DATA SHEETS

6. Mag-Amp Gain Tests Results

FIGURE 1



MAG-AMP CHARACTERISTIC CURVE

Slope of curve between 200 and 1000 MA. to be 400 to 700 ma/ma.
Minimum $I_{out}$ to be 70 ma. or less.

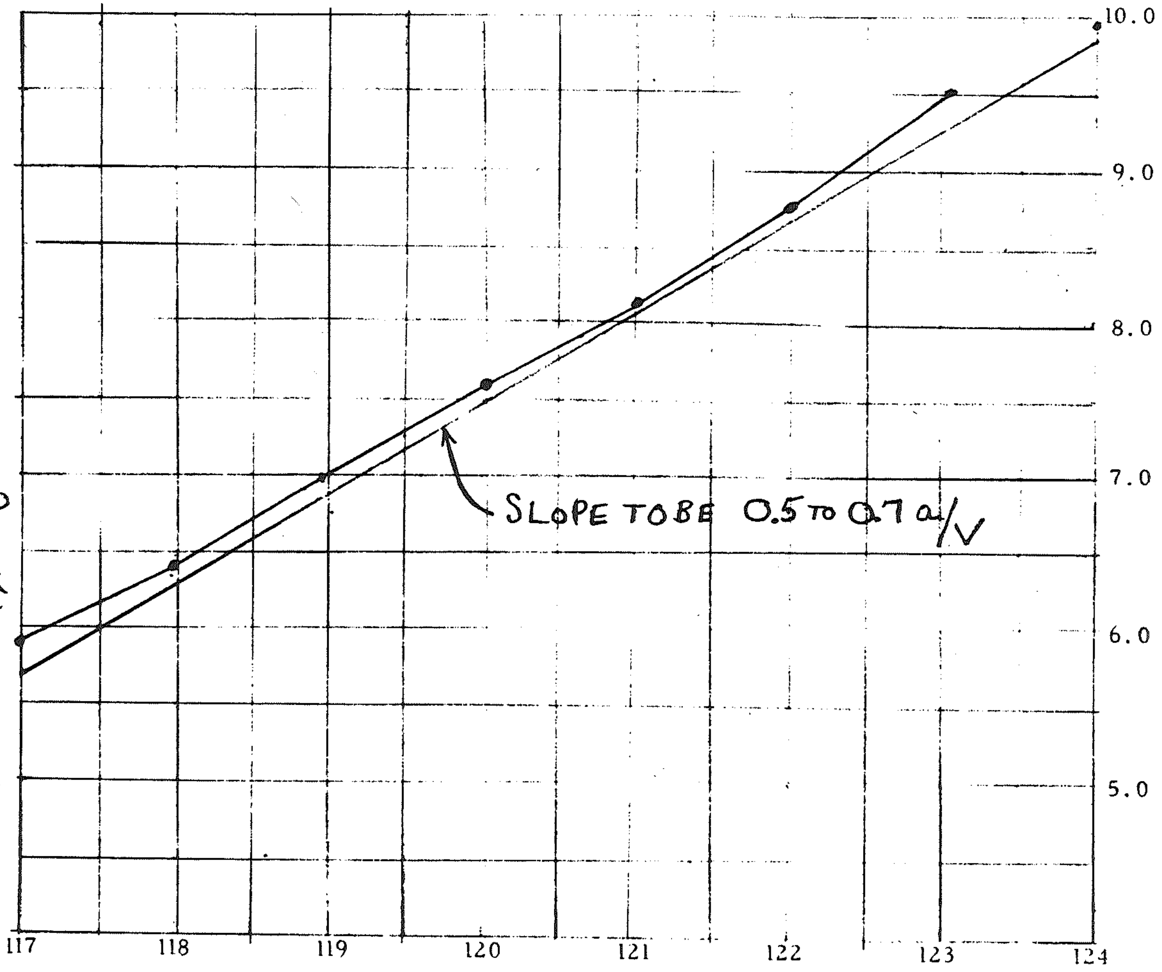
Serial No. 6270841
Tested By P.N. Gianaris
Date 10-20-66

7. Sensitivity Test Results

DATA SHEETS

763

FIGURE 2
SENSING CIRCUIT GAIN CURVE



SLOPE TO BE 0.5 TO 0.7 a/V

LINE-NEUTRAL VOLTAGE (AVERAGE OF 3 PHASES)

Serial No. 627084/

Tested By P. N.

Date 10-20-66

DATA SHEETS

7. Sensitivity Test Results (Con't)

TABLE 3

| Line-Neutral Voltage | | | AVERAGE VOLTAGE | MAG-AMP CONTROL CURRENT |
|---|---|---|---|---|
| ϕ1-N | ϕ2-N | ϕ-3-N | | |
| 115.9 | 117.0 | 118.7 | 117.2 | 5.90 MA |
| 116.9 | 117.6 | 119.5 | 118.0 | 6.42 MA |
| 117.9 | 118.8 | 119.4 | 119.9 | 7.00 MA |
| 118.9 | 119.8 | 121.4 | 120.3 | 7.60 MA |
| 120.0 | 120.9 | 122.5 | 121.1 | 8.20 MA |
| 121.0 | 121.9 | 123.5 | 122.1 | 8.80 |
| 122.0 | 123.0 | 124.5 | 123.2 | 9.50 |
| 123.0 | 124.1 | 125.9 | 124.7 | 10.0 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

8. Overvoltage Test Results

TABLE 4

| VL-N | | | AVERAGE VOLTAGE | $V_{C1}$ | $V_{C2}$ |
|---|---|---|---|---|---|
| ϕ1-N | ϕ2-N | ϕ3-N | | | |
| 118.8 | 119.9 | 121.4 | 119.7 | 134.0 | 118.0 |
| — | 135.0 | 137.0 | 136.0 | 134.0 | — |
| 132.9 | — | 136.0 | | 134.0 | — |
| 137.2 | 137.7 | — | 137.4 | 134.2 | — |

Serial No. 6270841
Tested By P.N Giannaris
Date 10-20-66

## DATA SHEETS

T63

9. Field Rectifier Test Results
Field Rectifiers ok. Check if output wave form is three phase full wave rectified with no phase missing.

10. Transient Test Results

SKETCH 1

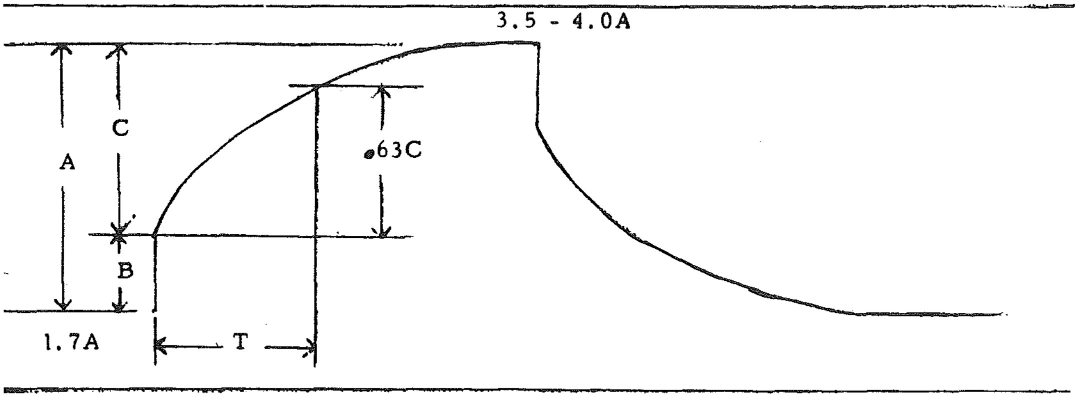


TABLE 5

| A | B | B/A | C | .63C | T (SEC.) |
|---|---|---|---|---|---|
| 25 | 1.5 | .06 | 23.5 | 14.7 | 2.8 |
| | | | | | |

a. B/A Should Be .05 To .09.
b. T Should Be 1.4 To 3.0.
c. Off Curve Should be approximately same as on Curve.
Serial Number Regulator 6270841, Exciter 5893245
Tested By P.N. [illegible].
Date 10-20-68.

11. Weight (with covers and all hardware).

3S2060DR139A1 50 Lbs. 3S2060DM150A1 39 Lbs.

# SECTION XX

## REFERENCES

1. "Heat Transfer Characteristics of Rotational and Axial Flow between Concentric Cylinders," by C. Gazley, Transactions of the ASME, January 1958.

2. "Measurements of Diabatic Flow in an Annulus with an Inner Rotating Cylinder," by K. M. Becker and J. Kaye, Transactions of the ASME, Journal of Heat Transfer, May 1962.

3. "Tooth Ripple Losses in Unwound Pole Shoes,"IEE Journal, February 1947.

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