

DEVELOPMENT OF ELECTRICAL SWITCHGEAR
FOR SPACE NUCLEAR ELECTRICAL SYSTEMS

Quarterly Progress Report No. 4

Covering the Period

September 4, 1965 thru December 4, 1965

Edited by:

A. H. Powell
Program Manager

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract NAS 3-6467

Technical Management
NASA-Lewis Research Center
E. A. Koutnik

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

FOREWORD

This report describes work which has been completed during the period from Sept. 4 to Dec. 4, 1965, the present status, and the future plans for the effort being performed by the General Electric Company under Contract NAS 3-6467 from the National Aeronautics and Space Administration. The objective, as outlined in the contract, is to develop and design ground prototype AC circuit breakers and DC engine contactors, suitable for, and tested under, expected launch and space requirements. The Breakers will be rated 1000 volts, 600 amperes, 2000 cps, while the DC Contactors will have a rating of 10,000 volts, 10 amperes.

Management of the program for General Electric Company has been assigned to A. H. Powell, Manager - Electrical Systems, Space Power and Propulsion Section. Consulting Engineer is R. N. Edwards, SPPS. Project Engineer for overall design is E. F. Travis of the Research and Development Center in Schenectady. Project Engineer for Capsule Assembly and Welding Techniques is W. R. Young of the Space Power and Propulsion Section. Contributors to this report, in addition to Messrs. Powell, Travis, and Young include G. Gati of SPPS.

Mr. E. A. Koutnik of the National Aeronautics and Space Administration is the Technical Manager for this contract.

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I. INTRODUCTION

This program is a continuation of the Electrical Switchgear development and investigation work which was completed under Contract NAS 3-2546 with the successful interruption of over 20 amperes at 10,000 volts DC, and over 1800 amperes at 1200 volts, 2000 cycles per second.

The goals for this program, Contract NAS 3-6467, were established so as to provide detail background information and knowledge on which final flight hardware for planned Nuclear Space Power Systems of 1 to 4 megawatts capacity could be built. The breaker is being developed to have a rating of 600 amperes (1000 to 3000 cps) and 1000 volts, and the contactor to handle 10 amperes at 10,000 volts DC.

Development effort on this contract will result in building and testing ground prototype Breakers and Contactors which can withstand launch environment (mechanical) conditions, as well as expected space conditions including low pressure, high temperature, and radiation. The devices are also to be able to successfully interrupt short circuits of twice normal current ratings.

Program Management is centered in the Space Power and Propulsion Section of the General Electric Company in Evendale. The major development work is being done at the Research and Development Center in Schenectady, with technical and test assistance from other Laboratories and Departments of the Company. The long time endurance and all interruption tests will be made at SPPS, vibration and mechanical tests in Schenectady, and the acoustic and acceleration tests in the RSD Mechanical Testing Laboratory in Philadelphia.

II. SUMMARY

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During the fourth quarterly period of this program, the balance of the raw material was procured, all fabrication started and many parts including items for the vacuum capsule delivered. Plans for testing and the general program status was reviewed with the cognizant NASA Technical Management at Cleveland on Sept. 28. A revised schedule and PERT diagram for completing the contract was prepared, and is up-dated for inclusion with this report.

In this report, detail information is presented under major component headings (Interrupter, Actuator, Test Plans, etc.). Engineering design effort has been at a minimum while parts are being built, but appreciable effort was devoted to developing the various assembly techniques and to detailing the test specifications and procedures.

There have been no insurmountable problems, and while deliveries of some vital parts such as springs, flexurals, and ceramic assemblies have held up certain assembly starting dates, the end dates for test completion appear attainable. A detail study of facilities for the interruption (electrical) testing has resulted in a decision to make these tests at SPPS. With this change it will be possible to utilize a vacuum tank which is available so that with a minimum facility expenditures, realistic (in vacuum) tests can be conducted.

Author

The schedule indicates that during the next quarterly period the first breaker and contactor will have been assembled, the devices set up in the vacuum tank, and testing started. Set up for the interruption tests will be well underway.

III. VACUUM INTERRUPTER

The sealed vacuum capsule is mounted in a supporting shell, and the overall assembly becomes the vacuum interrupter. It is the lower part of the complete device shown in sketch form in Figure 1. This section of the report will tell of detail activity in connection with the interrupter.

A) Vacuum Capsule

The vacuum capsule, shown in sketch form in Figure 2, involves major assembly and joining problems, which have been under detail study. The molybdenum contacts will be brazed to the rodar end spinnings and amzirc flanges. The alumina (ceramic) shells (with their rodar spinnings) will be attached to the bellows and end spinnings by electron beam welding.

The braze for the contact assembly will be made using a Nicuro type 80 braze alloy (Ni-3; Au-82; Cu-15) which melts at 910°C . A draft of the proposed manufacturing procedure is included in this report as Appendix A. The write-up also includes details for the inert gas welding (such as used to attach the stainless steel ion pump tube to the lower end spinning) as well as the electron beam welding mentioned earlier.

Parts for the end pieces have been received, and a photograph of typical items is included in this report as Figure 3. All parts are now undergoing detail check for dimensions and finish, prior to assembly. When the molybdenum contacts have been brazed to the amzirc, reference numbers will be assigned for future use and photographs of the actual contact surface (at 10 times normal size) will be made for use in comparison checking with the same contacts after all tests are complete.

The special bellows are also available, and have been leak checked. The quality control report stated that the units had no leakage in excess of 1×10^{-8} cc/sec. Helium, indicating an acceptable condition for the Switchgear capsules.

1. Ion Pump and Air Cooling

The ion pump which will be attached to the vacuum capsule, carries a rating of 0.5 liters per second of Hydrogen, and will aid in maintaining the capsule vacuum when it is at operating temperature, with the limited amount of outgassing expected from the metal parts. The details on this problem and estimate of outgassing volume was covered in the second quarterly report which also reported the decision to use an ion pump to help maintain the capsule at 10^{-5} Torr, or lower, pressure.

A temperature of 300°F is considered the maximum for the pump (although the magnet could stand a higher temperature) in order to obtain the required capacity. To keep the pump within this limit it is necessary to circulate cooling air around it. This air will be brought into the pump from outside the tank through a co-axial air line hose which is shown by the sketch in Figure 4.

In the sketch of the air line, it will be noted that a clamp (1) is used to attach a teflon hose (2) to the inner shell of the ion pump housing. The hose carries the incoming cool air and also the teflon insulated high voltage cable (4) from the pump power supply. At the outer end of the hose, outside the vacuum tank, air is brought in through a suitable fitting (10).

The incoming air hose is placed inside a stainless steel pipe made up of a straight section (3), a flexible (bellows) length (5) and another tube (7), with an insulator (6) near the tank wall to isolate the pump and vacuum capsule from ground. The entire assembly is installed from inside the tank through a feed-

thru (9) with tube (8), welded into place at the outer end. The straight section (3) and pump housing will be heavily heat shielded to make the pump heat removal a feasible task using a reasonable amount of air.

The magnet for the pump is being obtained with approximately a .015" radial clearance so that the overall pump assembly will include the cross section areas shown in Figure 5. Based on these dimensions, and the selected hose and tube sizes, air flow and heat transfer has been calculated as shown in Appendix B. The results are given in Table 1.

2. Final Assembly of Capsule

Assembly of the parts and sub-assemblies to provide the complete and sealed-off capsule, involves a number of steps, special bake-out temperatures, and processing techniques. The planned procedure, which has been developed, is covered in a manufacturing specification now in preparation. It is included in draft form in this report as Appendix C.

B) Interrupter-Overall Arrangement

The vacuum capsule is built for use in both the AC circuit breaker and the DC engine contactor. To build the 1000 volt AC breaker, shown in Figure 1, heat radiating fins are attached to the amzirc flanges of the capsule by a heat shrink process. The unit is then placed inside the copper enclosing shell, supported on ceramic insulation, and terminals are attached as described in detail in the third quarterly report.

Similarly, the basic capsule is mounted in a shorter enclosing shell made of nickel, with greater insulation than in the breaker unit, to provide the 10 KV DC contactor. No heat radiators are required because the 10 ampere load current will not result in any appreciable temperature rise.

Parts for the interrupter assembly are now being received, and the first unit should be assembled by early in January. The springs have required special consideration, for although they are being made of Inconel X, the expected operating temperature (1150⁰F in the breaker) and high continuous loading requires special heat setting techniques to reduce creep and change in characteristics during the 1000 hour endurance test.

The radiators for the breaker, as well as the inside of the shell opposite the radiators, is to be covered with an iron titanate coating. This coating, applied by a plasma torch spray, will provide a high (.85 or better) emissivity to improve heat transfer from the capsule contacts to the shell and main mounting (heat sink) plate. The iron titanate coating will be furnished by the G. E. Space Technology Laboratory. Samples of their application techniques and results using copper plates were furnished to SPPS for review and inspection.

IV. ACTUATOR (Mechanism)

The actuator, or operating mechanism, moves the contact in the vacuum capsule in the interrupter unit, and was described in detail in the third quarterly report. It is mounted above the interrupter, on the same center line, and includes a main operating solenoid held in location by flexible diaphragms, a flexible linkage, latch and trip solenoids, and opening springs.

Parts for the complete actuators are in fabrication, except for the coils which will be ordered shortly but which will be replaced by copper rings of equivalent size for the heat run and endurance test. The only part which may delay final assembly is the high temperature flexural and this part is late due to procurement problems with the Inconel X.

A modified version of the actuator will be used for the interruption test units. The trip and latch solenoids, and toggle (locking closed) linkage will not be used. The balance of the mechanism, with added weight to simulate the omitted parts, will be arranged for the close-open test operation. The closing coil circuit will be designed to operate as rapidly as possible, to reduce the closed time and thus the required Q of the test circuit.

In checking operating times, a calculation of the time to open, after closure and collapse of the closing solenoid coil field, has been made. This is given in Appendix C. The results indicate a total time to open, of 8.59 milliseconds. It is estimated that the closing coil control circuit can remove the field energy in 7 milliseconds or less after contacts touch. Thus, total time that the test circuit will carry current is about 15 milliseconds. The subsequent discussion of the test circuit will use this value for calculation of the needed Q.

V. TEST PLANS AND FACILITIES

A wide range of electrical and mechanical tests are required by the contract to prove out the sample vacuum breakers and contactors and at the same time, to provide guidance for future design improvements and performance criteria. Details of the planned test equipment, test procedures, and specifications will be covered in this section of the quarterly report.

A) Heat Run and Endurance

The heat run and endurance tests will be conducted at SPPS in an ultra-high vacuum tank, using a specially built oven to maintain the test samples at 1000°F. The tank, with controls and pumps, along with the oven lamp heater controls and automatic thermocouple recording equipment, is shown in Figure 6.

A special oven has been designed for the program and is now in assembly. Figure 7 shows the main (vertical) section of the oven in the inert gas welding tank, with the operator ready to weld a top clip to the assembly. The oven is made of vacuum processed Rodar, and as shown in Figure 8, consists of a bottom and main section. Six lamps are mounted on the top of the main section, along with the 18 lamps around the vertical side slats, with 6 on the bottom support section.

Behind each of the quartz tube lamps, three heat reflecting shields made of .003" rodar are mounted to reduce the heat loss to the vacuum tank walls. This amount of shielding was selected to permit a total of 5 to 7.5 kilowatt loss to the tank walls which are water cooled and can easily handle this amount of heat. Additional shielding would reduce the loss but make control of the lamps to maintain the samples at 1000°F more "fussy" and undesirable.

The overall assembly of the switchgear units and oven in the vacuum tank is shown in the one quarter scale sketch of Figure 9. Note particularly the location of the heat sink, contactor and breaker, the special low inductance 600 ampere bus, and the ion pump air lines with heat shields around the section above the bottom lamps. It is now planned to check out (and out-gas) the oven in the vacuum tank prior to set up of the switchgear in the oven for the heat run and endurance tests. This check out will monitor temperature of certain side, top, and bottom lamps at both the center of the quartz tubes and at the end seals, along with the 16 oven points, as shown in Figure 10, which will be monitored during the heat run and endurance tests.

During the tests, a total of 32 points will be checked for temperature on the samples and bus. These points, 20 on the breaker and 12 on the contactor, are shown in detail locations in Figure 11 and 12. These sketches, Figures 10, 11, and 12, will serve, along with a tabulation, to provide the output data resulting from the heat run and endurance tests.

Detailed test specifications for conducting the oven check out, plus the heat run and endurance tests are now being finalized. A preliminary draft of each test specification is included in this report as Appendix D-1, 2, and 3.

The endurance test is a continuation of testing in the vacuum chamber, after the heat run, and high potential (leakage) have been concluded. The endurance test plans are now being prepared and will be included in a subsequent report. However, it can be noted that this test will cover a period of 1000 hours with the breaker and contactor carrying rated current and the environment held at 1000°F and 10^{-6} Torr pressure.

B) Electrical Tests

It is now planned to conduct the electrical interruption tests at **SPPS** with the test sample mounted in a vacuum tank similar to the one being used for the endurance test and shown in Figure 6. The tank will be modified by removing the normal top section, replacing it with a flat lid on which the sample will be mounted, and this will be placed on top of a 22" long "spool piece". With this arrangement, the actuator (mechanism) will be outside the high temperature environment, but connected to the interrupter through a bellows seal.

Inside the tank the interrupter will be surrounded by a high temperature heater, which in turn will be heat shielded. Power leads, heater leads, thermocouple connections, and the cooling air for the ion pump will be brought out through feed-thrus in the spool piece. During test, the interrupter will be in a 10^{-6} Torr, or lower, pressure.

The tests will involve interruption of 10 amperes, 10,000 volts DC, and 1200 amperes, 1000 volts at 2000 cps (with a few tests at 1000 and 3000 cps). For the test power, two supplies will be built using suitable capacitors, inductance coils, along with related bus work, switches, and instrumentation. They will be described in detail in the next quarterly report as they are scheduled to be complete by March 1. However, the preliminary work on the main power circuit components is well underway and will be described briefly.

The DC interruption test circuit will be based on using a pulse forming network to generate a square wave of DC current through the switchgear on test. A lumped constant transmission line would consist of six paralleled capacitor sections, with six series reactor elements to provide the necessary impedance

to control the wave shape. Such a network requires only about 30% as much capacitance as would be required for an R - C discharge of substantially poorer quality. The variation from square (flat topped) wave during the pulse is less than 10% with six sections.

For the AC interruption tests a simple resonant L - C circuit with special high "Q" reactor coil and high frequency capacitors will be used. The capacitors would be charged to a peak value equal to the test voltage plus a margin for the expected decay during the time from breaker contact "make" to interruption (approximately 15 milliseconds - refer to section IV).

The value for the capacitance and inductance required for the discharge circuit is set by the requirement that the impedance yield the specified test condition of twice normal current (1,200 A) at normal voltage 1,000 V); that is 0.833 ohms. Then: -

$$2\pi f L = 1 / 2\pi f C = 0.833$$

And the following tabulation shows the values of impedance which should be suitable for testing over the specified range of 1000 to 3200 cps: -

<u>Frequency</u>	<u>Total Capacitance</u>	<u>Inductance</u>
1000 cps	191 μ fd	133 μ H
2000 cps	95 μ fd	66 μ H
3000 cps	60 μ fd	41 μ H

The proposed inductance coil will be made of wide copper sheet, with the width and diameter approximately the same to result in a relatively high "Q". The special coil, along with the high "Q", high frequency water cooled capacitors that are proposed, should limit the test voltage decay to about 20% during the

"circuit closed" condition at 3000 cycles. The decay would be approximately 10% at 1000 cycles.

Detail test specifications for all electrical tests will be in preparation during the next reporting period.

C) Mechanical Tests

The mechanical test program will be divided into two sections. Vibration and shock tests will be conducted at the Research and Development Center in Schenectady. The acoustic and acceleration tests will be performed at the RSD Mechanical Testing Laboratory in Philadelphia.

Samples to be tested are those which will have gone through the endurance test. The AC sample will be modified to replace the copper rings with operable coils, and the unit will be operated for 100 close-open cycles. It will then be sent to Schenectady for the vibration and shock test. Detail test specifications have not yet been developed for this work, but will be prepared as soon as vibration and shock requirements for the expected launch vehicle have been reviewed and revised or confirmed.

The DC sample will be modified to install operating coils, and after bench operation and check-out will be sent to Philadelphia for acoustic and acceleration tests. Detail test specifications have now been prepared, and are included in this report as Appendix D-4 and D-5.

VI. SCHEDULE

The overall schedule has been reviewed and up-dated as a result of delays in some final drawing details and longer procurement and manufacturing times. It now appears that the first vacuum capsule will be assembled by the end of December. The AC breaker and DC contactor for the heat run test should be completed by the end of January.

Vacuum processing, assembly, evacuation and seal off of the capsules, along with assembly of the interrupter units is now to be done at SPPS. The actuators will be assembled at R & DC and then shipped to SPPS for mating with the interrupters.

The PERT diagram indicates the status of, and schedule for, the entire program. Some additional detail steps are shown in the latest revision, including the check-out of the endurance test oven in January, and the design and assembly of the electrical testing equipment. The present schedule indicates completion of this program by May 31, 1966.

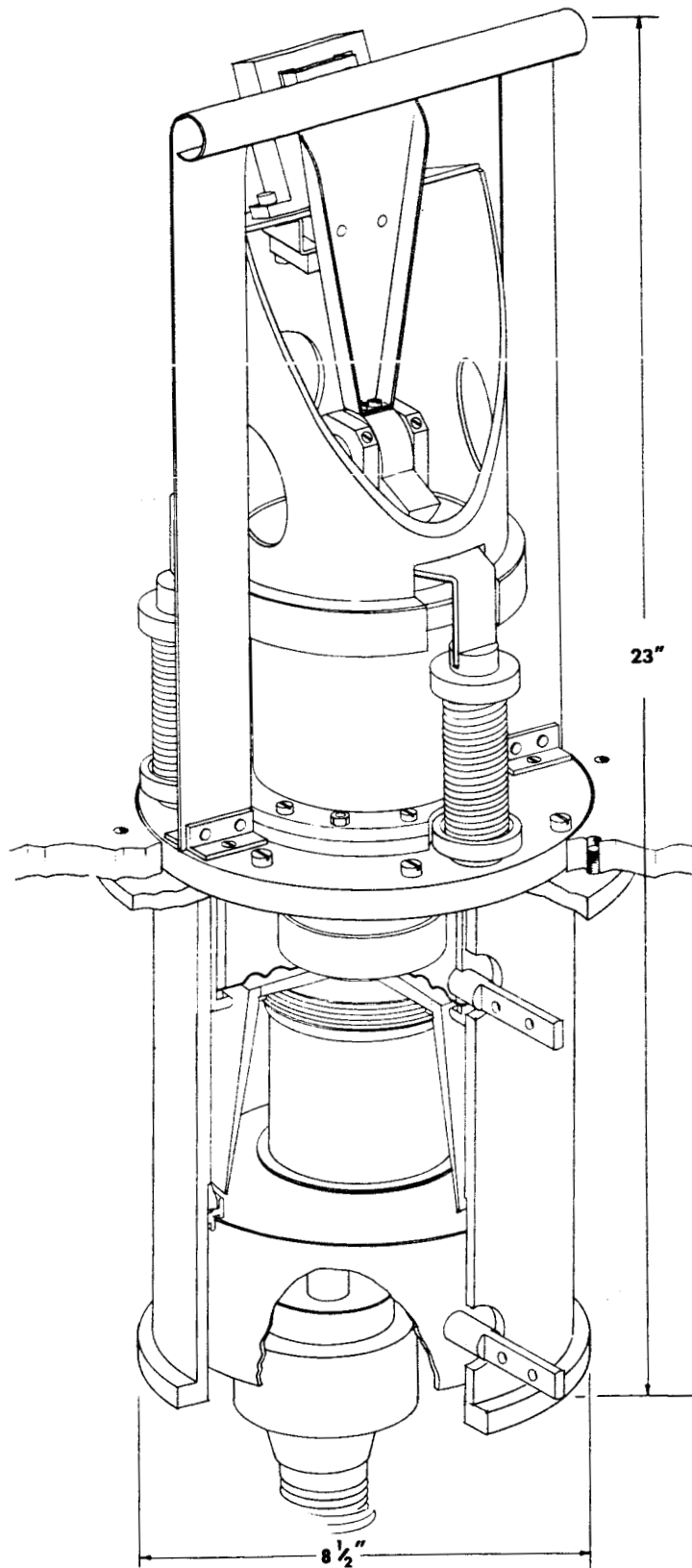


Figure 1. Artist's Concept of AC Vacuum Breaker Rated 600A, 1000 V., 2000 cps.

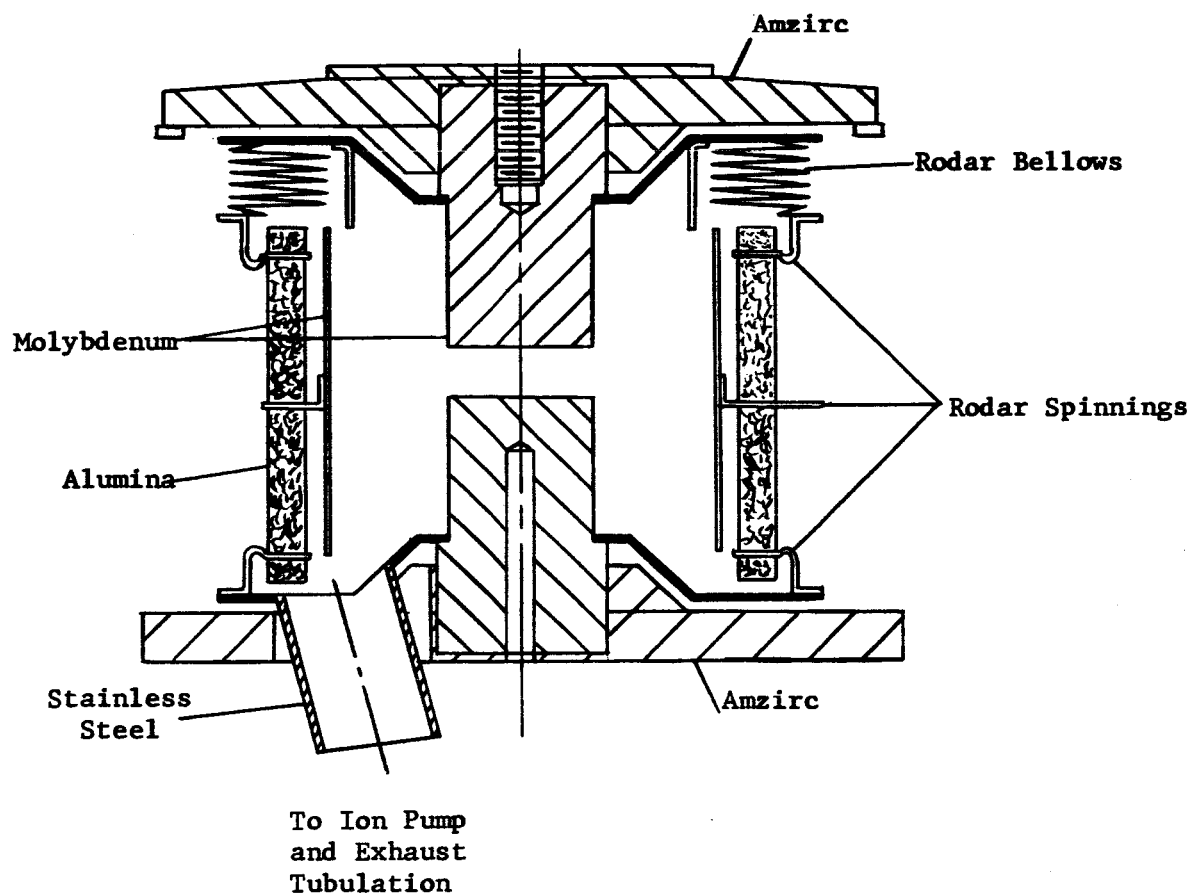


Figure 2. Sketch of Vacuum Capsule for Both AC Breaker and DC Contactor.

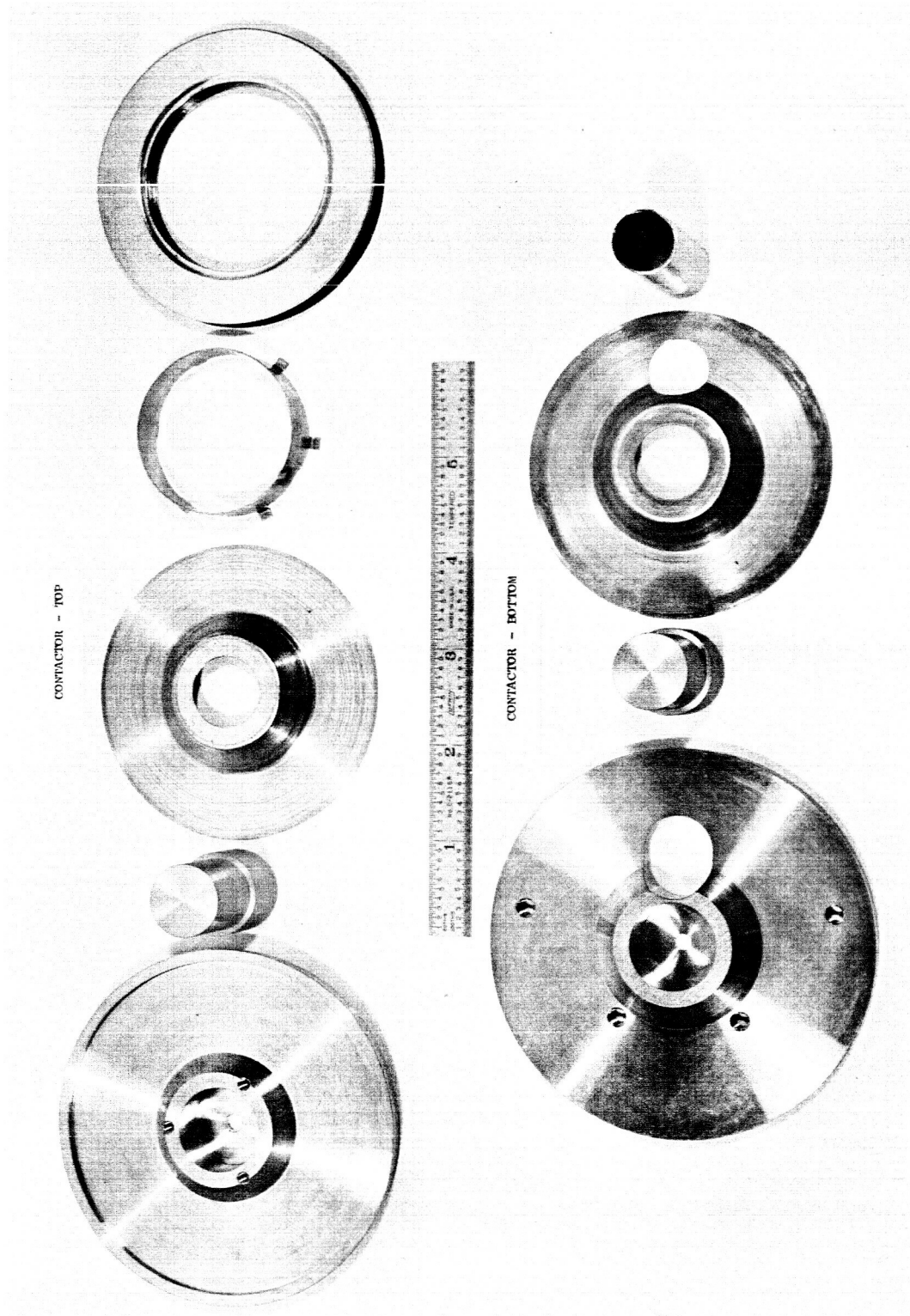


Figure 3. Parts for the End Pieces of the Vacuum Capsule Shown in Figure 2.

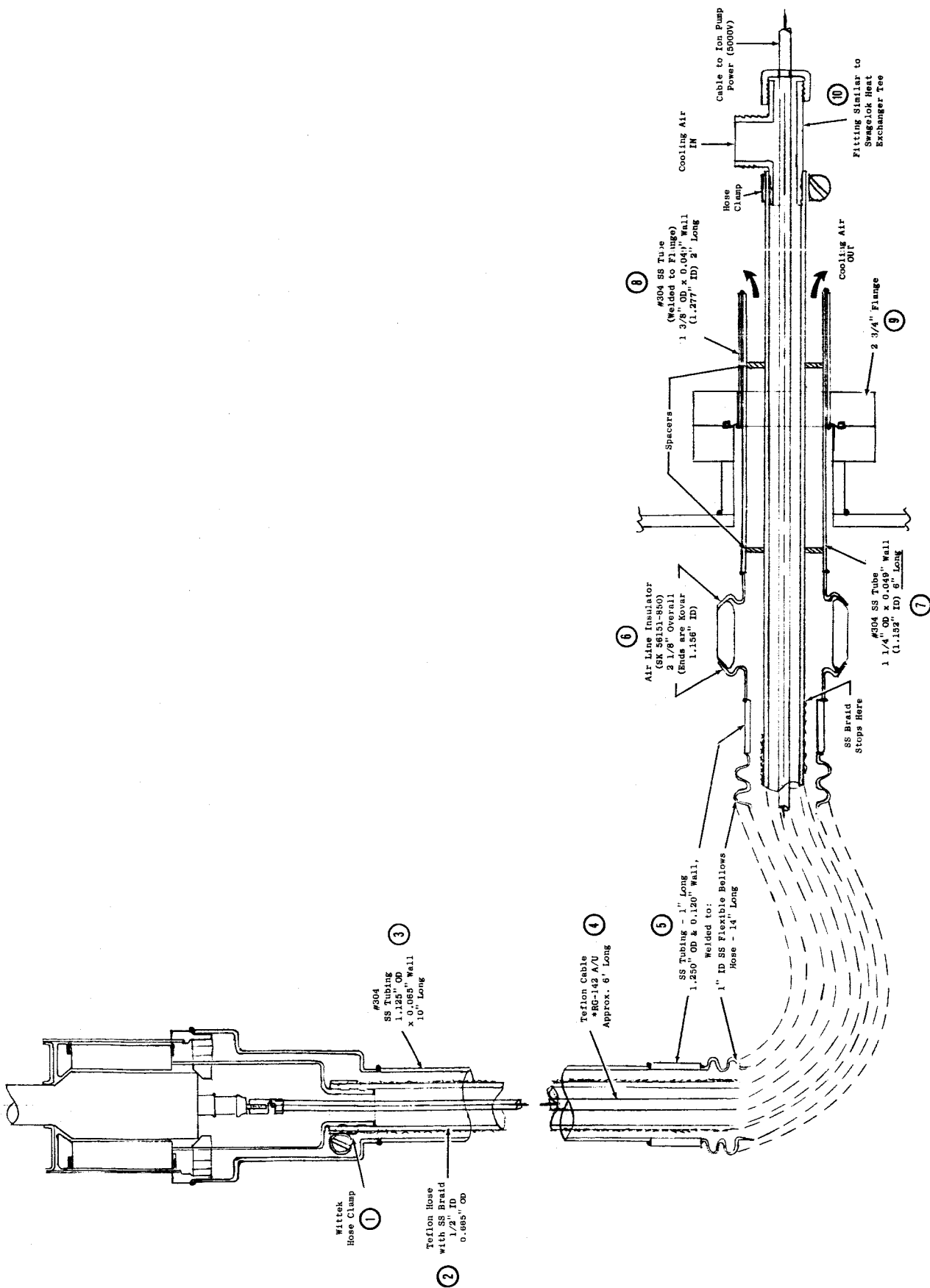


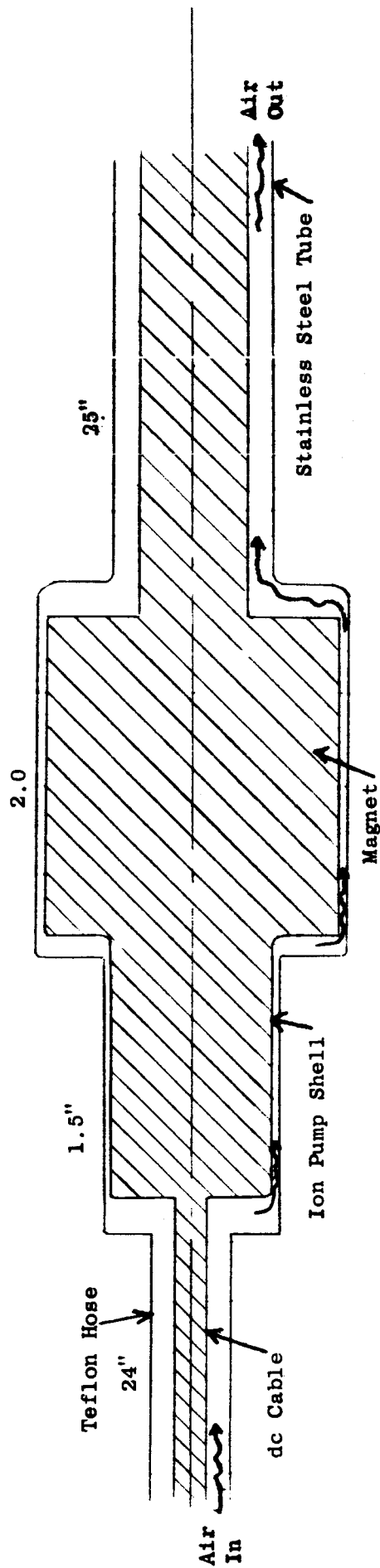
Figure 4. Sketch of Air Line for Ion Pump Cooling and Power Supply.

Section: 1

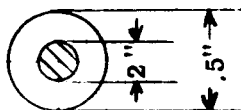
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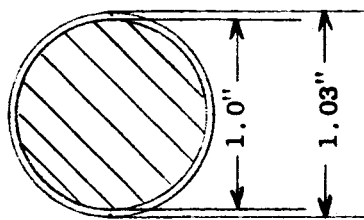
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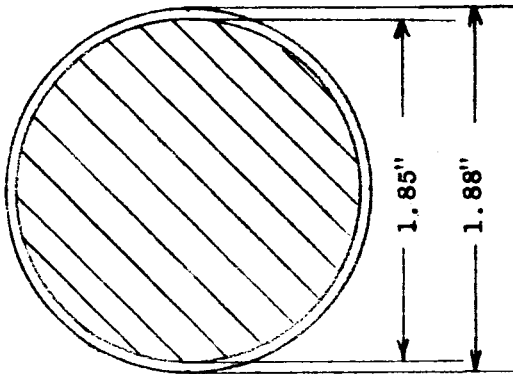
$A = .165 \text{ sq. in.}$



$A = .048 \text{ sq. in.}$



$A = .088 \text{ sq. in.}$



$A = .438 \text{ sq. in.}$

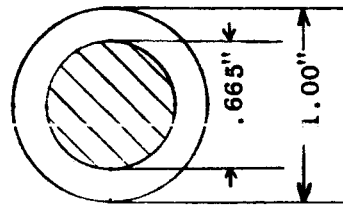


Figure 5. Schematic Drawing of the Cross Sections of the Air Passages for the Ion Pump and the Electrical Connections.

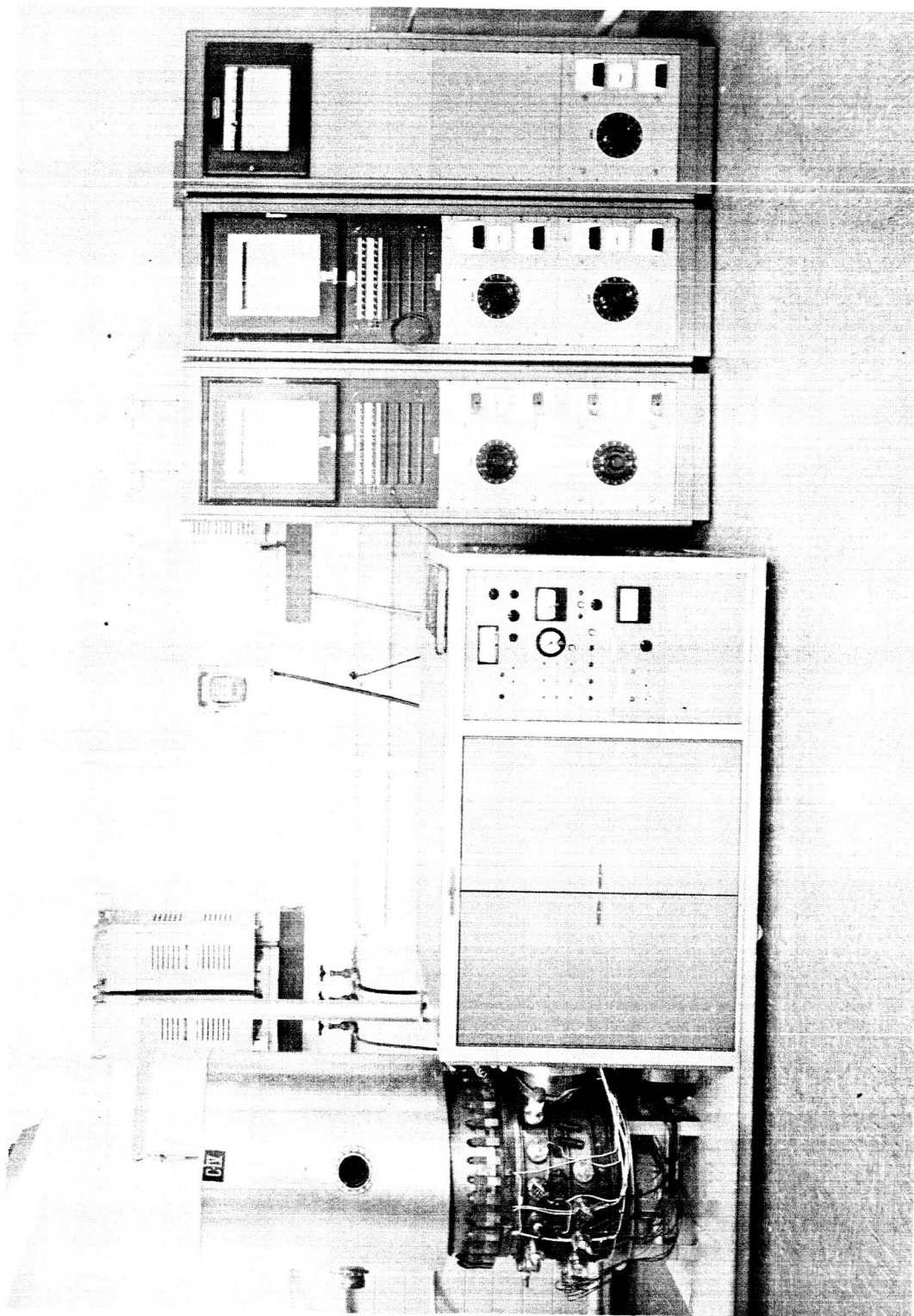


Figure 6. Ultra High Vacuum Chamber, Controls and Pumps, and Automatic Recorders for Switchgear Tests.

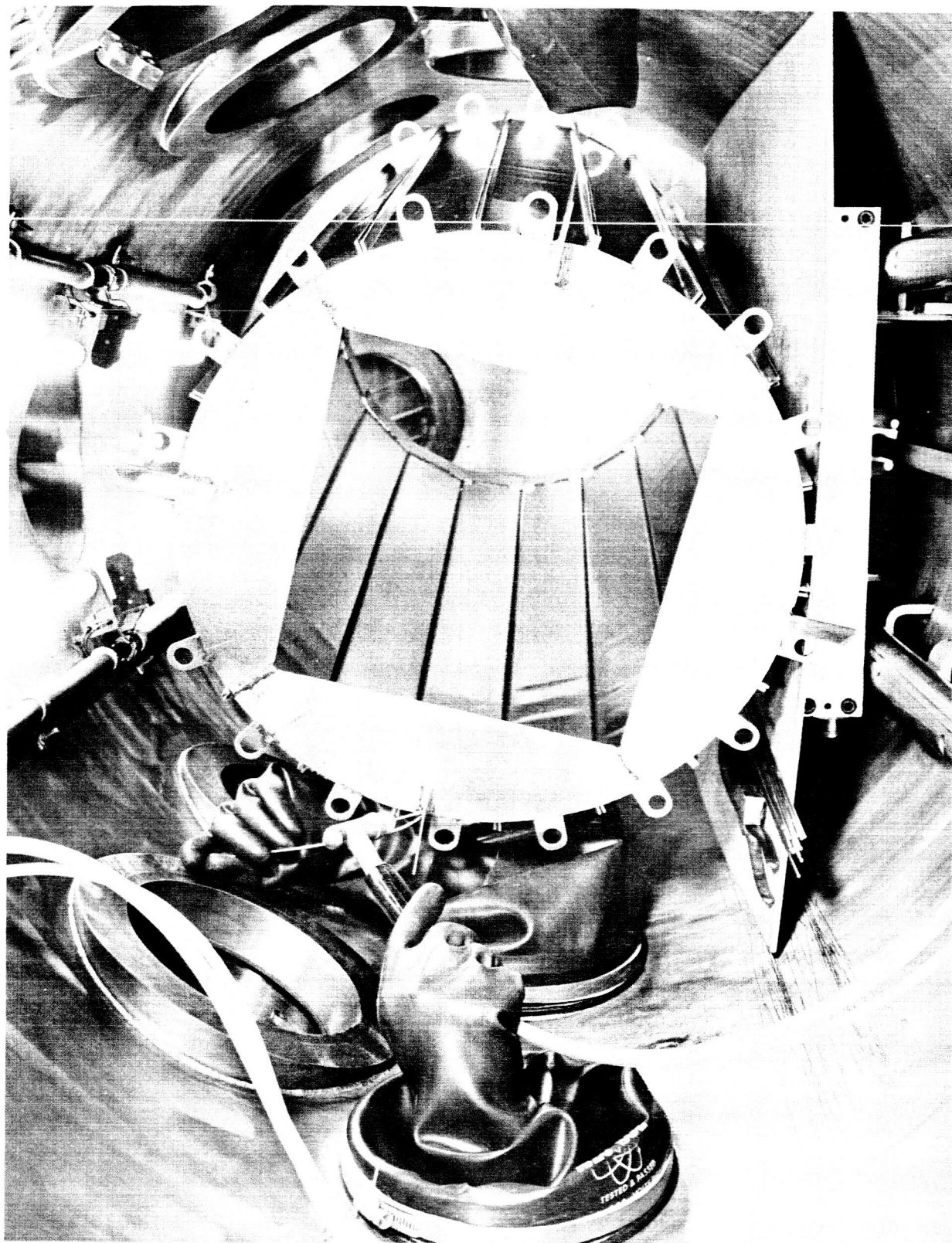


Figure 7. Main Section of High Temperature Oven for Switchgear Heat Run and Endurance Tests in Inert Gas Welding Tank with Operator Ready for Welding Process.

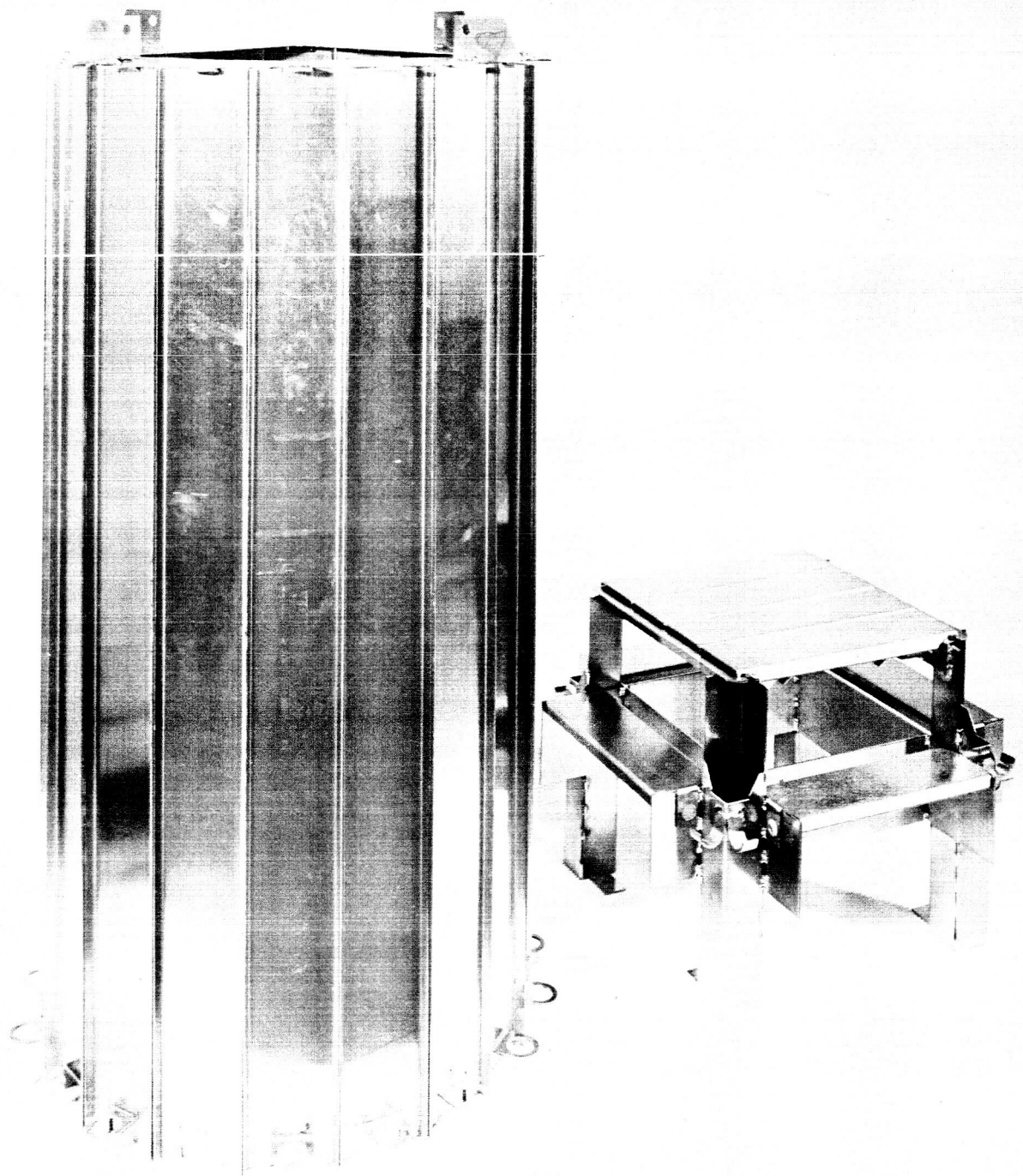
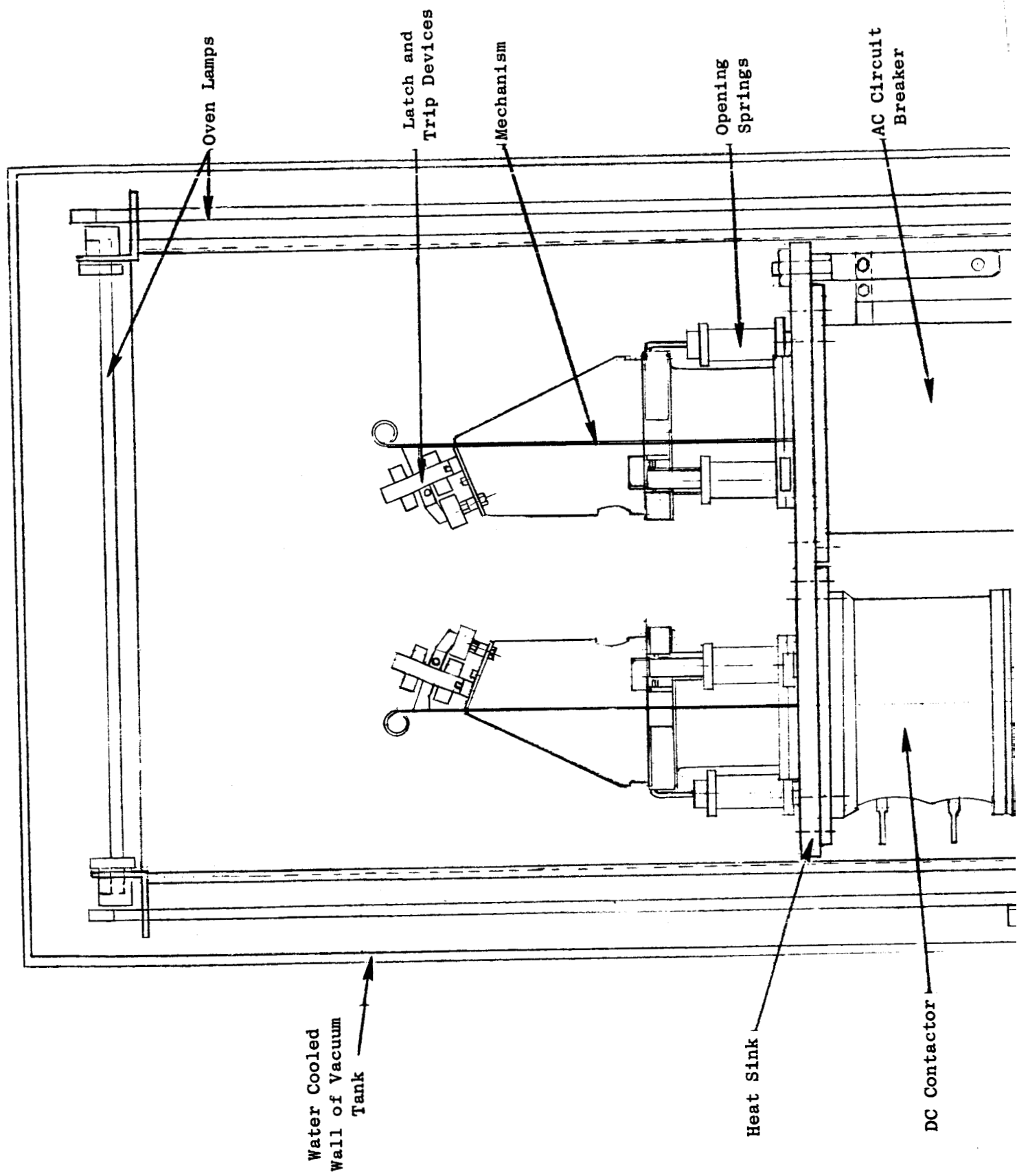


Figure 8. Parts of High Temperature Oven for Switchgear Heat Run and Endurance Tests.



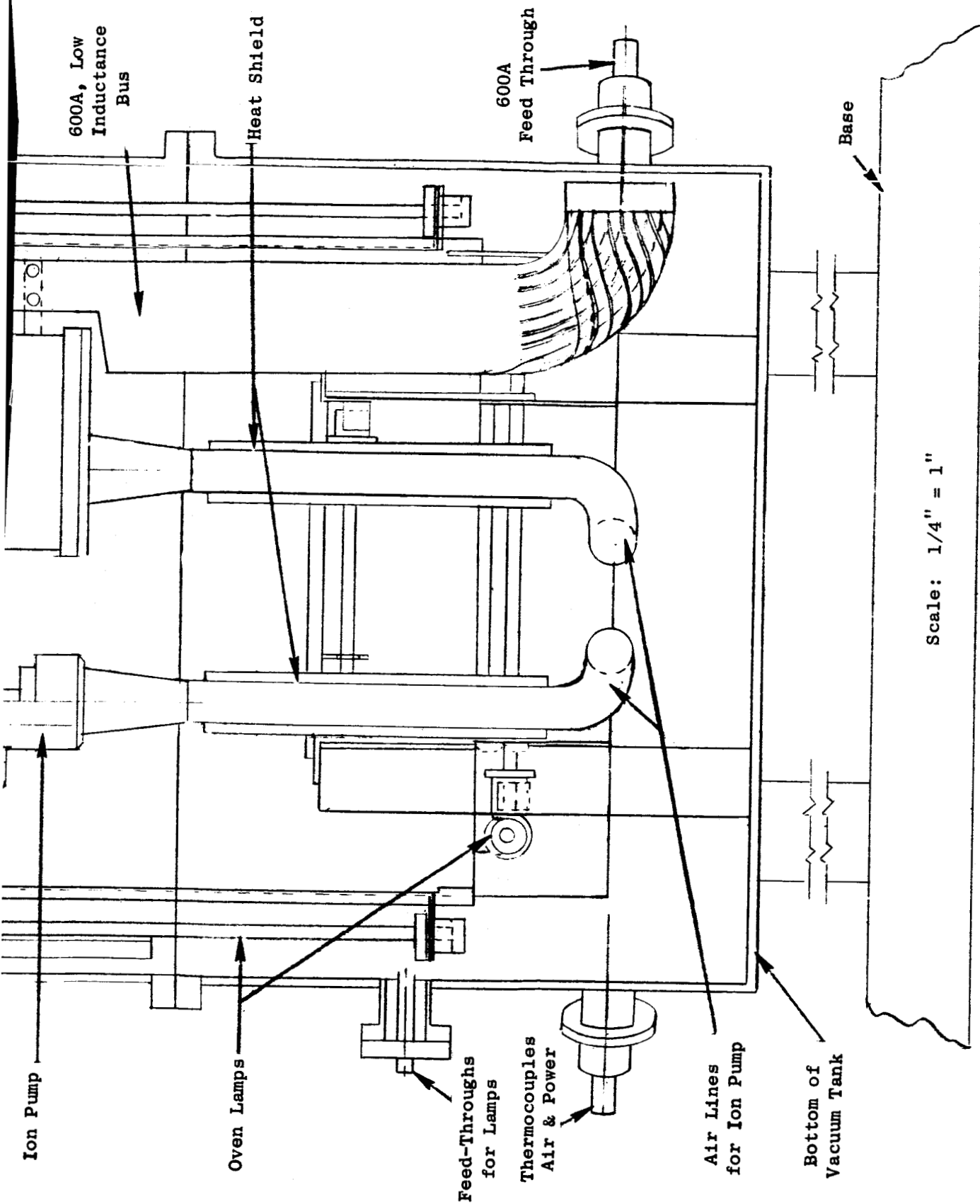


Figure 9. Sketch of Section Through CIV Vacuum Tank and Special Oven, with Vacuum Breaker and Contactor in Planned Position.

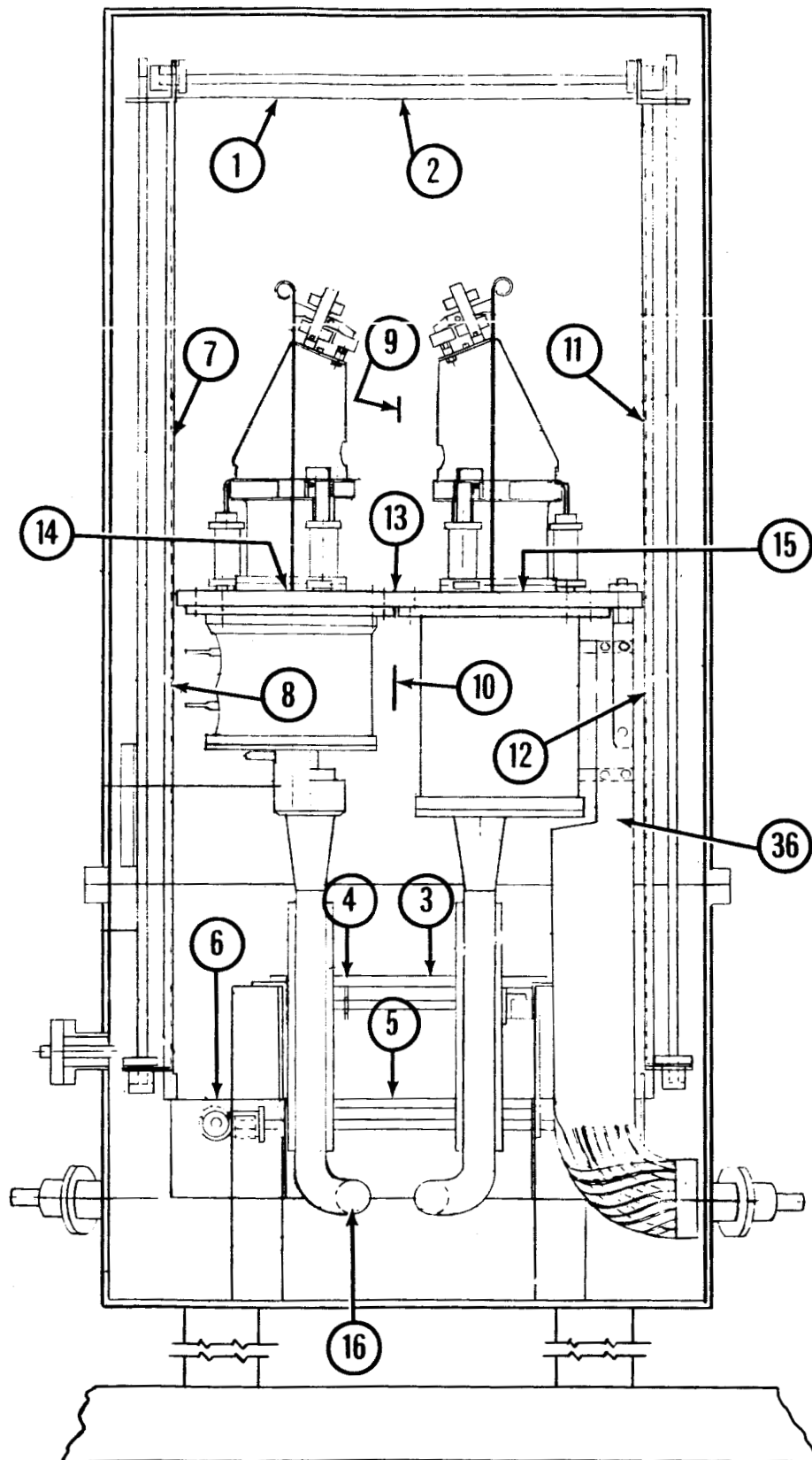


Figure 10. Location of Thermocouples in Various Parts of the Special Oven for the Heat Run and Endurance Tests.

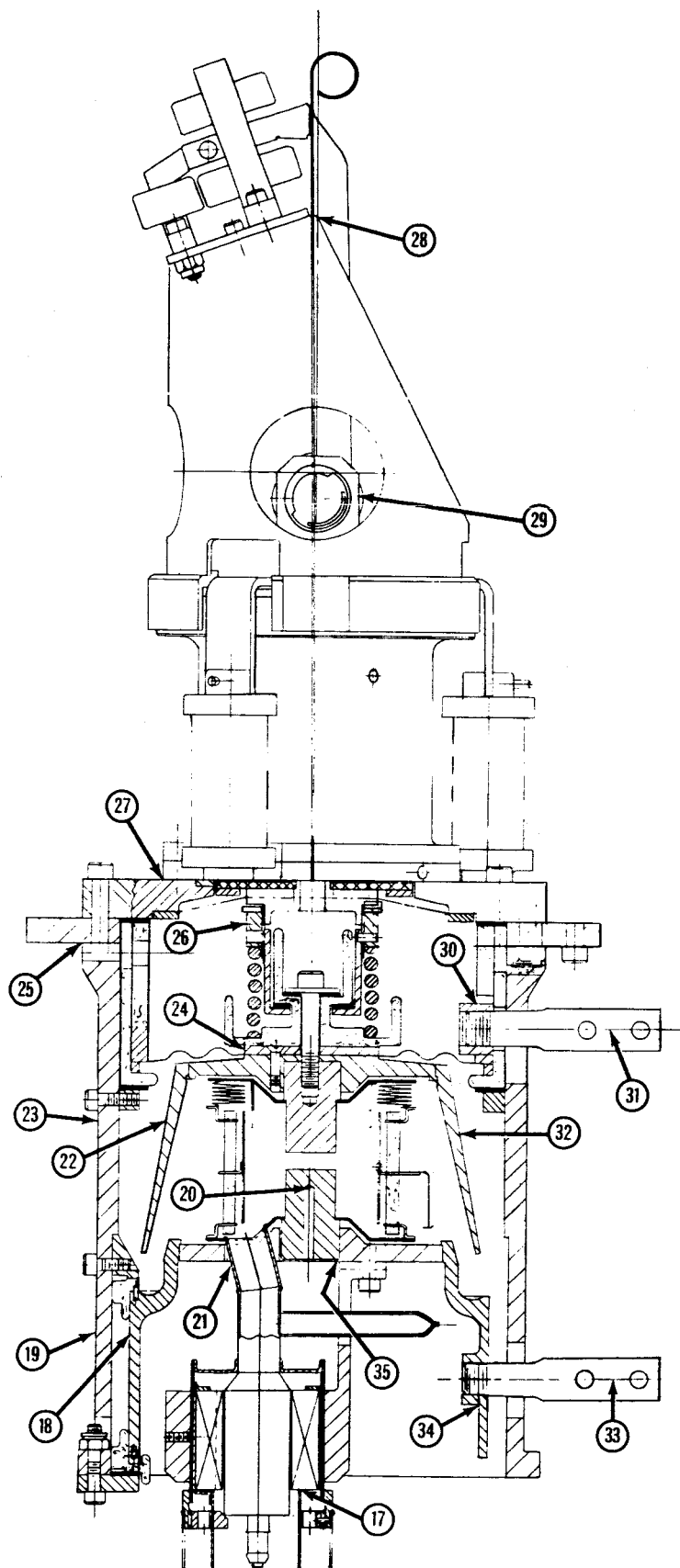


Figure 11. Location of Thermocouples on the AC Breaker for Heat Run and Endurance Test.

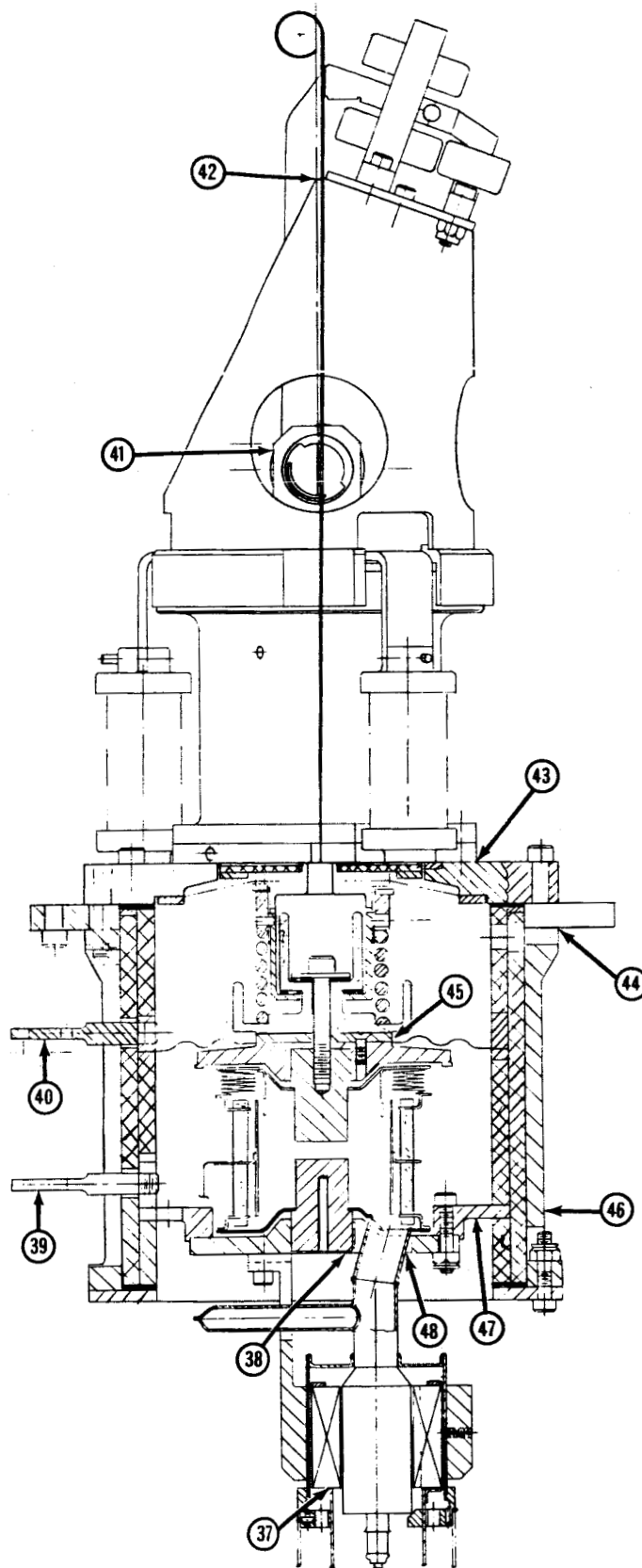
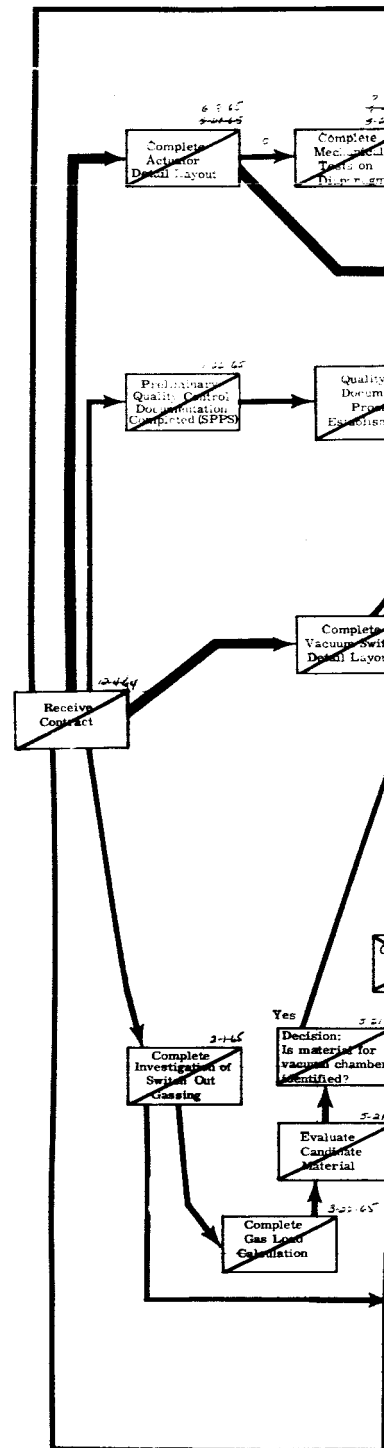


Figure 12. Location of Thermocouples on the DC Contactor for the Heat Run and Endurance Test.

Switchgear Development

Contract NAS 3-6467

Date Issued: 10-10-65
Previous Date Issued: 10-4-65
Program Revision: 1-29-65



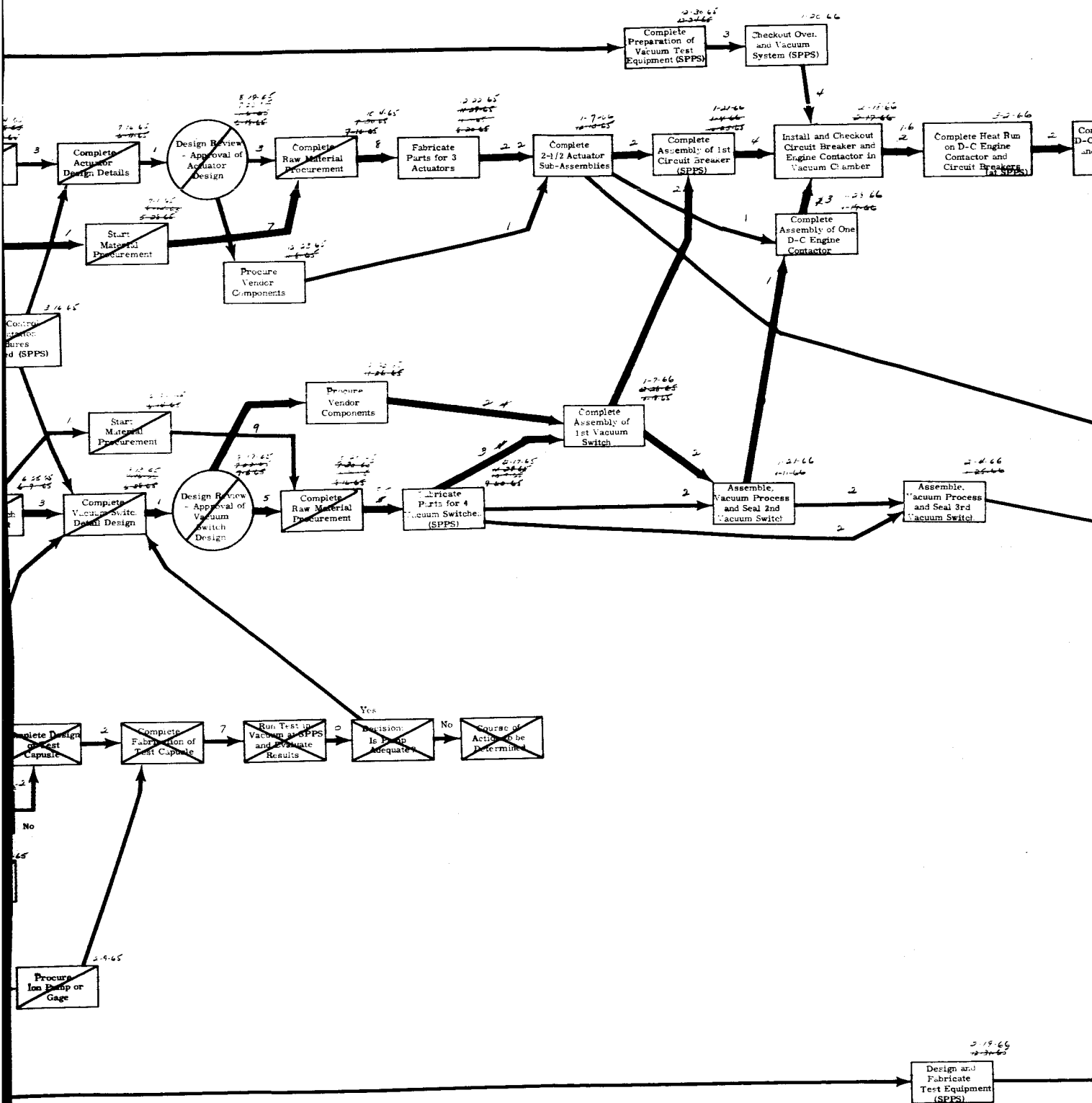
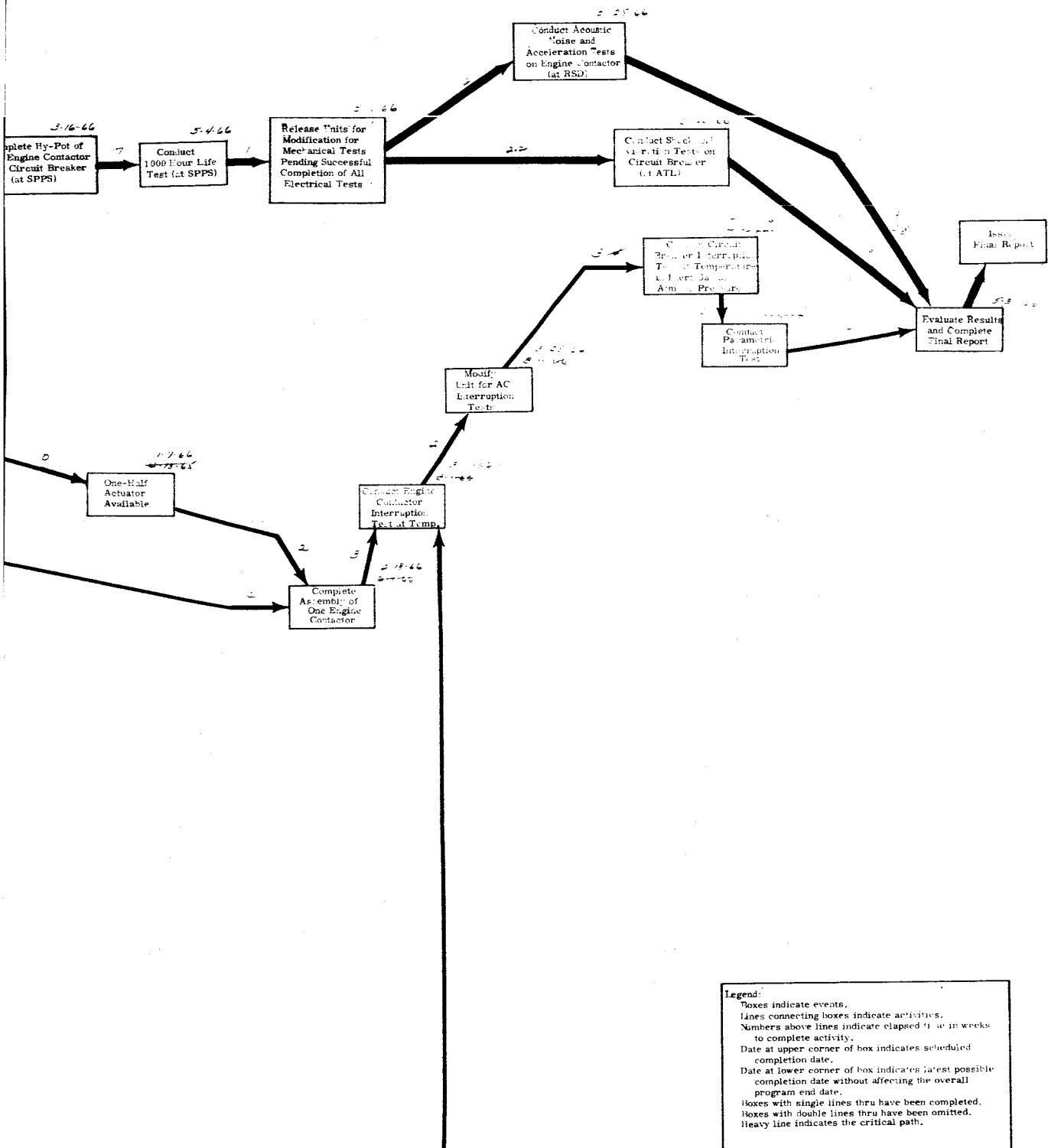


Figure 13.

3



APPENDIX A

FABRICATION OF CAPSULE AND PUMP ASSEMBLY 561B516
HIGH-TEMPERATURE SWITCHGEAR

SPECIFICATION NUMBER: SPPS 02-0136-00-A

December 23, 1965

GENERAL ELECTRIC**SPACE POWER & PROPULSION SECTION
CINCINNATI, OHIO 45215**

SPECIFICATION NO.

SPPS 02-0136-00-A

DATE

December 23, 1965

ENGINEERING SPECIFICATION

TITLE

FABRICATION OF CAPSULE AND PUMP ASSEMBLY 561B516
HIGH-TEMPERATURE SWITCHGEAR

ORIGINAL CONTRACT

NAS 3-6467

PREPARED BY: W. R. Young*W. R. Young*DATE 12/23/65APPROVED BY: J. W. Semmel, Jr.*J. W. Semmel, Jr.*DATE 12/23/65APPROVED BY: A. H. Powell*A. H. Powell*DATE 12/23/65ISSUED BY: D. A. Pritchett
DRAFTINGMAIL ZONE N-21PHONE 2438/392

SUPERSEDES SPECIFICATION NO.

DATED

SEE SPPS INSTRUCTIONS
SERIES 03.106

FABRICATION OF CAPSULE AND PUMP ASSEMBLY 561B516
HIGH-TEMPERATURE SWITCHGEAR

- CONTINUED

DATE
12/23/65

NO.
SPPS 02-0136-00-A

1. SCOPE

1.1. Scope. This specification establishes the fabrication procedures, process substantiation and quality requirements for the capsule and pump assembly and its subassemblies.

2 APPLICABLE DOCUMENTS

2.1. Government Documents. None

2.2. Non-Government Documents

SPPS 03-0013-00-B
(1965)

Mass Spectrometer Leak Detection
Using Helium

ASTM B297-55T

Tungsten Arc Welding Electrodes

3. REQUIREMENTS

3.1 Materials. Materials shall be those specified on the engineering drawings.

3.2 Equipment.

3.2.1. Vacuum Furnace. The vacuum furnace shall be capable of operation at a pressure of less than 5×10^{-5} torr at 1800°F.

3.2.2. Auxiliary Equipment. Auxiliary equipment shall be capable of monitoring furnace vacuum and part temperature (plus or minus 10°F).

3.3. Cleaning Procedures

3.3.1. General. All parts shall be free of dirt, grease, or other extraneous material. The final cleaning procedures described below shall be applied immediately prior to assembly.

3.3.2. Rodar

3.3.2.1. Machine Surface. Wash in free-rinsing detergent followed by degreasing with acetone and rinsing in ethyl, methyl or isopropyl alcohol.

3.3.2.2. Light Scale. Parts shall be immersed for 20 seconds in a solution containing 50 gm of ferric ammonium sulfate, 30 ml of H_2SO_4 (1.84 sp. gr.), 150 ml of HCL (1.16 sp. gr.), 150 ml of HNO_3 (1.42 sp. gr.) and 670 ml of water maintained between room temperature and 140°F. Residual acid shall be removed by rinsing with deionized water. Repeat as necessary.

3.3.3. Am Zirc. Parts shall be immersed for 30 seconds in an aqueous solution containing 50% by volume HNO_3 (1.42 sp. gr.) maintained between room temperature and 150°F. Residual acid shall be removed by rinsing with deionized water. Repeat as necessary.

3.3.4. Molybdenum. Parts shall be degreased with acetone, then cleaned by either of the following methods: (a) Electrolytically by immersion in an aqueous solution of 66% by volume H_2SO_4 (1.84 sp. gr.) maintained at room temperature. Current densities of 100 to 300 amps/ft² shall be used with the molybdenum as the anode. Cleaning time shall be adjusted to obtain a uniform surface cleanliness. Residual acid shall be removed by rinsing with deionized water, (b) By an 1800°F/30 min. heat treatment in a vacuum furnace wherein the pressure shall be maintained at less than 5×10^{-5} torr during the thermal cycle. Parts shall be cooled to less than 150°F before removal from the furnace.

FABRICATION OF CAPSULE AND PUMP ASSEMBLY 561B516
HIGH-TEMPERATURE SWITCHGEAR

- CONTINUED

DATE
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SPPS 02-0136-00-A

3.3.5. Braze Alloy. The Nicuro Type 80 braze alloy shall be degreased with acetone, followed by rinsing in ethyl, methyl or isopropyl alcohol.

3.3.6. Stainless Steel. Parts shall be degreased with acetone, followed by rinsing in ethyl, methyl or isopropyl alcohol. Pickle in an aqueous solution containing 25% by volume HNO_3 (1.42 sp. gr.) and 25% by volume HCl (1.16 sp. gr.) at 75°F to 100°F for 1 to 2 minutes. Rinse with deionized water to remove residual acid. Repeat as necessary.

3.4. Handling Procedures

3.4.1. Handling. After final cleaning and during all assembly operations, the parts shall be handled with clean nylon or vinyl gloves.

3.4.2. Packaging. If storage is necessary, parts shall be sealed in polyethylene bags.

3.5. Welding Procedures

3.5.1. Inert Arc. Tungsten inert gas welding shall be done using direct current, straight polarity. The torch gas cup shall be of adequate size to provide optimum gas coverage to the weld zone. Tungsten electrodes shall conform to ASTN B297-55T and shall be class EWTh-2. Welding shall be done in an argon filled chamber when the back side of the weld cannot be mechanically cleaned.

3.5.1.1. Shielding Gas. Argon of 99.95% minimum purity shall be used for both torch shielding and weld joint backup protection.

3.5.1.2. Filler Wire. The filler wire shall be that specified on the engineering drawing or in the manufacturing instructions.

3.5.1.3. Metal Vapor. Deposits of metal vapor produced by the welding process shall be removed by brushing with stainless steel wire brushes and rinsing with acetone and ethyl, methyl, or isopropyl alcohol.

3.5.2. Electron Beam. The electron beam welding shall be done where shown on the engineering drawing.

3.5.2.1. Fixturing. Gas tungsten arc tack welds per paragraph 3.5.1. may be used to align the components prior to electron beam welding.

3.6. Brazing Procedure

3.6.1. Brazing Alloy Placement

3.6.1.1. Assembly. Joint components shall be assembled per the engineering drawing.

3.6.1.2. Placement. Nicuro Type 80 braze alloy shall be positioned at each joint in adequate quantity to fill the joint.

3.6.1.3. Stop-Off Compound. A stop-off compound, Nicrobraz green or its equivalent, shall be applied as necessary to limit braze alloy flow. If stop-off compound contaminates the braze joint, the joint shall be disassembled and recleaned before proceeding with braze assembly. After brazing, the stop-off residue shall be removed by dry grit blasting and wire brushing.

FABRICATION OF CAPSULE AND PUMP ASSEMBLY 561B516
HIGH-TEMPERATURE SWITCHGEAR

- CONTINUED

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3.6.2. Brazing Cycle

3.6.2.1. Temperature Measurement. Two Pt/Pt-10%Rh thermocouples shall be attached to the assembly near the braze joints on components which represent the heaviest sections being joined. During the brazing cycle, the temperature recorded by these thermocouples shall not differ by more than 200°F.

3.6.2.2. Vacuum. Before applying heat to the assembly, a pressure of less than 5×10^{-5} torr shall be attained. During heating, pressure rises to 1×10^{-3} torr for short time intervals are acceptable. Pressure shall be maintained at less than 5×10^{-5} torr when the assembly is above 1000°F.

3.6.2.3. Brazing Temperature. The brazing temperature shall be 1700°F, $\pm 10^\circ\text{F}$ for 2 minutes duration.

3.6.2.4. Protective Envelope. The assembly shall be placed in a clean zirconium can, (minimum 0.010-inch thick wall), for brazing. Suitable supports shall be used to prevent direct contact between the assembly and the zirconium can.

3.6.2.5. Cooling Cycle. The brazed assembly cooling rate shall be approximately 10°F per minute from 1650°F to 1050°F. The assembly shall be cooled to less than 150°F before removal from the furnace.

4. QUALITY ASSURANCE PROVISIONS

4.1. General. All welded and brazed joints shall be examined visually (10X). Joints shall be free of the following defects.

1. Cracks
2. Porosity
3. In-complete braze alloy flow
4. Undercutting along the edges of the weld or braze
5. Non-uniform weld or braze contour.

4.2. Mass Spectrometer Leak Tests. Each welded or brazed joint shall be tested in accordance with Specification 03-0013-00-B at a sensitivity of 5×10^{-10} std cc/sec of air before inclusion in the next assembly. No leaks are allowed.

4.3. Rejection. Weldments or brazes not conforming to this specification shall be rejected.

4.4. Reports. A report shall be submitted with the finished assemblies and shall include all pertinent process information and results of quality assurance testing.

5. PREPARATION FOR DELIVERY

5.1. Packaging. The completed assembly shall be sealed in a polyethylene bag.

5.2. Identification. Assemblies shall be tagged with the drawing number, part number, and serial number.

6. NOTES. None

APPROVALS:

W. H. Kearns
W. R. Young

MANUFACTURING INSTRUCTION

NO.

SWG-1

DATE

12-8-65

NAME

CONTACT BRAZE ASSEMBLY

DRAWING NO. & DESCRIPTION

(SERIAL NO: IF NEEDED)

115A5166

F.C.F. on Pl-115A5168G1
F.M.F Hi-Temp Switchgear

MATERIAL: Rodar, Amzirc, Molybdenum, Nicuro Type 80 Braze Alloy

PART NUMBER	DESCRIPTION	MATL. CONTR. NO.	(SERIAL NO: IF NEEDED)
1	<u>PL115A5166G1 Lower Contact Assembly</u>		
2	561B477PT-1 Lower Flange		
3	115A5160 PT-1 Dish		
4	115A5163 PT-1 Contact		
7	Tube 5/8" O.D. x .032" wall, Type 304SS		
8	<u>PL115A5166 G2 Upper Contact Assembly</u>		
9	115A5162 PT-1 Upper Flange		
10	115A5160 PT-2 Dish		
11	115A5161A PT-1 Guard		
12	115A5169 P-1 Bellows		
14	Braze Alloy, Nicuro 80 Wire and Foil		
15	115A5163 PT-2 Contact		

MANUFACTURING INSTRUCTION - CONTINUED

DATE

12/8/65

NO.

SWG-1

PROCESSES: VACUUM BRAZING AND WELDING

STEP	OPERATION	SEQUENCE	OPERATOR BADGE NO.	COMPLETION DATE	REMARKS
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LOWER CONTACT ASSEMBLY PART 1

1. Cut and fit P7 to P3
2. Clean P7 and P3 per
02-0136-00-A
3. Weld P7 to P3 per 02-0136-00-A
4. Trim P7 to B/P
5. Helium leak check per
03-0013-00-B
6. Clean P2, P3 and P4 per
02-0136-00-A
7. Braze P2 and P3 to P4 per
02-0136-00-A
8. Helium leak check per
03-0013-00-B
9. Seal in plastic bag

UPPER CONTACT ASSEMBLY PART 8

1. Clean P10 and P12 per
02-0136-00-A
2. Tack weld P10 to P12 by EB -
Alt. TIG in V.P. chamber per
02-0136-00-A
3. EB weld P10 to P12 by EB weld-
ing - Alt. TIG in V.P. chamber
per 02-0136-00-A
4. Helium leak check per 03-0013-00-B
5. Store in plastic bag
6. Clean P9, P10, P11, P15 per
02-0136-00-A
7. Braze P9 and P10 to P15; P11
to P10 per 02-0136-00-A
8. Helium leak check per
03-0013-00-B
9. Thread hole in P15 (1/4" - 20 UNC
- 2B x .62" dp)
10. Take photo of both assemblies

APPROVALS:

W. H. Kears
W. R. Young

MANUFACTURING INSTRUCTION

NO.

SWG-2

DATE

12-8-65

NAME

CONTACT CAPSULE

DRAWING NO. & DESCRIPTION

(SERIAL NO: IF NEEDED)

115A5168

FMF Hi-Temp Switchgear

MATERIAL:

PART NUMBER

DESCRIPTION

MATL. CONTR. NO.

(SERIAL NO: IF NEEDED)

- | | | |
|---|---|--|
| 1 | Assembly | |
| 2 | PL115A5166G1 Contact Braze Assembly-Lower | |
| 3 | PL115A5167G1 Seal Assembly | |
| 4 | PL115A5166G2 Contact Braze Assembly-Upper | |

MANUFACTURING INSTRUCTION - CONTINUED

DATE

12-8-65

NO.

SWG-2

PROCESSES: EB and/or TIG WELDING

STEP	OPERATION	SEQUENCE	OPERATOR BADGE NO.	COMPLETION DATE	REMARKS
1	Clean seal assembly P2 acetone and alcohol rinse				
2	Helium leak check seal assembly P2 per 03-0013-00-B				
3	Weld P2 to P3 (See B/P Note 1) per 02-0136-00-B				
4	Helium leak check per 03-0013-00-B				
5	Clean P4 and P3 per 02-0013-00-A Weld P4 to P3 per 02-0136-00-A (See Note 1 on B/P)				
	A. Clamp assy to hold .003" F.I.R. per B/P				
	B. Shield bellows from beam				
	C. Tack weld				
	D. Remove clamp and weld seam				
	E. Reclamp to protect bellows during handling				
6	Helium leak check per 03-0013-00-B				
7	Take photo of assembly				

APPROVALS:

W. H. Kanne
W. R. Young

PAGE 1 OF 2

MANUFACTURING INSTRUCTION	NO. SWG-3
	DATE 12-8-65
NAME PUMP ASSEMBLY	
DRAWING NO. & DESCRIPTION 561B483A	
(SERIAL NO: IF NEEDED)	
FMF Hi-Temp Switchgear	

MATERIAL: 304SS

PART NUMBER	DESCRIPTION	MATL. CONTR. NO.	(SERIAL NO: IF NEEDED)
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1	Assembly		
2	Magnet		
3	Ion Pump Cat. No. 22TP050		
4	561B484-G1 ASM. Magnet Holder		
5	561B485-G1 Pump Housing		
6	Dowel Pin .062 dia. x .19 lg. 304SS		
7	Tubing .25 O.D. x .03 wall nickel (length per capsule evac. and seal proc.)		
8	561B483P8 Air Guide		

MANUFACTURING INSTRUCTION - CONTINUED

DATE

12-8-65

NO.

SWG-3

PROCESSES: TIG

STEP	OPERATION	SEQUENCE	OPERATOR BADGE NO.	COMPLETION DATE	REMARKS
1.	Ref. B/P 561B4844, check magnet installation, concentric with O.D. PT3 within .010"				
2.	PT 3 drill .25"D hole, cut pump inlet tube to length and bevel. Note orientation. Remove tabs - note 3.				
3.	Helium leak check PT5 per 03-0013-00-B				
4.	Attach thermocouple to magnet per instructions - H. Powell				
5.	Final check method of pump lead attachment with H. Powell. Install if necessary (see 12)				
6.	Install pump PT3 in PT4, TIG tack weld PT3 to PT4, 3 places per 02-0136-00-A				
7.	Slip PT5 over pump neck PT3. Screw on to PT4 flush. Drill and ream, pin with PT6				
8.	Seat pump PT3 in PT4, TIG weld PT5 to PT3 in V.P. chamber per 02-0136-00-A				
9.	Helium leak check PT3 and PT5 per 03-0013-00-B				
10.	TIG weld PT7 to pump PT3 in V.P. chamber (see note 1). Check length of PT17 for evacuation and sealing procedure. Ref. 02-0136-00-A				
11.	Helium leak check Pump PT3 per 03-0013-00-B				
12.	Take photos after steps 5 and 10				
13.	Store in sealed plastic bag				

APPROVALS:

W.H. Kears
W.R. Young

MANUFACTURING INSTRUCTION

NO.

SWG-4

DATE

12-10-65

NAME

ASSEMBLY, CAPSULE AND PUMP

DRAWING NO. & DESCRIPTION

(SERIAL NO: IF NEEDED)

561B516

FCF PL454C748 - Next PL454C778

FMF Hi-Temp Switchgear

MATERIAL:

PART NUMBER

DESCRIPTION

MATL. CONTR. NO. (SERIAL NO: IF NEEDED)

1	PL115A5168G1 Contact Capsule	
2	561B483G1 Pump Assembly	
3	454C764P1 Ion Pump Support	
5	#10-32 x 1/2" lg Self-Locking Socket HD Screw	
6	#6-32 x 1/2" lg Self-Locking Socket HD Screw	
7	#8-32 x 3/4" lg Self-Locking Socket HD Screw	

MANUFACTURING INSTRUCTION - CONTINUED

DATE

12-10-65

NO.

SWG-4

PROCESSES: TIG, EB

STEP	OPERATION	SEQUENCE	OPERATOR BADGE NO.	COMPLETION DATE	REMARKS
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- | | | | | | |
|----|---|--|--|--|--|
| 1 | Clamp PT1 and PT2 with PT3 using PTS 5, 6, 7. Note orientation on B/P | | | | |
| 2 | TIG Tack PT1 to PT2 in VP chamber and complete most of weld. Use 308 filler wire. Remove PT3 and complete weld per 02-0136-00-A | | | | |
| 3 | Replace PT3 | | | | |
| 4 | Helium leak check entire assy. thru .25" tube per 03-0013-00-B (see 9) | | | | |
| 5 | Outgas assembly in EB welder per special instructions and check operation of ion pump (see 9) | | | | |
| 6. | Remove outgassing furnace and flatten tube at location shown on B/P | | | | |
| 7. | Seal tube by EB welding per 02-0136-00-A | | | | |
| 8. | Check ion pump operation again | | | | |
| 9. | Take photos after step 4, during step 5, after step 8. | | | | |

APPENDIX B

The ion pump for the vacuum capsule requires the temperature be kept low (200°C preferably) for full pumping capacity. The switchgear environmental temperature will be 1000°F , or above. Thus, a scheme of cooling is being planned to keep the ion pump and the electrical connections at the required temperature.

This method of cooling consists of two parts:

1) Radiation Shielding

A large number of stainless steel cylinders are placed around the ion pump, air tube, and the electrical conductor. These thin wall (foil) cylinders are separated from each other by a stainless steel wire whose diameter is a few mills. This radiation heat shielding is applied to reduce the heat picked up by the parts to one tenth of the value which would be produced if there were no heat shielding. The estimated heat pickup by the ion pump and the electrical conductor is 200 watts with this heat shielding.

2) Forced Air Convection Cooling

Coaxially with the high voltage dc lead, two tubes are provided to carry air to and from the ion pump. This air cools the ion pump and the high voltage dc lead. Calculations for the air cooling have been made in the following manner, using the information included in the sketch of the system, Figure 4.

The total heat which has to be removed by the air is approximately 683 Btu/hr. Assume a 100°F air temperature rise. Then,

$$Q = W C \Delta t$$

and

$$Q = \text{heat flow, Btu/hr.}$$

$$W = \text{weight flow, lb/hr.}$$

$$\Delta t = \text{temperature rise, } ^{\circ}\text{F}$$

C = specific heat, Btu/lb-°F

For air - $C = .24$ Btu/lb-°F

$$W = \frac{683}{.24 \times 100} = 28.5 \text{ lb/hr.}$$

The volume flow W_v is equal to the weight flow divided by the density at the operating pressure and temperature.

$$W_v = \frac{W}{\rho \text{ at } 1 \text{ atm}} \times \frac{T_{\text{operation}}}{T_{\text{(known } \rho)}} \times \frac{1 \text{ atm}}{P_{\text{of operation}}}$$

For the above conditions (and assuming an operating pressure of 25 psi).

$$W_v = \frac{28.5}{.0765} \times \frac{660}{560} \times \frac{14.7}{25} = 260 \frac{\text{ft}^3}{\text{hr.}}$$

or

$$W_v = \frac{260}{3600} = 7.3 \times 10^{-2} \text{ ft}^3/\text{sec.}$$

Velocity of air in duct:

$$V = \frac{W_v}{A}$$

where V = velocity, ft/sec.

A = cross sectional area, in. ft^2

The velocity of the air in various sections of the tubing is shown in Table I.

The pressure drop was calculated from the following equation:

$$p_f = 4 f \frac{v^2 L}{2gD}$$

where

f = friction factor

ρ = density

v = velocity

g = gravitational constant - 32.3 ft/sec²

L = length of tube

D = hydraulic diameter

$D = 4 \times \frac{\text{cross section of stream}}{\text{wetted perimeter of duct}}$

Friction factor (f) was obtained from Glasstone, "Principles of Nuclear Reactor Engineering" pg. 688.

The total estimated pressure drop, in the various sections as shown in Table I, is only a few psi and well within the available shop air pressure. Calculations for the exit air temperature shows that the temperature rise is within the assumed 100°F.

Thus, the ion pump and the high potential dc lead can be cooled with forced air within a 100°F temperature rise and a few psi pressure drop for the air, as long as the air pipe within the 1000°F environment is adequately shielded to minimize heat transfer by radiation.

TABLE I

DATA OBTAINED FOR AIR FLOW THROUGH SYSTEM SHOWN IN FIGURE 4

Section (refer to Figure 4)	v - Velocity, ft/sec.	D - hydraulic diameter, ft.	$Re = \frac{Dv\rho}{\mu}$ Reynold's Number	f - friction factor	v^2 - velocity square	$A = 2\rho/g$	L - length, in. ft.	Δ_{pf} - psi
1	63.7	.025	13863	8.0×10^{-3}	4058	.00752	2.0	.1356
2	219.0	.0025	4766	1.0×10^{-2}	47961	.00752	.125	1.2523
3	119.4	.0025	2598	1.25×10^{-2}	14256	.00752	.1667	.6205
4	24.0	.0279	5829	9.8×10^{-3}	576	.00752	2.0	.0211

$$\Delta_{pf} = \frac{AfV^2L}{D.144}$$

$$\rho = .121 \text{ lb/ft}^3$$

$$\mu = 1.39 \times 10^{-5} \text{ lb/ft-sec.}$$

APPENDIX C

DETERMINATION OF OPENING TIME FOR AC VACUUM CIRCUIT BREAKER

The calculations to determine total time for the breaker from collapse of the solenoid coil field until contacts part 0.020" is given below:

M_1 = Moving mass before contacts part.

M_2 = Additional moving mass after contacts part.

M_1 Includes:

	<u>Pounds</u>
Flexure and Spring Retainer	0.92
Toggle	0.05
Armature	1.11
Coupling	0.16
Stem	0.13
Retainer	0.12
Counter Weight	1.45
Flexural Pivot	<u>0.14</u>
M_1 - TOTAL WEIGHT	4.08

M_2 Includes:

Dish	.04
Guard	---
Upper Flange	.65
Contact	.21
Radiator	1.08
Wipe Spring	.16
Insulator	.34
Copper Washer	<u>.13</u>
M_2 - TOTAL WEIGHT	2.61

To determine t_1 , which is the time between collapse of the closing coil magnetic field and parting of the contacts:

$$t_1 = \sqrt{\frac{2S M_1}{F_1}}$$

and:

$$M_1 = \frac{4.08 \text{ lbs}}{32.2} = .126 \text{ slugs}$$

$$S = 1/2 a t^2 - t = \sqrt{\frac{2S}{a}}$$

$$F = \frac{M_1}{32.2} a, \text{ and } a = \frac{F}{M_1}$$

$$S = 1/8" \text{ or } 1/96 \text{ ft.}$$

$$F_1 = F_W + F_O - F_A$$

$$(\text{Force of atmosphere on bellows}). F_A = 65 \text{ lbs.}$$

$$(\text{Average force of wipe spring}). F_W = 40$$

$$(\text{Average force of 3 opening springs}). F_O = 71.43$$

$$F_1 = 40 + 71.43 - 65 = 46.4$$

Then:

$$t_1 = \sqrt{\frac{2 \times .126}{96 \times 46.4}} = \sqrt{\frac{.252}{4450}}$$

$$t_1 = 7.46 \times 10^{-3} = 7.56 \text{ Milliseconds}$$

To determine t_2 , which is the time to open the contacts 0.020":

$$1/2 a_2 t_2^2 + V_2 t_2 - S_2 = 0$$

and:

$$t_2 = - \frac{V_2 \pm \sqrt{V_2^2 + 2a_2 S_2}}{a_2}$$

$$V_1 = a t_1 = \frac{F_1 t_1}{M_1}$$

$$V_1 = \frac{46.4 \times 7.56 \times 10^{-3}}{.126} = 2.78 \text{ ft/sec.}$$

$$M_2 = \frac{2.61 \text{ lbs}}{32.2} = .081 \text{ slugs}$$

$$M_1 V_1 = (M_1 + M_2) V_2 \text{ and } V_2 = \frac{M_1 V_1}{M_1 + M_2}$$

$$V_2 = \frac{.126 \times 2.78}{.126 + .081} = 1.7 \text{ ft/sec}^2$$

$$a_2 = \frac{6.4}{.207} = 30.9 \text{ ft/sec}^2$$

$$S_2 = .020" \text{ (Contact gap equal to twice length required to extinguish arc).}$$

$$S_2 = \frac{.026}{12} \text{ ft.} = 1.66 \times 10^{-3} \text{ ft.}$$

Thus:

$$t_2 = -1.7 \pm \frac{\sqrt{1.7^2 + (2 \times 30.9 \times 1.66 \times 10^{-3})}}{30.9}$$

$$t_2 = -1.7 \pm \frac{\sqrt{2.9929}}{30.9} = 0.938 \times 10^{-3} = .938 \text{ milliseconds}$$

$$\text{Total time equals } t_1 + t_2 = 7.56 + .938 = \underline{8.59 \text{ milliseconds.}}$$

DRAFT TEST SPECIFICATION		TEST SPEC. NO. Switchgear TS # 7
PROGRAM Electrical Switchgear for Space Nuclear Electrical Systems		
TYPE OF TEST Check-Out of Special High Temperature Oven		CONTRACT NO. NAS 3-6467
LOCATION OF TEST FACILITY (CITY, STATE) G. E. Co., Evendale - Building # 700 - SPPS		APPROVED BY
I. Special High Temperature Oven - Drawing # 246R863 II. Place completely assembled oven in vacuum tank, evacuate to 10^{-6} Torr, and raise temperature of oven surface facing inside space to 1150°F, holding this value for 48 hours. III. Special oven will be tested in Varian ultra-high vacuum tank designated CIV. Thermocouples to be Platinum/Platinum Rhodium. High current conductor and "dummy" load to be connected to 2000 cycle power from Behlman unit and step down transformer. IV. Assemble oven in tank after thorough cleaning and other preparation to mount thermocouples on oven per drawing 941D631 and on high current conductor per Engineering instructions. Connect to feed-thrus per same drawing. Check out operation of all lamps and thermocouple recording equipment. Close tank and evacuate while raising tank and oven temperature to obtain 10^{-6} Torr pressure. Constantly monitor thermocouples, maintain 600 ampere flowing in power test conductor, and continue test until stable conditions with oven surface facing inside space has been at 1150°F for 48 hours. Shut down test, and prepare to set up for heat run test TS # 1.		
FORMAT		PREPARED BY
I. Device to be tested II. General description of test III. Test facilities including description, reference & type IV. Detail test procedure		<i>A. H. Powell</i> A. H. Powell SIGNATURE 12/10/65 DATE

DRAFT TEST SPECIFICATION		TEST SPEC. NO. Switchgear - TS # 1
PROGRAM Electrical Switchgear for Space Nuclear Electrical Systems		
TYPE OF TEST Heat Run - Design Evaluation Test		CONTRACT NO. NAS 3-6467
LOCATION OF TEST FACILITY (CITY, BLDG) G. E. Co., Evendale, Ohio - Bldg. # 700 - SPPS		APPROVED BY
I. AC Vacuum Circuit Breakers rated 1 phase, 1000 volts, 600 A, 2000 cps. II. Place Breaker in an environment of 1000°F, 10⁻⁶ Torr (or lower) pressure, and measure temperature rise while carrying up to 600 A continuously until a steady state condition is observed. Record temperature of critical parts and current with 200, 400, and 600 A. III. Units to be mounted in special oven, Drawing # 246R863, and placed in high vacuum chamber designated CIV. Power for test current supplied by special high current transformer from Behlman high frequency electronic generator. Thermocouples to be Platinum-Platinum Rhodium with automatic reading of values on Honeywell recorder along with current measurements. IV. <u>Test Procedure</u> A. <u>Set-Up</u> 1) Attach thermocouples to show vital hot spots on accessible points of Breaker as shown on detail sketch. NOTE: A total of 20 thermocouples will be used for the AC Breaker with 3 on the actuator and 16 on the interrupter, and 1 on the ion pump magnet. All leads must be twisted while in high frequency field. 2) Connect Breaker to a pair of high current feed-thrus, using co-axial copper bus provided by Engineering. Also connect the floating shield of the breaker to a 5A, 7.9 KV feed-thru conductor. 3) Outside terminals of high current feed-thrus are to be closely connected to the high current transformer, permitting current adjustment and high voltage testing. 4) Use primary current measurement as an indication of the high current (from previous calibration). B. <u>Heat Run</u> 1) Connect the Breaker power feed-thrus in series with the high current transformer. The primary of the transformer will be supplied by the Behlman variable frequency power unit, set at 2000 cps. 2) Use calibrated ammeter suitable for the frequency to measure current and then a voltage measurement which will be plotted on the automatic recorder with the DC current and all thermocouple values. 3) Raise voltage (and current) in steps of 200A., holding each value until temperature is constant with the oven at 1000°F. 4) At the conclusion of the Heat Run, make High Voltage Leakage test (Refer to Test Specification # Switchgear - TS # 3).		
FORMAT		PREPARED BY
I. Device to be tested II. General description of test III. Test facilities including description, reference & type IV. Detail test procedure		<i>A. H. Powell</i> A. H. Powell SIGNATURE 12/9/65 DATE

DRAFT TEST SPECIFICATION		TEST SPEC. NO. Switchgear TS # 2
PROGRAM Electrical Switchgear for Space Nuclear Electrical Systems		
TYPE OF TEST Heat Run - Design Evaluation Tests		CONTRACT NO. NAS 3-6467
LOCATION OF TEST FACILITY (CITY, BLDG) G.E. Co., Evendale, Ohio - Bldg. # 700, SPPS		APPROVED BY
I. One DC vacuum contactor rated single pole, 10 A., 10 KV. II. Place contactor in an environment of 1000°F, 10⁻⁶ Torr (or lower) pressure, and measure temperature rise while carrying 10 amperes continuously. III. Unit to be mounted in special oven Drawing # 246R863 and placed in high vacuum chamber, designated CIV. Current for test supplied by DC rectifier power supply from AC input. Thermocouples to be Platinum-Platinum/Rhodium, with automatic reading of values, along with current measurement. IV. <u>Test Procedures</u> A) <u>Set-Up</u> 1) Attach 12 thermocouples to measure the enclosing shell, pump, and mechanism temperature. Few thermocouples will be placed on live parts, as the rise with 10 amperes DC flowing should have minimum effect on the temperature, and over-all temperature only will be monitored. Refer to detail sketch for thermocouple locations. 2) Connect the terminals to pairs of 5A., 1 KV feed-thru leads with # 12 copper conductors. Connect the external feed-thru terminals to the DC power supply, with provisions for current measurements. 3) Attach a well insulated (ceramic beads) (25 KV) small (# 14) lead from the floating shield on the contactor to the 25 KV feed-thru, for use in the Hi-Potential Leakage Test. B) <u>Heat Run</u> 1) Connect the contactor to the 10 A DC power supply, at the feed-thrus. Use an ammeter to measure the current, and a series resistor to provide a voltage measurement which will be recorded on the automatic equipment along with all thermocouple values. 2) Raise current to 10 amperes, and maintain this value during the heat run test. 3) At the conclusion of the Heat Run, make High Voltage Leakage Test (refer to Test Specification # Switchgear - TS # 4).		
FORMAT		PREPARED BY
I. Device to be tested II. General description of test III. Test facilities including description, reference & type IV. Detail test procedure		<i>A. H. Powell</i> A. H. Powell SIGNATURE 12/9/65 DATE

TEST SPECIFICATION

TEST SPEC. NO.

Swgr. TS # 6

PROGRAM

Switchgear

TYPE OF TEST

Acoustic Excitation

CONTRACT NO.

NAS 3-6467

LOCATION OF TEST FACILITY (CITY, STATE)

Philadelphia - RSD Mechanical Testing Lab.

APPROVED BY

A. H. Powell

- I. Sample is DC Vacuum Contactor rated 10 KV., 10 amps. Overall size: 22" long x 8-1/2" maximum diameter of mounting plate. See drawing 422D130.
- II. Make acoustic excitation test with sample suspended from the ceiling at a location which will provide a total intensity of 148DB. Duration of the test will be 5 minutes, with pressure level recorded in a Bruel Kjaer sound pressure level recorder. A tolerance of + 3 DB is required over the range of 1/3 octave center band frequency from 20 to 2000 cps.

NOTE: 12 Volts DC will be used to energize the launch latch device during these tests.

- III. The acoustic test facility consists of a Noise Unlimited Model 204 broadband random noise generator rated at 5000 acoustic watts and a 120 cu. ft. reverberant acoustic test chamber.

The noise field will be monitored and analyzed with a Bruel and Kjaer 4133 microphone, 2111 Audio Frequency Spectrometer and 2305 Level Recorder.

- IV. The contactor will be suspended on elastic shock cord and installed in the acoustic test chamber.

The broadband random noise generator will be turned on providing an average sound pressure level of 148 db re 0.0002 dynes/cm². The spectrum will consist of broadband random noise from 20 to 9600 cps.

A spectrum analysis will be made at start of test and after 4 minutes running time.

After 5 minutes running time, the acoustic environment will be shut down.

After the acoustic test, the contactor will be checked visually for degradation, and then checked on the bench for normal operation.

FORMAT

PREPARED BY

- I. Device to be tested
 II. General description of test
 III. Test facilities including description, reference & type
 IV. Detail test procedure

Leon Rosenthal/Bob Adel (RSD)
 and A. H. Powell (SPPS) *APR*

SIGNATURE

DATE

12/6/65

TEST SPECIFICATION

TEST SPEC. NO.

Swgr. TS # 5

PROGRAM

Switchgear

TYPE OF TEST

Acceleration

CONTRACT NO.

NAS 3-6467

LOCATION OF TEST FACILITY (CITY, STATE)

Philadelphia - RSD Mechanical Testing Laboratory

APPROVED BY

Art Powell

I. Sample is DC Vacuum Contactor rated 10 KV., 10 amps. Overall size: 22" long x 8-1/2" maximum diameter of mounting plate. See drawing 422D130.

II. Make acceleration test with sample mounted in six (6) positions:

- 1) In line with axis of arm and with top of mechanism facing away from center point of arm.
- 2) Same as (1) except turned 180° - mechanism facing center of arm.
- 3) 90° to axis of arm, with magnetic latch toward center point of arm.
- 4) Same as (3) except rotated 90° clockwise.
- 5) Same as (3) except rotated 180° and magnetic latch away from center of arm.
- 6) Same as (3) except rotated 90° counterclockwise.

Use on acceleration gradient to obtain a maximum of 7 "G" at any point on Breaker. The duration of the test in each position will be 15 minutes. No special instrumentation. Observe if Breaker is tripped open during any of the tests. Check before and after each test to detect any permanent deformation of parts.

NOTE: 12 Volts DC will be used to energize the launch latch device.

III. The test will be performed on a Genisco, Model E-185 Accelerator. This facility is capable of 30,000 G-pounds, maximum and is housed in a specially built pit for greater operating efficiency and safety.

IV. A test fixture will be designed and fabricated to mount the Vacuum Contactor such that the longitudinal axis is in line with the arm of the accelerator as described in Paragraph II 1), above. In this position, the top of the mechanism (facing away from the center) will be subjected to a load of 7.0 G's, and the base of the contactor (facing toward the center of the accelerator) will be subjected to a load of 5.3 G's. These loads will be held for 15 minutes. The breaker will then be checked for degradation. For test 2), the sample will be rotated 180°, so the base will be subjected to a load of 7.0 G's.

The test fixture utilized in the longitudinal axis test will be rotated 90° to provide the required setup noted in Paragraph II 3) above, where the sample is 90° to the accelerator arm. In this position, the edge of the contactor farthest away from the center of the accelerator will be subjected to a loading of 7.0 G's and the inner surface to approximately 6.2 G's. These loads will be held for 15 minutes. The contactor will then be checked for degradation.

For tests 4, 5, & 6 the contactor will be rotated in the fixture, so that during test the edge farthest from the center of the accelerator will be subjected to 7.0 G's. Each test will run for 15 minutes, after which the sample will be checked for degradation.

After the acceleration tests are complete the sample will be bench tested for operation.

FORMAT

PREPARED BY

I. Device to be tested

II. General description of test

III. Test facilities including description, reference & type

IV. Detail test procedure

Leon Rosenthal/Bob Adel - (RSD)
and A. H. Powell (SPFS) *AM* 12/6/65

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