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DEVELOPMENT OF ELECTRICAL SWITCHGEAR FOR SPACE NUCLEAR ELECTRICAL SYSTEMS

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CONTRACT NAS 3-6467 - PHASE I

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

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FOR SPACE NUCLEAR ELECTRICAL SYSTEMS

Quarterly Progress Report No. 6

Covering the Period

March 4, 1966 to June 4, 1966

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 March 4, 1966 to June 4, 1966, 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. Project Engineer for over-all design is E.F.Travis of the Research and Development Center in Schenectady. Project Engineer for Capsule Assembly, Welding, and Evacuation Techniques is W.R.Young, R.A.Scheffer is in charge of installation and testing, while G.Gati is following the test set-up and planning. All these Engineers are in the Space Power and Propulsion Section.

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, a continuation of the Electrical Switchgear investigation which was completed under Contract NAS 3-2546, is designed to provide detail background and knowledge for final flight hardware for space nuclear power systems of 1 to 4 megawatts capacity. The breaker is to have a continuous rating of 600 amperes and an interrupting rating of 1200 amperes, at 1000 volts, 1000 to 3000 cps. The contactor is designed to carry 10 amperes continuously and to interrupt the same value at 10,000 volts DC.

Over-all development effort on this contract is providing ground prototype breakers and contactors which can withstand limited (1000 hour) endurance testing (with normal current flowing) in a typical space environment of $1000^{o}F$ and 10^{-6} torr (or lower) pressure. The samples are scheduled to be tested to demonstrate their interrupting ability at high temperature, and to provide data on their ability to withstand expected launch (mechanical) conditions of shock, vibration, accoustic, and acceleration loadings.

Program Management is centered in the Space Power and Propulsion Section of the General Electric Company in Evendale. The major development and design work has been done at the Research and Development Center in Schenectady with technical assistance from various laboratories and personnel within the company. Final assembly of the actuators (mechanism) was done at R&DC while the interrupter unit, including the vacuum capsule assembly and outgassing processing was done at SPPS. All vacuum environment testing (endurance & interruption) will be done at SPPS while mechanical tests will be performed at the R&DC in Schenectady (vibration and shock) and the RSD Mechanical Testing Laboratory (acoustic and acceleration) in Philadelphia.

N66-33505

II SUMMARY

During the sixth quarterly period of the Switchgear Program, assembly of the first breaker and contactor was completed, the units installed in the ultra-high vacuum test tank, and testing was initiated. The heat run and high potential check was completed, and the endurance test started, with full rated current flowing in the Switchgear. At the close of this period a total of 575 hours had been successfully accumulated toward the planned 1000 hours of the endurance test.

The leak which developed in the ceramic capsules at the close of the last quarterly period, was subsequently reduced by use of a sealing fluid to the point where the attached ion pump would maintain the vacuum while under room conditions. Therefore, two capsules were used to complete the AC Breaker and DC Contactor for the heating and endurance tests. At the same time, the leak problem was reviewed in detail and the design was modified to improve the joints between the ceramic and metal spinning. New ceramic seal assemblies were ordered for use in the subsequent interruption tests.

Planning for the interruption tests continued during this period, while the heating tests were completed in the vacuum tank and the endurance test was started. New schedules were also developed which indicated that with the delay because of the capsule replacement, the interruption tests and program completion may be delayed until September.

Author

III VACUUM INTERRUPTER

The vacuum interrupter is the part of the Switchgear unit which includes the supporting shell, heat transfer and insulating members, and terminals with current conductiong parts, used to mount and attach the vacuum capsule to the power circuit. This section of the report will cover the activity connected with the vacuum capsule and assembly of the interrupter units.

A) Vacuum Capsule

Two vacuum capsules were baked out, evacuated, and sealed off with the 0.5 liter per second ion pumps attached. Quarterly Report #5 described the braze and welding procedure to provide the assembled capsule. As also mentioned in that report, a leak in the ceramic seal assembly was indicated as bake-out processing in the vacuum tank was completed and the tank was brought to atmospheric pressure to permit pinch-off of the tubulation. It was subsequently determined that the leak was in the metal-to-ceramic seal at the spinnings on the ends of the assembly. These assemblies had been checked and found tight, immediately after being welded together. Apparently stresses in the spinning from the welding were transmitted to the seal which started to leak after a period of "shelf" time.

The leak was quite low, being approximately 3×10^{-7} standard cc of air per second. However, calculations indicated the attached ion pump would not handle the leak, so two courses of action were initiated. First a vacuum sealing silicon resin liquid solution, known as GE VAC, was obtained from the GE Vacuum Products Dept. This was applied to the ceramic-metal joint at the points of indicated leaking. The capsule was then heated in vacuum to approximately 400°F, which cured the material and reduced the leak enough so the ion pump could maintain the desired low pressure. Unfortunately, the sealing compound can not stand the test temperature (1000°F) so the capsule leakage became a problem after the heat run was started, and the test tank was opened to correct a deficiency, as described in Section VIII B.

A second course of action was to plan for the endurance test to be made with the capsules purposely opened to the vacuum tank. The opening would be done by piercing a small hole, equal to 10% of ion pump capacity, in the tubulation. Thus the capsule could be suitably evacuated for endurance testing and the ion pump would still indicate with a good reliability the amount of outgassing experienced in the capsule during the test. This plan was reviewed with the NASA Technical Manager of the program who approved the procedures, but it did not become necessary to implement the plan as the leak rate was within the capacity of the ion pumps.

The two capsules were then out-gassed, evacuated, and finally sealed off, ready for the further assembly work. Figure 1 shows one of the capsules in position in the oven and vacuum tank, ready for bake-out and seal-off. Figure 2 shows the external vacuum pumping system which reduced the vacuum inside the capsule during the processing and until pinch-off of the tubulation was completed. The end of the pinched-off tubulation was subsequently electron beam welded to make the end secure and tight. The overall procedure for this processing is described in detail in Appendix A.

After completing the seal-off, the teflon air line was attached to the ion pump support, thermocouples for checking pump line temperature were attached, and the first section of the outer air line tube was attached to the pump enclosing shell. Figure 3 shows a completed assembly, with the ion pump power lead attached to a pump control unit, maintaining vacuum while awating subsequent assembly work and mounting in the Interrupter Unit shell and support.

During this period, the ceramic seal assembly was restudied in detail, in view of the leak which developed between the ceramic and metal spinning. After consultation and review with Engineers at NASA and several departments of General Electric including the Research & Development Center, it was concluded that the relatively short length of the spinning from the ceramic seal to the point where it is welded to the rodar end disks, probably produced an abnormally high stress. This condition may have placed an excessive shear force on the titanium-hydride, gold-nickel metalize/brazed joint causing a granular fracture and minute gas passages.

The spinnings were then redesigned to provide a new ceramic seal assembly with the configuration shown in Figure 4. Furthermore, a new ceramic to metal joint was selected, with a molybdenum based manganese metalized ceramic (97% pure alumina) surface which is fired in Hydrogen prior to making the braze assembly. The Kovar spinnings will then be joined to the metalized surfaces using a 50-50 gold copper brazed assembly. New parts are on order and will be available for assembly by the end of June.

The NASA Technical Manager provided important data using a NASA computer program on heat transfer, concerning temperature gradients during welding of the spinnings and flanges. This will aid in planning for the next assembly.

B) Interrupter Unit

To prepare the vacuum capsule and pump for assembly into the interrupter unit, the heat shield was put in place around the pump housing. Figure 5 shows the technician sliding the previously built shield assembly over the pump enclosure. The shield is made of 15 layers of .003" thick stainless steel with .014" diameter nichrome wire as separation between layers. This design followed the requirements given in detail in the Fourth Quarterly Report.

After placing the heat shield and attaching the thermocouples located on the vacuum capsule, the assembly (without any radiators) was installed in the D.C. Interrupter shell as shown in Figure 6. The pinched off and electron beam welded tubulation is clearly visible, along with the ceramic insulation and main power terminals.

A view of the top of this assembly is given in Figure 7. The electrical diaphragm, contact "wipe" spring, and the nut to which the actuator plunger is attached are all visible. The flat ring, held by 4 bolts, was used as a temporary aid in assembly of the parts and is removed to permit the actuator to be attached to that surface using the same mounting holes.

The radiators for the A.C. Breaker capsule cooling were assembled to the end flanges by a heat shrinking process. The radiators were heated to 425°F to produce the clearance required by the 0.002" to 0.003" interference fit. They were then placed over the flanges, positioned properly in relation to the tubulation, and held stationary until they shrank, on cooling, onto the flanges. The lower radiator was attached first, and the upper one second.

The completed unit, prior to insertion in the A.C. Breaker Interrupter unit shell, is shown in Figure 8. This picture also shows the outer bellows type air hose for the ion pump cooling, welded to the tube over which the heat shield has been placed, along with the piece of straight tube, ceramic insulator, and final straight tube which is welded to the vacuum tank feed-through during installation for test.

IV ACTUATOR

The first actuator assembled at R&DC was shipped to SPPS in January. The second actuator was assembled and then used in Schenectady for a series of preliminary tests to determine speed of operation, prior to delivery to SPPS in March.

To check performance, a fixture was developed to provide a load similar to that which is encountered with the actual interrupter. Figure 9 shows the initial design which has been used to obtain some preliminary data. This data shows that the closing time for the breaker may be as high as 30 milliseconds, with opening time a little less. A coil on the moving part of the fixture has a voltage generated in it by the stationary magnet to provide an output for a oscilloscope trace.

More complete data on operating speeds of both the Breaker & Contactor will be obtained after the heat run and endurance test is complete. It will be necessary to have this data to plan the final timing circuits for both closing and tripping the Switchgear units.

The actuator performed well, and satisfactorily latched the interrupter in the closed position. The tripping mechanism, which uses the flux from a pair of coils to repell the plunger attached to the moving toggle, needs some refinement. An open position stop for the toggle is also desireable, and will be incorporated before making the interruption test series.

V ASSEMBLY OF ACTUATOR AND INTERRUPTER UNIT

The D.C. Interrupter was assembled to the first actuator, to complete the contactor. Figure 10 shows the contactor after assembly and mounting on the copper heat sink, (at the left in the picture) in the SPPS clean room. The ion pump air line hangs below the interrupter unit, along with the thermocouple leads which are used to check on the temperatures in the capsule area during test.

To make the assembly, the wipe spring nut was held by a rod placed into one of the holes in the side of the nut, and the threads of the actuator plunger were coated with magneside oxide to simplify eventual removal. The actuator was then placed above the interrupter with 1/8" thick spacers between its base and the interrupter shell flange. The operating rod from the actuator was attached to the wipe spring nut by turning the actuator clockwise until mating thread parts were in position and the base was against the spacers. The spacers were then removed and bolts were installed to pull the actuator flange tight against the interrupter flange. This bolting action compressed the "wipe" spring the required 1/8". Of course, the vacuum capsule contacts were held in the closed position by atmospheric pressure.

Figure 10 also shows the A.C. Interrupter shell temporarily mounted to the heat sink, with the special laminated high current conductor in place, to check arrangement and alignment. The shell was then removed from the heat sink, and the vacuum capsule with the radiator attached (see Figure 8) was installed and the terminals attached to the current carrying members.

The procedure for mating the actuator to the A.C. Interrupter was the same as followed for the D. C. Contactor. Only minor problems were encountered and the units went together satisfactorily with the proper "wipe" spring compression. Figure 11 shows the completed A.C. Breaker, along with the previously assembled

D.A. Contactor, mounted on the heat sink prior to installation in the vacuum tank. Heat sink cooling coils, thermocouple leads, and the four heat sink supporting rods, are all clearly visible.

VI TEST FACILITIES

Facilities for performing the various tests required are described in this section of the report.

A) Heat Run & Endurance Test

The oven for the heat run and the endurance test (which had been baked out as described in the last report) was dismantled, and the ultra-high vacuum tank was prepared for the test. Additional feed-through flanges with adapters for the air lines were prepared and installed. (Three feed-throughs are used - one for the heat sink air and two for the ion pump cooling lines.) Thermocouples used only for the oven bake-out were removed, and the terminal boards for the connections in the oven were rearranged.

The Switchgear, mounted on the heat sink, was moved from the clean room assembly area and mounted on the oven base. Figure 12 shows the samples in position, after attachment of the thermocouples, power leads, and air lines was complete. Figure 13 is a close up view of the installation. The special high current conductor is shown at the left, attached to the Breaker. Note that both actuators (mechanisms) are wired closed to prevent accidental opening or jarring of the contacts in the capsule during set-up and test.

A view looking down towards the bottom oven lamp holders, Figure 14, shows the terminal boards where the joints are made between the thermocouple leads and feed-through leads. It will be recalled that the thermocouple leads are made of Platinum and Platinum 10% Rhodium. This material is carried through the feed-throughs to external terminal boards and then connected to recording milli-voltmeters by constant resistance lead wire.

The high frequency power supply is basically a high power electronic amplifier, driven by an oscillator with a frequency adjustable from 300 to 3000 C.P.S., made by Behlman and with a maximum continuous output of 7 KW. This supply unit is connected to a step down transformer to provide the 600 ampere current to the Breaker. Approximately 3 volts is required at the feed through terminals, and the Behlman output required is about 31 amperes at 82 volts for a load of about 2.8 KW.

The D.C. power comes from a silicon rectifier bridge with variable input voltage control to adjust the output to 10 amperes. The two ion pumps are supplied from individual pump control units having current limited circuits and maximum open circuit voltage of 4.5 KV.

B) Electrical (Interruption) testing

During this quarterly period, the capacitors for the planned interruption tests were mounted in their insulated boxes (the capacitor cases are at mid-potential during the tests) and placed in the power supply metal enclosure. The special high Q inductance coils for the A.C. "ringing circuit" were tested and rejected because of short circuits between the laminations of the built-up conductor. This would have caused eddy currents and losses in the circuit, so they are now being rebuilt.

Other components for the main power supply, including the co-axial current measuring shunts, safety high voltage grounding switches, non-inductive charging resistors, etc., are available. Layout of the bus work, adjustable jumper connections, etc., is nearly complete. Study of the overall testing circuit is also underway to determine what modifications could be made if the test procedure is changed and it becomes necessary to maintain test voltage and current for longer than the 20 to 30 milliseconds that has been expected.

However, the work on the test power supply has been at a minimum because the delay in obtaining the new ceramic capsules for the test samples will extend the date for start of the tests.

C) Mechanical Testing

Final work on the fixtures for the mechanical testing program has been held up due to the delays in sample procurement and completion of the endurance tests. However, test plans are available and will be implemented so as to make the vibration, shock, acceleration, and acoustic noise tests towards the middle of the next quarter, after the endurance tests are complete.

VII HEAT RUN AND ENDURANCE TEST

A) Test Procedure

When the installation was complete, the Switchgear equipment was checked out by passing rated current through it and observing thermocouple action, while at room conditions. The oven top was then installed, all lamp connections made, and lamp current as well as switchgear current was used to again check operation of T.C.'s, etc. The tank lid was then put in place and pump-down started. Initial pumping was with a mechanical pump through a suitable manifold, and a helium leak check was made to be sure the equipment was tight. Pumping then continued, using sorbtion pumps until the vacuum tank was contained on its 1000 liter/sec. ion pump. Subsequently, the power on the oven lamps and tank heaters was gradually increased while outgassing took place, until a generally stable condition was reached on May 2, with the heat sink and switchgear outer shells at approximately 1000^{o}F. The tank pressure was at 2.3 X 10^{-6} torr. Refer to Appendix B-1,2,3,4 & 5.

B) First Heat Run

The first heat run was started on May 2, by applying 10 A, to the DC contactor and 200 A to the AC breaker. After 12 hours there was no appreciable change in the temperature of various parts of the Switchgear, so the AC current was increased to 400 A, and eventually to 600 A. It was noted that shortly after increasing the current to 400 A, certain thermocouple readings on the AC bus and breaker lower terminals went down. At that time the change was attributed to changes in the general heat pattern. (Subsequently it was decided that this change took place when the closely spaced AC bus distorted (as described below) and shorted together near the high current feed throughs).

Finally, on May 4, two check tests demonstrated that the AC bus was indeed shorted. First, little or no voltage could be measured across the breaker contacts. Second, the AC power was turned off, and after about 2 hours the power was turned on. Voltage appeared across the breaker contacts, and the contacts started to heat as shown by temperature measurements, until approximately 45 minutes after power was turned on, when the breaker contact voltage dropped suddenly to zero. This last test was repeated (current off, then on) with the same results. Therefore, it was decided to shut down the test and open the tank and oven for inspection.

The temperatures obtained from representative thermocouples during the first heat run test described above are listed in Table 1. The thermocouples are located as shown in Figure 15. All the basic data has been permanently recorded on chart rolls from the two 24 point recording millivoltmeters. Important representative data has been hand transferred onto copies of a special data sheet which has been developed for this program and will provide quick, permanent reference data.

Several important results and observations were obtained during the initial test activity, even though final results on the heat run could not be obtained until the second heat run (see Paragraph B).

1) With the variety of adjustments available including 5 groups of lamps, air for heat sink and ion pumps, and water for high current feed-throughs and tank walls, it is possible to hold the environmental (and heat sink) temperature at 1000^{o}F within $\pm$ 25^{o}F.

2) The 0.5 liter/second ion pumps attached to the capsules were able to hold the pressure inside to 3×10^{-7} torr, or lower, even with maximum temperatures above 1000^{o}F. This would indicate that outgassing of the material in the capsule may not be as serious as expected during the design stages of the program.

3) The surface of the ceramic parts of the vacuum capsule may be contaminated. A "Megger" check (with 500 volts) between the floating (center) spinning and end connections (ground) indicated a resistance of as much as 50 megohms originally, in vacuum, at room temperature, decreasing to less then 0.5 megohms after a period of time at environment temperature. This could result in excessive leakage and in fact, difficulty during interruption, although it may improve as the test progresses. It also indicates that the problem may require more detailed investigation.

C) Second Heat Run

The vacuum tank was opened at the close of the first heat run, and it was found that the closely spaced and laminated AC bus had indeed moved and shorted together as a result of expansion and vibration from the 2000 CPS test current. Therefore, ceramic spacers were added to prevent recurrence of the failure.

Opening the tank resulted in an oportunity to observe the switchgear after approximately 50 hours at test temperature in a vacuum of 10^{-6} torr. It was noted that the switchgear opening springs and supports were slightly blueish (the springs are made of inconel). There was also some dark coloring on the ceramic beads on the DC leads, etc. Oven slats and other stainless and copper parts were quite bright.

A check of the resistance between the capsule center spinnings and end terminals at the time the tank was being prepared for opening gave the following results.

Unit	@ 200°F & 10^{-6} torr	@ Room Temp. & pres.
AC Capsule	3.2 Megohms	500 Megohms
DC Capsule	1.7 Megohms	500 Megohms

Note: These values may be compared with the results shown in Table 1, which indicated resistance was less than 1 Megohm at high temperature and vacuum.

An additional problem developed during opening of the tank in that while the DC capsule ion pump continued to perform satisfactorily and indicate a good vacuum when the switchgear was at room condition, the AC capsule pressure apparently went up appreciably. The AC pump control indicated the vacuum in the capsule was at least 10^{-3} torr, a value that was confirmed by subsequent DC leakage checks. However, it was decided to close up the tank and proceed with the second heat run, with the hope that the AC capsule pressure would reduce (when the tank pressure was in the 10^{-6} or 10^{-7} torr range) and the ion pump would start pumping again.

The tank was closed, pumped down and checked out over a 24 hour period. The oven was brought up to full temperature and when conditions had stabilized, the second heat run was started on May 11 at 0900. The first check was made with 300 amps, 2000 cps, applied to the AC breaker and 10 amps DC applied to the DC contactor. In 45 minutes the temperature of the Switchgear had apparently stabilized. Critical data is listed in table II. The results showed the AC contacts rose 45°F, the top of the capsule rose 35°F, the upper terminal rose 65°F, the lower terminal 35°F, and the bottom of the capsule rose 50°F.

At 1115 the AC current was raised to 600 amperes (the DC remained at 10 amperes). Temperatures were about stable at 1300. The results at this time showed the AC contacts rose another 65°F, the top of the capsule another 45°F, the upper terminal another 45°F, the lower terminal an additional 90 degrees, and the bottom of the capsule another 50°F.

In summary, the heat run showed a final total rise at key points, of the following temperatures (which are taken from Test Results Reports, Appendix C-1 & 2)

		Rise	Total
A C -	Contact surface	110°F	1070°F
	Top of Capsule	80°F	1090°F
	Upper term	110°F	1080°F
	Bottom of Capsule	100°F	1045°F
	Lower term	125°F	1045°F
	Upper Radiator	85°F	1060°F
	Shell (near upper rad.)	55°F	1045°F
	Heat Sink	15°F	1025°F (With air cooling coils)
D C -	Top of Capsule	50°F	1025°F
	Bottom of Capsule	55°F	975°F
	Terminal	35°F	965°F
	Heat Sink	45°F	1055°F (No special cooling)

One conclusion from this data would be that the AC temperature rise of the contacts was less than one third the maximum possible rise considered during the design stages of the program (see Quarterly #3). This may be due to welding of the contacts (which cannot be checked until the test is completed) but more likely is due to lower then expected resistance. The conductor bars were at such a temperature that there was only a small difference across the terminals (5 to 15°F in more than 1000°F). The DC contactor temperature rise due to current heating was actually smaller then shown above, because the heat sink rose appreciably (45°F) due to lack of heat removal facilities, as compared with the area around the AC breaker which rose only 15°F due to the air filled cooling coils.

The heat run data also showed that the temperature of the AC actuator pivot reached a total of 1115°F (probably due partly to the slat and upper lamp heating) while the main solenoid coil pocket had a temperature of 1085°F. Both temperatures could be compared with the reading at the top of the AC capsule of 1090°F, and the DC capsule of 1025°F. The capsule ion pumps were both being cooled by a continuous air flow, which kept the tube connecting the pump to the lower capsule disk at about 925°F. The thermocouples on the pump magnet supports (the side away from the capsule) showed a temperature of 300°F or less, indicating the heat shielding and air cooling was effectively keeping the pump temperature within desired operating limits.

D) High Potential Test

Initial high potential check was made between the center (floating) spinning of each capsule and the end terminal, while at low (room) temperature, at vacuum and atmospheric pressure. The results, including data obtained after termination of the first heat run, are included in part C. above. At room conditions the resistance was more than 500 megohms (with 500 Volt Megger) on both AC & DC capsules, but at high temperature was much lower.

On May 11 at 1400, while taking heat run data recorded in table II, both the AC & DC capsule high voltage withstand ability was given a preliminary DC high potential check between center spinning and end terminals. The AC unit would hold a maximum of only 400 volts, at which point the leakage was 1.0 milliamps. As the voltage control was further advanced, the voltage would not increase but the current rose rapidly. The DC unit held a maximum of 5 KV (the limit of the initial test set), at which point the leakage current was 1.5 milliamperes. The leakage current with 2.5 KV applied was 0.5 millamperes.

The initial high potential test with full rated power supplies was made on May 13, shortly after the start of the endurance test. Data from these tests are given in Test Results Report TR #3 & 4 - Appendix C-3 & 4.

1) D.C. Test

The DC voltage was raised to 8.1 KV, at which point the leakage current was 3.5 milliamperes.Attempts to further increase the voltage resulted in no voltage change but a radical increase in leakage currents.

Subsequent tests on the DC unit showed further reduction in voltage withstand ability (and appreciable leakage current) indicating deterioration of the capsule ceramic insulation (or the integrity of the insulation on the lead connecting to the capsule).

Results of the tests for this first check, are given in more detail in Report TR #4 (see Appendix C-4). A second series of tests will be conducted at the conclusion of the Endurance Test.

2) A.C. Test

The AC voltage of 2000 cps was originally used to check the capsule ceramic insulation on May 17, but no appreciable voltage could be observed. Apparently there was excessive leakage current, thus limiting the output of the special transformer.

Subsequently, the leakage condition improved, and on May 19, eight days after the Endurance test started, a recheck showed that a withstand of 1000 volts, 2000 cps was obtained, with a leakage current of 0.3 milliamperes.

Data from the test is given in more detail, in TR #3 (see Appendix C-3) for this first series of tests. A second series will be made at the end of the Endurance test.

E) Endurance Test

Following the heat run test, and as soon as the temperature of all critical points had apparently stabilized, the endurance test was started. Test time recording was initiated on May 11 at 1600. Through the close of this quarterly reporting period, a total of 575 hours had been logged so the required 1000 hours was more then half completed.

As the test progresses, a continual chart record is made every 5 to 6 minutes of all active thermocouples. Technician observations and hand recording of key readings are made twice a day on a continuing log sheet. Typical readings from this log are listed in table III. The results indicate a very stable condition exists in the oven, test tank, and the switchgear. Minor variations are undoubtedly due to slight misalignment of chart paper as rolls are changed, and minor variations in readings by the several technicians involved with the test.

VIII SCHEDULE AND PLANS

The development of assembly and sealing techniques, plus extra assembly time to complete the interrupter units and actuators, delayed the start of installation in the test tank for the heat run and endurance tests. The installation also involved more complexities than originally expected, and the initial heat run test had to be terminated and corrections made before starting the actual test, as explained in Section VII B & C of this report. The overall result has been a six weeks slippage in completion of the endurance test, now expected by the end of June.

An even greater delay will be encountered in completing the interruption tests, for new ceramic seal assemblies made to the new design discussed in Section III A of this report will not be available until the end of June. New vacuum capsule with the new ceramic assemblies must be processed and assembled into interrupter units, before the interruption tests can start. In now appears that these tests should be completed by the middle of September.

As soon as the endurance test is complete, coils will be installed in the actuators, and the Switchgear units will be mechanically tested (as previously planned) in Schenectady and Philadelphia. These tests should be complete by early August.

It is expected that the program, as now defined, will be completed during the next quarterly period.

TABLE I

TEMPERATURE READINGS (^{o}F) - AT CRITICAL POINTS

DURING FIRST HEAT RUN

DATE AND TIME	Thermocouple Numbers - (See Fig. 15 for Location)											Switchgear Current AC is 2000 cps
	1	6	12	15	29	24	33	34	36	39	45	
4-30-66 1230	Oven Lamps turned on after tank was on Ion Pump at 6.8 X 10^{-7} torr pressure											0
5-2-66 1630	1090	913	1037	1005	965	974	901	929	883	983	983	200 AC - 10 DC
5-3-66 1530	1063	1028	1108	1010	974	1010	945	1005	935	937	1019	600 AC - 10 DC
5-4-66 1330	1090	1060	1130	1040	1040	1075	1040	1040	1010	960	1040	600 AC - 10 DC
5-4-66 1505	Shut off Switchgear and Lamp Power to shut down test											0

Notes: 1. Tank Pressure was a maximum of 8 X 10^{-6} torr during heat-up (and outgassing). Pressure was at 2.1 X 10^{-6} torr at time of shut down.

2. Capsule Pressure rose from approx. 3 X 10^{-7} torr to 1 X 10^{-6} torr as heat was applied and maintained.

3. Capsule Resistance (Center Ring to End Term.) changed from approx. 50 megohms (cold) to 0.3 meg. on AC and 0.17 meg. on DC when at environment temperature (1000^{o}F).

TABLE II

TEMPERATURE READINGS (^{o}F) - AT CRITICAL POINTS

DURING SECOND HEAT RUN TEST

DATE AND TIME	Thermocouple Numbers - (See Fig. 15 for Location) 1	6	12	15	20	23	24	31	33	35	38	39	43	45	Switchgear Current - Amps AC is 2000 cps
5-11-66 0800	1045	920	1070	1010	945	990	975	935	930	935	920	930	1045	975	No Current - Conditions Stable
5-11-66 1100	1075	965	1108	1000	990	1010	1010	1000	955	985	955	955	1075	1010	Current on at 0915 A.C.-300, D.C.-10
5-11-66 1200	1075	965	1108	1000	1045	1030	1070	1035	1035	1030	955	955	1075	1010	Current raised at 1120 to A.C.-600, D.C.-10
5-11-66 1300	1075	975	1115	1010	1055	1035	1080	1080	1045	1035	965	960	1075	1020	A.C.-600, D.C.-10 (oven lamps adjusted)
5-11-66 1400	1080	980	1115	1010	1065	1035	1080	1085	1050	1035	966	960	1080	1020	A.C.-600, D.C.-10
5-11-66 1600	1075	965	1100	1010	1045	1030	1080	1085	1035	1035	955	950	1075	1020	A.C.-600, D.C.-10

Notes: 1. Heat run completed and endurance test started on 5-11-66 at 1600.
2. Tank pressure varied from 1.4×10^{-6} to 2.4×10^{-6} torr during test.
3. D.C. Capsule pressure was 6×10^{-7} torr during test, but A.C. Capsule was at 10^{-3} or higher.

TABLE III

TEMPERATURE READINGS (^{o}F) - AT CRITICAL POINTS DURING ENDURANCE TEST

DATE AND TIME	Thermocouple Numbers - (See Fig. 15 for Location)												
	1	6	12	15	20	23	24	31	33	38	39	43	45
5-11-66 1700	1070	075	1100	1010	1055	1040	1080	1085	1035	965	955	1075	1025
5-12-66 1600	1060	980	1095	1010	1045	1020	1060	1075	1035	955	945	1070	1015
5-16-66 1630	1070	980	1088	1015	1060	1035	1068	1068	1040	965	950	1070	1015
5-20-66 1730	1070	980	1095	1015	1060	1037	1077	1090	1045	977	950	1075	1020
5-24-66 1630	1060	970	1088	1015	1055	1030	1065	1085	1045	985	960	1075	1023
5-27-66 1700	1070	980	1088	1015	1060	1035	1070	1085	1042	975	955	1075	1023
5-31-66 0630	1068	990	1088	1015	1060	1035	1067	1080	1050	978	958	1080	1028
6-3-66 0635	1068	980	1088	1015	1060	1035	1070	1090	1050	977	958	1080	1027

Switchgear Current is 600 A., 2000 cps & 10 A. D.C.

Note: Tank pressure varied from 1.4×10^{-6} to 3.0×10^{-7} torr during this period.

APPENDIX A

APPENDIX A

EVACUATION, BAKE-OUT, AND SEAL-OFF OF VACUUM CAPSULE FOR HIGH TEMPERATURE SWITCHGEAR

The completed capsule assembly (the capsule with an ion pump and nickel evacuation tube welded in place) was baked-out at 1200^{o}F for 25 to 30 hours. A special clam shell type furnace was constructed, using six 500 watt quartz lamps as the heat source. The clam shell furnace was placed about the capsule assembly inside a vacuum chamber, as shown in Figure 1. The vacuum chamber at a pressure of 10^{-5} torr, or lower, provided protection from oxidation to the outside of the capsule during bake-out, while the inside of the capsule assembly was evacuated through a tube to an external pumping system. The external pumping system consisted of a liquid nitrogen cooled sorbtion pump and a 25 liter per second ion pump, arranged as shown in Figure 2.

Because teflon insulation was used for the high voltage ion pump lead of the capsule assembly, the ion pump temperature could not exceed 400^{o}F during bake-out. A maximum temperature of 360^{o}F was maintained by placing a water cooled copper coil around the ion pump assembly.

Pressure measurements inside the capsule assembly were read at the external pumping system. Because of conductance limitation of the evacuation tube, pressure in the capsule assembly was calculated to be approxim ately 100 times the external reading. Prior to bake-out, the ceramic components of both completed capsule assemblies, had very small leaks on the order of 2.9 X 10^{-7} stc. cc/sec. of air at the lower metal to ceramic brazed joint.

The pressure in capsule 4-5 (which was used for the AC Circuit Breaker) was 1.2 X 10^{-8} torr, as read at the external pumping station before turning on the furnace for bake-out. After a 25 hour bake-out and slow cooling to room temperature, the pressure was 1.0 X 10^{-8} torr. Back-filling the vacuum chamber with air caused the pressure to rise to 1.6 X 10^{-8} torr, again indicating the before mentioned leak. A vacuum leak sealer, silicone resin GE SR-82 and Xylol solvent, was painted on the leaking metal to ceramic joint, and cured at 400^{o}F for 1 hour. The capsule pressure after cooling was 8.4 X 10^{-9} torr, and after pumping over night it read 8.0 X 10^{-9} torr. At this time the capsule assembly was ready for pinch-off sealing of the nickel evacuation tube.

Several trial pieces of "as-received" nickel tube had been pinched-off using a hydraulic powered pinch-off tool. Leak testing of these joints with a helium mass spectrometer, showed them to be leak tight. Since these tubes had not been vacuum outgassed prior to cooling, no difficulties were contemplated in sealing capsule tubes.

After pinch-off of the capsule tube the pressure dropped to 4.8 X 10^{-9}, which indicated very minute leakage of the capsule assembly. This leakage was easily overcome by the small ion pump on the capsule assembly as shown by its successful operation after pinch-off. The pinch-off sealed capsule assembly was then transferred to the electron beam weld chamber, where it was permanently seal welded at the pinch.

Capsule 3-2 (which was used for the DC Contactor) was baked-out under the same conditions, with only small differences in processing pressures. The pressure before bake-out was 1.1 X 10^{-8} torr, almost identical with capsule 4-5. After bake-out the pressure was down to 5.6 X 10^{-9} torr, which was lower than was achieved with capsule 4-5. Back-filling the chamber with air brought the pressure up to 1.3 X 10^{-6} torr, indicating a larger leak. Vacuum leak sealer was applied to the lower metal to ceramic brazed joint, with only slight improvement in the pressure. With localized spraying of argon gas and observation of the pressure, a leak was found apparently in the spun Rodar dish at the bottom of the capsule. Application of the vacuum leak sealer brought the pressure down to 4.4×10^{-9} torr. Pinch-off and seal weld was made as with capsule 4-5, with equally good results. The ion pumps of both capsule assemblies were kept pumping during final assembly to preserve the calculated 10^{-7} torr internal pressure.

Previous experimentation with the above mentioned silicone vacuum sealant, had shown no difficulty with out-gassing at temperatures to $1100^{\circ}F$ when first cured at $400^{\circ}F$ for 1 hour. It is possible the sealant will not remain throughout the endurance run. However, it will maintain the capsule vacuum until the test chamber reaches test conditions and so will have achieved its intended purpose. The ultra high vacuum of the test chamber will preserve the capsule vacuum, even if slight leakage occurs during endurance run.

APPENDIX B

TEST SPECIFICATION	TEST SPEC. NO. 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: AHPowell

I. AC Vacuum Circuit Breakers rated 1 phase, 1000 volts, 600 A, 2000 cps.

II. Place Breaker in an environment of $1000^{o}F$, 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 300 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.

IV Test Procedure

A Set-Up

1) Attach thermocouples to show vital hot spots on accessible points of Breaker as shown on detail sketch, Figure 15.
2) Connect Breaker to a pair of high current feed-thrus, using laminated low inductance 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 transformer primary current measurement as an indication of the high current (from previous calibration).

B. Heat Run

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 meters suitable for the frequency to measure current and voltage. All temperatures to be plotted on the automatic millivolt recorders.
3) Raise voltage (and current) in steps of 300A, holding each value until temperature is constant with the oven at $1000^{o}F$.
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 and type IV. Detail test procedure	AHP A. H. Powell 12-9-65 Revised 6-15-66 SIGNATURE DATE

SP 1145

TEST SPECIFICATION	TEST SPEC. NO. 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 (signature)

I. One DC vacuum contactor rated single pole, 10 A., 10 KV.

II. Place contactor in an environment of 1000^{o}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. Test Procedures

A) Set-Up

1) Attach thermocouples to measure the enclosing shell pump, and mechanism temperature as shown in Figure 15.

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) Heat Run

1) Connect the contactor to the 10 A DC power supply, at the feed-thrus. Use an ammeter to measure the current.

2) Raise current to 10 amperes and maintain this value during the heat run test.

3) Record thermocouple output values on automatic millivolt char recorders.

4) 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 and type IV. Detail test procedure	A.H.Powell 12-9-65 (SIGNATURE)	Revised 6-15-66 (DATE)

SP 1145

TEST SPECIFICATION	TEST SPEC. NO. TS #3
PROGRAM Electrical Switchgear for Space Nuclear Electrical Systems	
TYPE OF TEST High Voltage Leakage	CONTRACT NO. NAS 3-6467
LOCATION OF TEST FACILITY (CITY, BLDG.) G. E. Co., Evendale, Ohio - Bldg. 700 - SPPS	APPROVED BY AHPowell

1) One AC vacuum (sealed) circuit Breaker rated 1 phase, 600 A, 2000 cps.

2) With Breaker in high temperature and vacuum environment as described in Switchgear T.S. #1, determine leakage current across capsule insulation with 1500 volts, 2000 cps applied.

3) Breaker will be mounted in the special oven, and in the high vacuum chamber designated C IV, as it was for the Heat Run Test (Switchgear T.S. #1) and without changing the set-up in the chamber. The high voltage will be supplied from the special high frequency transformer, with a milliammeter used to measure leakage current.

4) A determination of the leakage current, if any, across the vacuum capsule insulators will be made immediately after 1) the Heat Run test, and also 2) after the long time Endurance Test. The procedure for making the test is as follows:

   A) The high current transformer leads need not be disconnected. The Ion Pump power supply also to be left energized. Maintain environment temperature and pressure.

   B) Apply one of the high voltage leads (from special transformer) to lead from "floating" shield at 7.9 KV feed-thru.

   C) Apply other lead, through a suitable milliammeter, to one of power feed-thrus and connection to sealed unit contacts.

   D) Raise voltage to min. of 1.5 KV and if possible (without flashover) to a max. of 3 KV, 2000 cps applied. This checks vacuum capsule insulation to ground.

FORMAT	PREPARED BY
I. Device to be tested II. General description of test III. Test facilities including description, reference and type IV. Detail test procedure	AHP A. H. Powell 8-2-65 Revised 6-15-66 SIGNATURE DATE

SP 1145

TEST SPECIFICATION

TEST SPEC. NO. TS #4

PROGRAM

Electrical Switchgear for Space Nuclear Electrical Systems

TYPE OF TEST

High Voltage Leakage

CONTRACT NO.

NAS 3-6467

LOCATION OF TEST FACILITY (CITY, BLDG.)

G. E. Co., Evendale, Ohio Bldg. 700, SPPS

APPROVED BY

1) Device is single pole DC vacuum Contactor rated 10 A, 10 KV.

2) Test will determine leakage current across insulation of vacuum capsule with up to 15 KV applied while Contactor is in the high temperature and vacuum environment described in Switchgear T.S. #2.

3) Test facility will include the oven and vacuum chamber used for the Heat Run, without disturbing the set-up in the chamber. High voltage will be supplied by a DC test set, and a milliammeter will be used to measure leakage current.

4) A determination of the leakage current, if any, will be made immediately after 1) the Heat Run and also 2) after the Endurance Test. The procedure for making the test is as follows: This test will be made at the same time as the test on the AC Breaker (T.S. #3).

A) Remove DC power supply and connect the feed-thru conductors to ground. Leave Ion Pump power supply energized. Maintain environment temperature and pressure.

B) Attach one side of high voltage DC test power supply to the grounded terminals, through a suitable milliammeter. Connect the other lead to the 25 KV feed-thru and the floating shield of the vacuum capsules.

C) Raise voltage to a min. of 15 KV and if possible (without flashover) to a max. of 25 KV., measuring the leakage current across the vacuum unit insulation. This checks the vacuum capsule insulators.

FORMAT

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

PREPARED BY

SIGNATURE		DATE
A. H. Powell	8-21-66	Revised 6-15-66

SP 1145

TEST SPECIFICATION

TEST SPEC. NO.	TS #8
PROGRAM	Electrical Switchgear for Space Nuclear Electrical Systems
TYPE OF TEST	Endurance (Heating)
CONTRACT NO.	NAS 3-6467
LOCATION OF TEST FACILITY (CITY, BLDG)	G. E. Co., Evendale, Ohio Bldg. 700, SPPS
APPROVED BY	[signature]

I Samples to be tested are:

AC Breaker rated 1 phase, 1 KV, 600 A, 2000 cps Dwg. #422D129
DC Contactor rated 10 KV., 10 A., Dwg. #422D1301

II After completion of Heat Run tests and first High Potential (leakage) test, make Endurance test for 1000 hours.

A) Use same switchgear current settings, oven temperatures, and heat sink cooling as recorded at completion of Heat Run test.

B) Continue test for 1000 hours.

C) Measure thermocouple outputs (to provide temperature measurement) of all active T.C.'s, using a continuous paper chart millivolt recorder.

D) Periodically (at least twoce/day) check specific and critical temperatures (as determined by Engineering) and hand record information on special form, along with data showing Switchgear current, tank and capsule pressure, resistance of capsule to ground, and hours on test.

FORMAT	PREPARED BY	
I. Device to be tested II. General description of test III. Test facilities including description, reference & type IV. Detail test procedure	A.H. Powell (SIGNATURE)	5-11-66 (DATE)

SP 1145

APPENDIX C

TEST RESULTS

NO. TR #1

PROGRAM

Switchgear

TYPE OF TEST

Heat Run - (A.C.)

CONTRACT NO.

NAS 3-6467

LOCATION OF TEST

G.E. Co Evendale Ohio, Bldg. 700 SPPS

TEST SPEC. REF. (NO. & DATE)

TS #1 Revised 6-15-66

Measurements made with calibrated recorders and special high frequency Ammeter and Voltmeter, on May 11.

With the oven, heat sink, and switchgear at approximately 1000°F, in the C IV vacuum tank with a pressure of about 2 X 10^{-6} torr, the heat run started with 300 amps 2000 cps, applied to the AC breaker. The total temperature stabilized after approximately 1 hour with the load current. Results were shown in detail on the chart read-out of thermocouple outputs. Typical important results are shown in the table below.

After checking the results with the 300 amperes flowing, the breaker load current was raised to 600 amperes. After approximately 1 hour, temp rise had again stabilized. Following another 2 hours of operation, final results were recorded, and typical data is given in the table below.

Measurement Point	Rise - 300 A.	Rise - 600 A.	Total Rise
A.C. Contact Surfaces	45°F	65°F	110°F
Top of Capsule	35°F	45°F	80°F
Upper Term	65°F	45°F	110°F
Bottom of Capsule	50°F	50°F	100°F
Lower Term	35°F	90°F	125°F
Upper Radiator	35°F	50°F	85°F
Outer Shell (nr. Rad.)	25°F	30°F	55°F
Heat Sink	5°F	10°F	15°F

Conclusion - Temperature rise is reasonable and lower then originally expected. Maximum rise of the contacts above the heat sink is only 95°F.

FORMAT	PREPARED BY		APPROVED BY	
I. Device tested II. Reference to measuring instruments used - date last checked III. Results - Description - Tabulation of values	A. H. Powell	6-15-66	A H Powell	6/17/66
	SIGNATURE - [redacted]	DATE	SIGNATURE	DATE

SP 1146A

TEST RESULTS	NO. TR #2
PROGRAM: Switchgear	
TYPE OF TEST: Heat Run - (D.C.)	CONTRACT NO.: NAS 3-6467
LOCATION OF TEST: G. E. Co., Evendale Ohio, Bldg. 700 SPPS	TEST SPEC. REF. (NO. & DATE): TS #2 Revised 6-15-66

Measurement of current made with specially calibrated panel meter in D.C. (static) generator.

With the oven, heat sink, and switchgear at approximately 1000°F, in the C IV vacuum tank with a pressure at about 2×10^{-7} torr, the heat run was started with 10 amperes applied to the contactor, on May 11.

It was hard to detect any specific temperature rise of effect from the relatively low D.C. current. A total rise, over temperature before the test started, of critical points in the Switchgear are given below.

Measurement Point	Total Rise
Top of Capsule	50°F
Bottom of Capsule	55°F
Terminal	35°F
Heat Sink	45°F

It should be noted that the heat sink temperature went up 45°F, due apparently to the heat generated by the AC breaker which is mounted on the same heavy copper plate with only 1" separating the two devices. Note that the maximum total rise over the heat sink is only 10°F.

FORMAT	PREPARED BY		APPROVED BY	
I. Device tested II. Reference to measuring instruments used - date last checked III. Results - Description - Tabulation of values	A. H. Powell	6-15-66	A H Powell	6/17/66
	SIGNATURE - ~~TESTER~~	DATE	SIGNATURE	DATE

SP 1145A

TEST RESULTS	NO. TR #3
PROGRAM Switchgear - AC	
TYPE OF TEST High Potential (Leakage) Test #1	CONTRACT NO. NAS 3-6467
LOCATION OF TEST G. E. Co., Evendale, Ohio Bldg. 700 SPPS	TEST SPEC. REF. (NO. & DATE) TS #3 Revised 6-15-66

An initial high potential check on the AC capsule was made with a DC supply, on May 11 which indicated a maximum withstand of 400 volts. Subsequently on May 13, the DC withstand was only 300 volts, at which point the leakage was 0.5 milliamperes but as the voltage control increased the leakage went up sharply with no change in voltage. Environment was at 1000 $^{\circ}$F and 2.4 X 10^{-6} torr pressure.

On May 17, (6 days after the Endurance test started) another check was made with the same results in that the maximum withstand was 300 volts. The high potential A.C. testing transformer was then connected to the test points but a maximum of only 30 volts could be applied before the high resistance built into the transformer prevented higher voltage because of the leakage current. After the AC test, another attempt was made to apply a DC voltage, and as the current suddenly dropped while the voltage went up to 2 KV. By slowly raising the voltage control it was possible to get the DC withstand up to 4 KV with no more than 1 milliampere of leakage current. (It was at this point that the AC Ion Pump also started operating). Possibly there had been a metal "whisker" or some other low resistance part in the capsule and/or pump, which burned loose and corrected the high potential and pumping problem. On the other hand, pressure in the capsule may have gotten below the "Paschen" minimum so the withstand value went up.

On May 19, the "Megger" showed a resistance between the center spinning and end terminals of the AC unit, of 2 megohms at 500 volts. A new AC test resulted in a withstand of 1000 volts at 2000 cps, with a leakage current of 0.3 milliamperes (the voltage being limited by the built-in resistor). A DC check showed a withstand of 2 KV with a leakage current of 0.5 milliamperes.

FORMAT	PREPARED BY		APPROVED BY	
I. Device tested II. Reference to measuring instruments used - date last checked III. Results - Description - Tabulation of values	G.Gati G.G.	6-15-66	R A Powell	6/16/66
	SIGNATURE - TESTER	DATE	SIGNATURE	DATE

SP 1145A

TEST RESULTS	NO. TR #4
PROGRAM Switchgear - DC	
TYPE OF TEST High Potential (Leakage) - Test #1	CONTRACT NO. NAS 3-6467
LOCATION OF TEST G. E. Co., Evendale, Ohio Bldg. 700 SPPS	TEST SPEC. REF. (NO. & DATE) TS #4 Revised 6-15-66

Test was made with a D.C. high voltage static generator, capable of providing 35 KV and 15 milliamperes, on May 17. Environment was 1000°F and 1.8 X 10^{-6} torr pressure.

The DC voltage was applied between the High Voltage feed-through and power terminals, and was raised slowly to 8.1 KV, at which point the leakage current was 3.5 milliamperes. As the voltage control was further advanced, the voltage would not go higher but the leakage current started to rise very sharply. Voltage was reduced to zero and a repeat test made, but this time the maximum voltage obtained was 7 KV before leakage current rose sharply. A third attempt resulted in a maximum of 5.5 KV with 0.7 millamperes leakage, after which the current rose sharply with no change in voltage. Apparently the resistance of the capsule surface or insulation on the lead wire in the tank was deteriorating.

Subsequent tests on the DC unit showed further reduction in the voltage which could be held across the center spinning (and lead wire) and end terminals (ground). On May 18, 3.5 KV high potential resulted in a leakage of 0.3 milliamperes, which rose sharply to 5 milliamperes at 4 KV. On May 19, 3.5 KV resulted in a leakage of 0 5 milliamperes, but at 4 KV it went up to 15 milliamperes. On May 20, no DC voltage could be held across the test points. A check with a "Megger" at this point showed 0.7 megohms resistance with 50 volts applied, but less than 0.5 megohms with 500 volts A further check on May 21 resulted in no measureable resistance with 50 or 500 V on the megger, although a voltohmist (low voltage) indicated about 100 K ohms. Obviously there has been a major change in the insulating surfaces, or perhaps there has been some movement and high resistance grounding of the hipot lead inside the tank. The answer cannot be obtained until the endurance test is terminated.

FORMAT	PREPARED BY		APPROVED BY	
I. Device tested II. Reference to measuring instruments used - date last checked III. Results - Description - Tabulation of values	G.Gati G.G.	6-15-66	R.A. Powell	6/16/66
	SIGNATURE - TESTER	DATE	SIGNATURE	DATE

SP 1165A

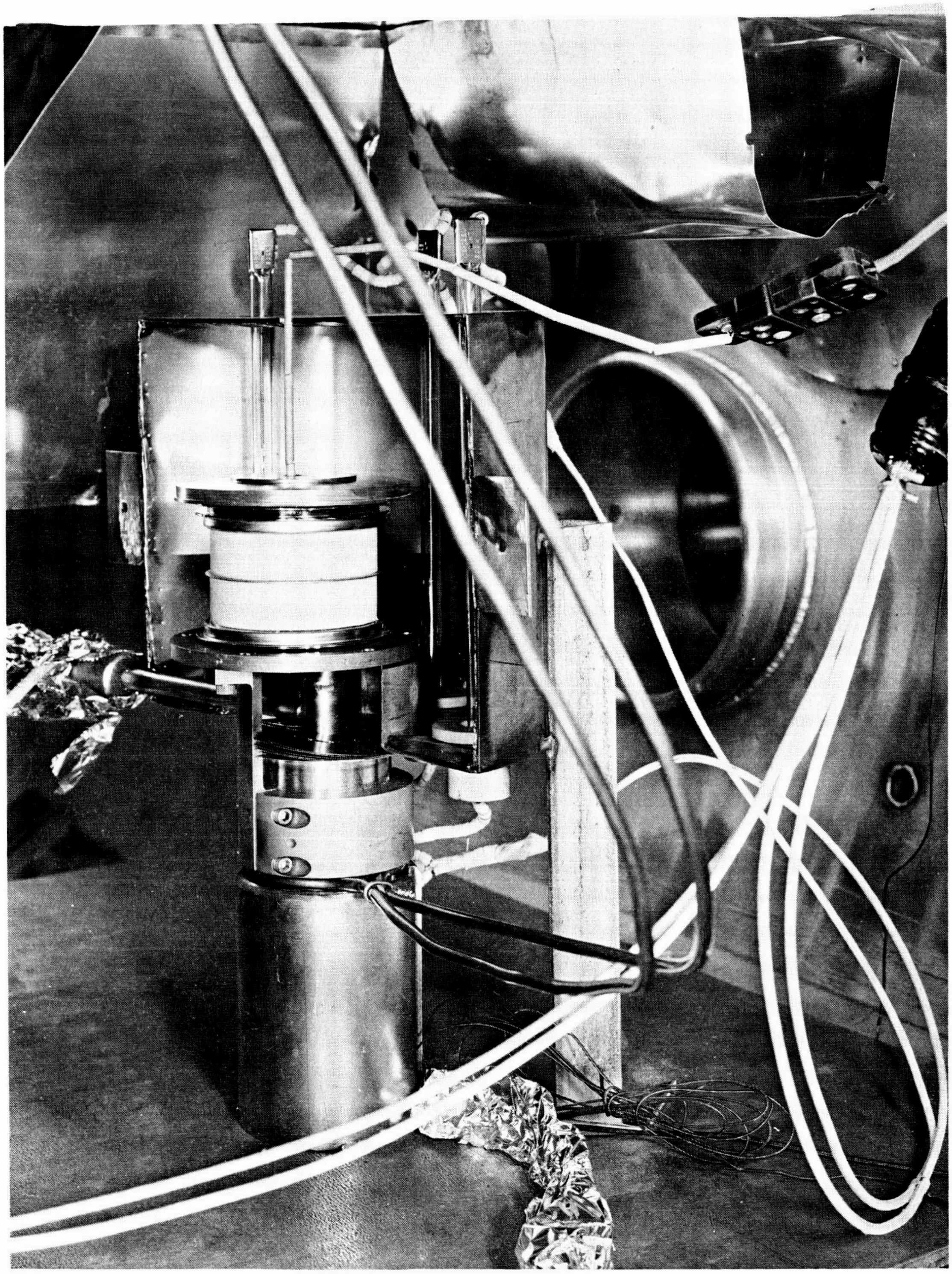


Figure 1. Vacuum Capsule with Ion Pump, in Vacuum Tank with Partially Assembled Oven During Set-up for Bake-out and Seal-off Processing.

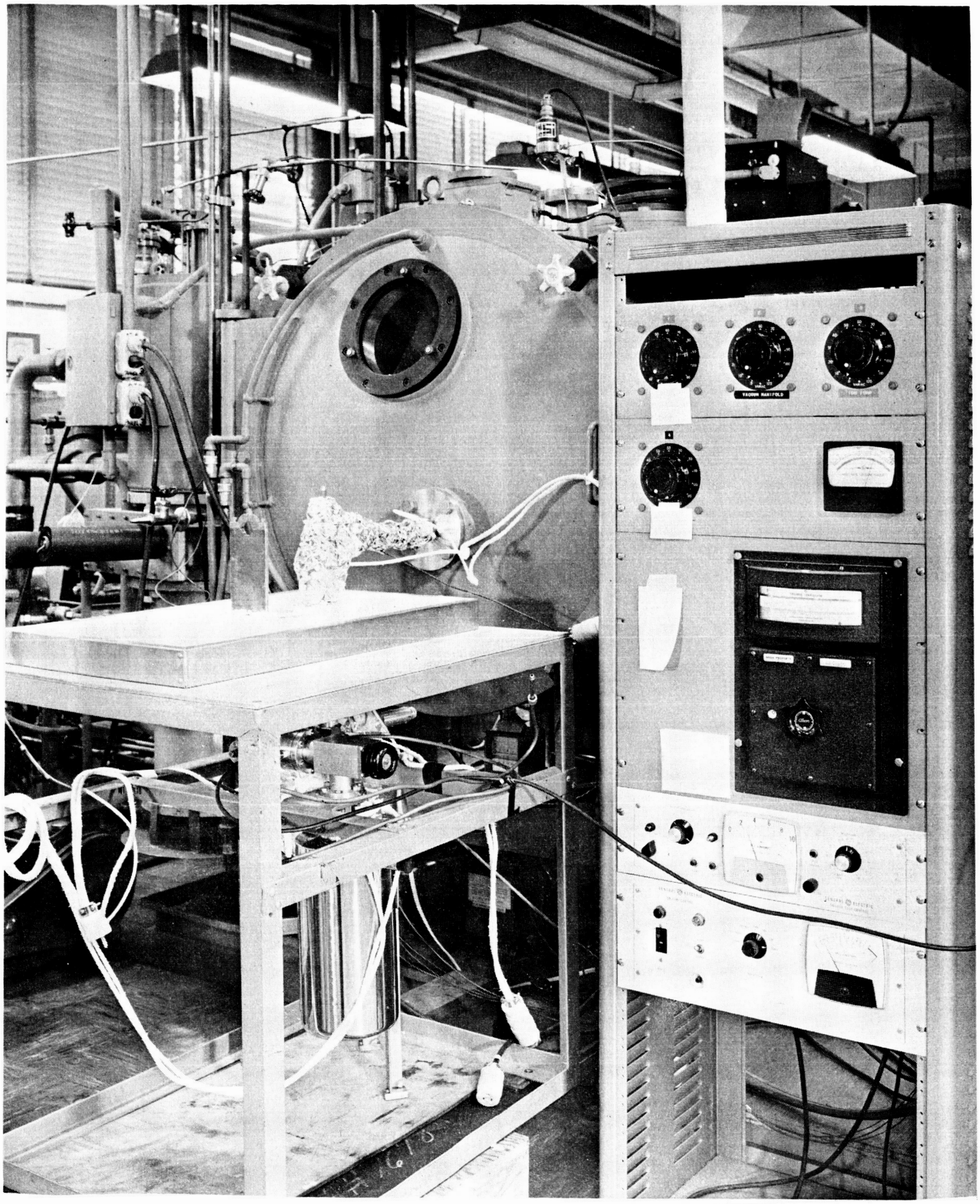


Figure 2. Capsule Auxiliary Pumping Line from Vacuum Tank, Heading to 25 Liter per Second Ion Pump, with the Power Control Unit at the Right.

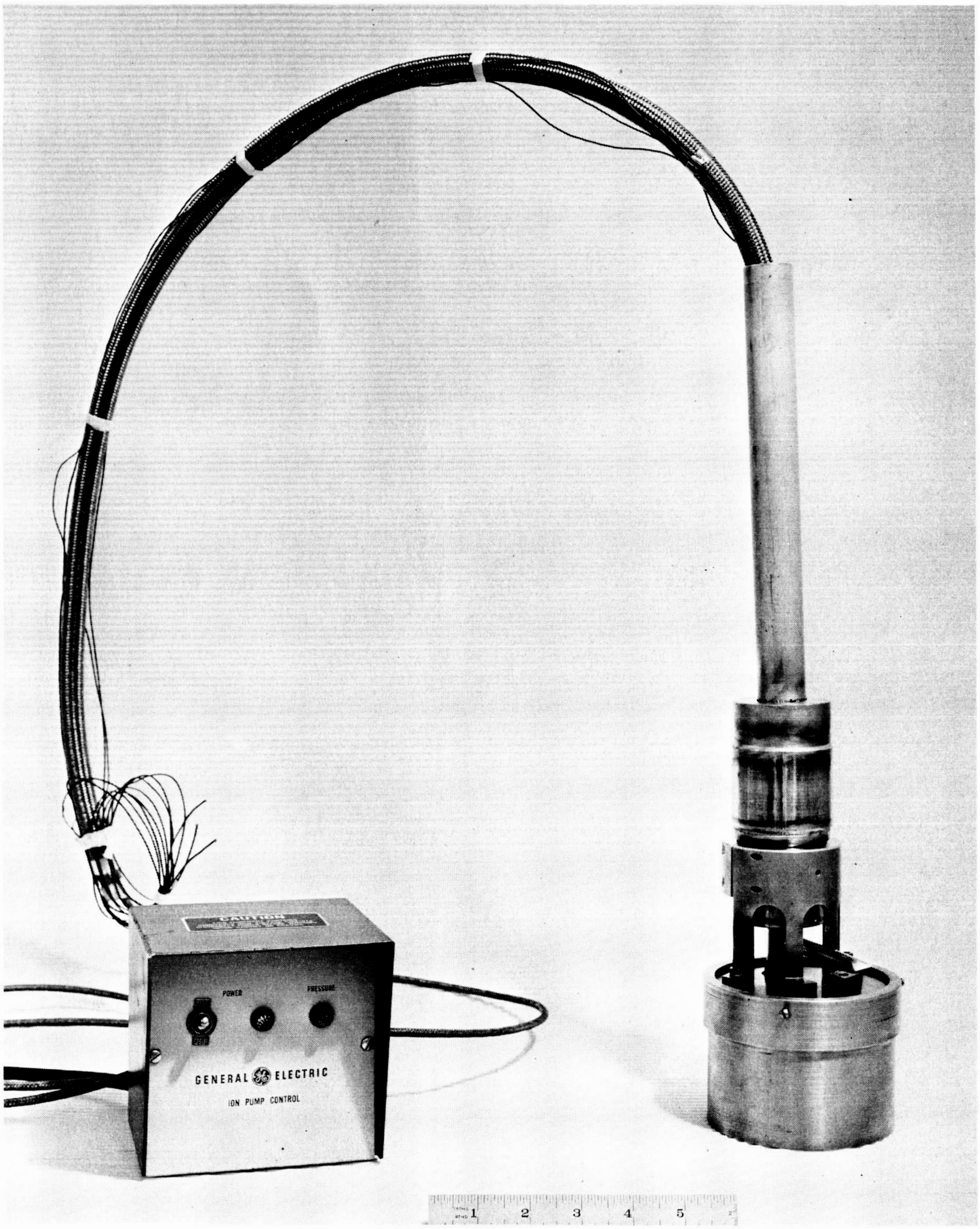


Figure 3. Vacuum Capsule with Ion Pump Air Line and Power Lead, Attached to the Pump Control Unit to Maintain Lower Pressure in Capsules.

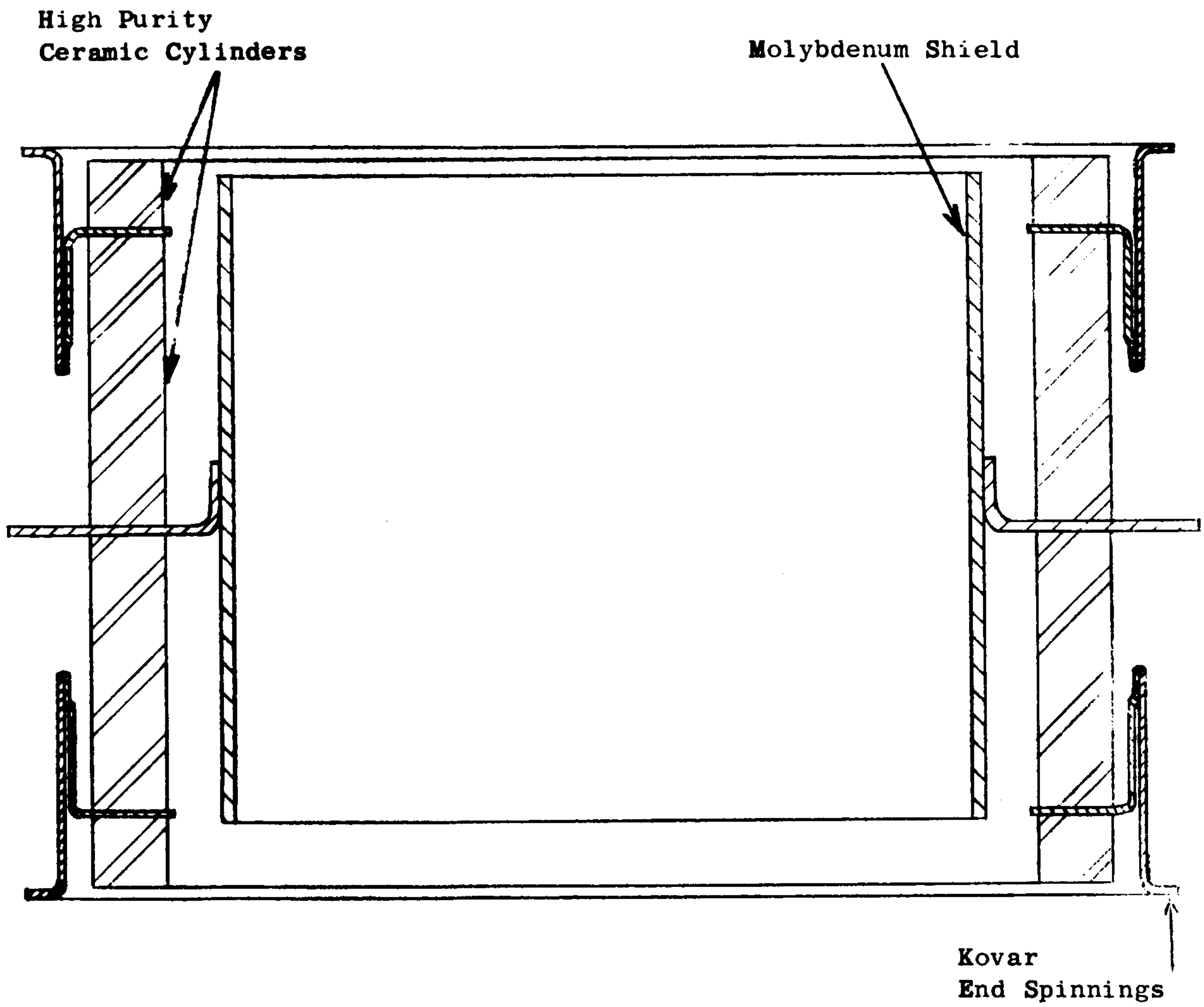


Figure 4. Sketch of Cross Section (Double Size) of Ceramic Seal Assembly with New Design End Spinnings.

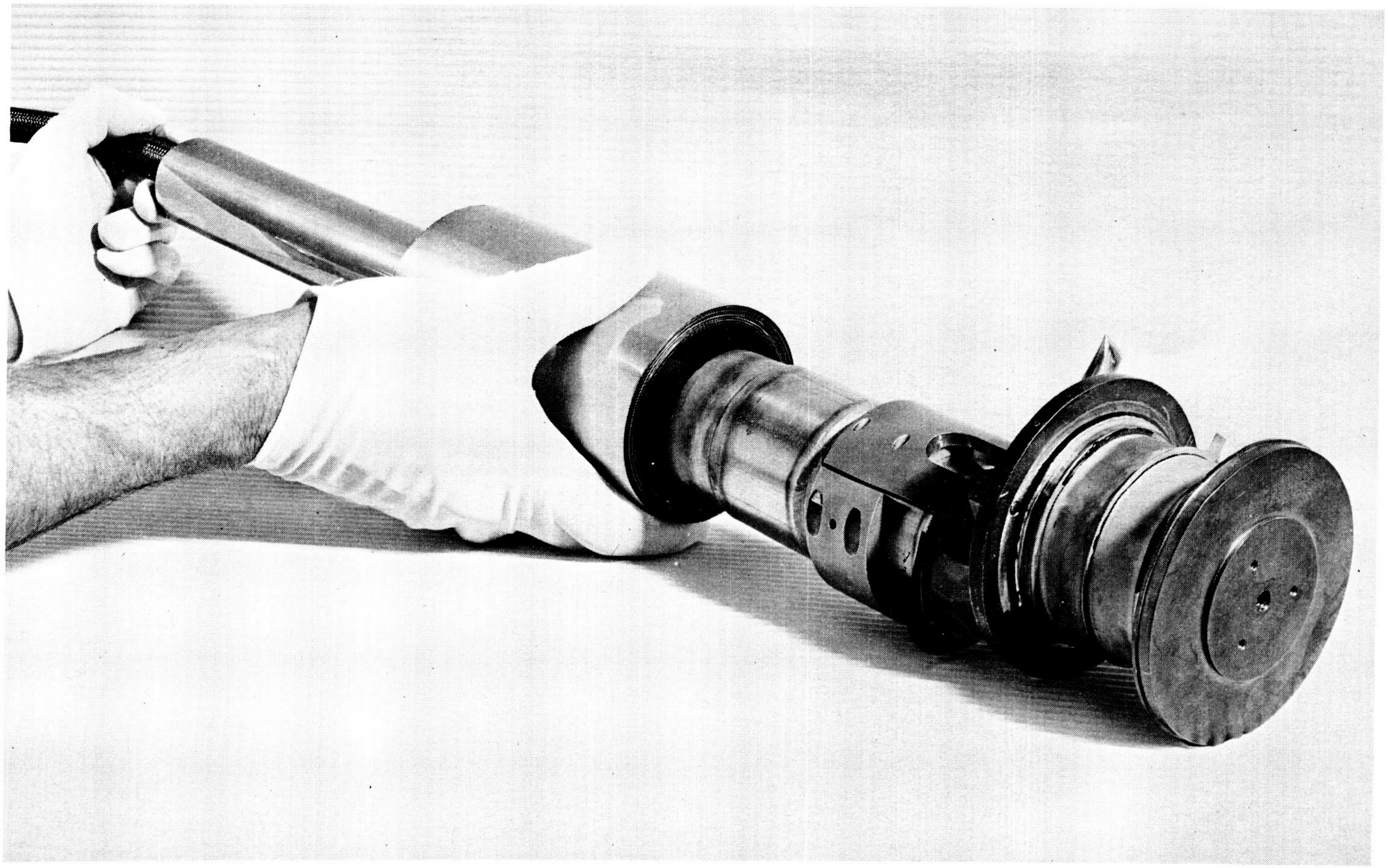


Figure 5. Fifteen Layer Heat Shield Being Slid Over Ion Pump Air Line and Enclosure, Attached to Vacuum Capsule.

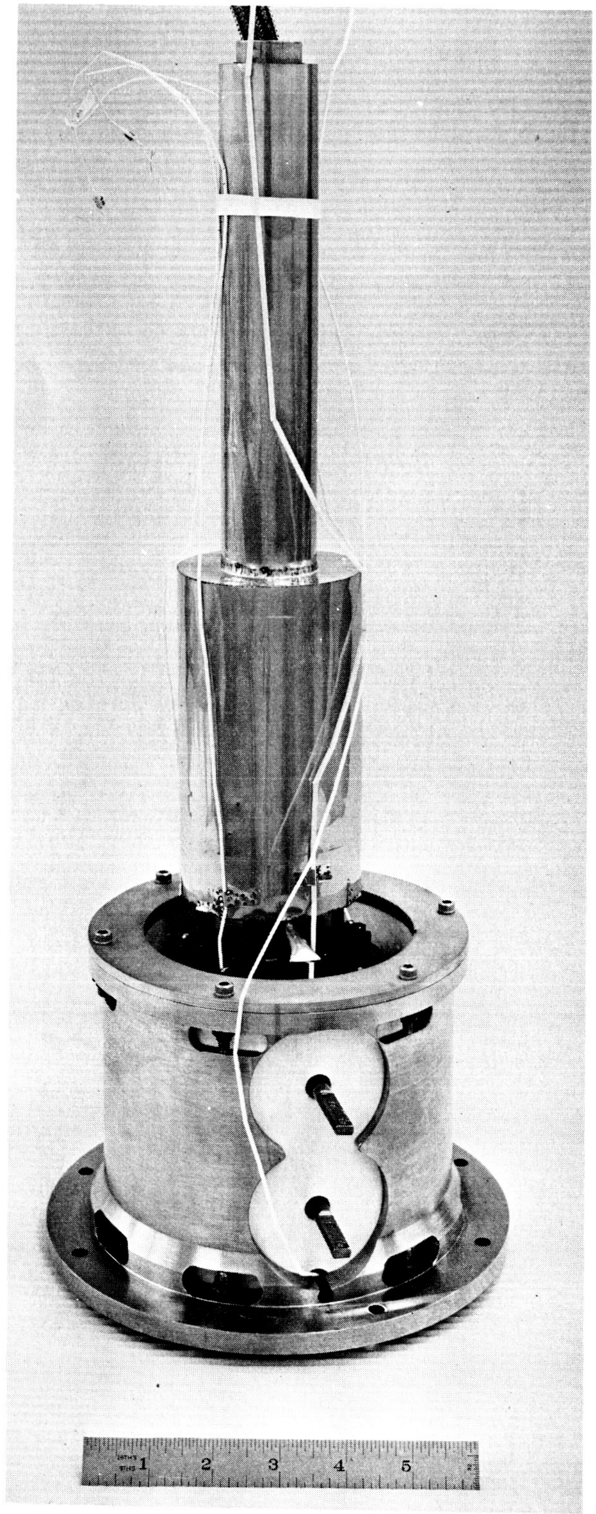


Figure 6. Vacuum Capsule with Attached Ion Pump and Air Line, Installed in D.C. Contactor Interrupter Unit Supporting Shell.

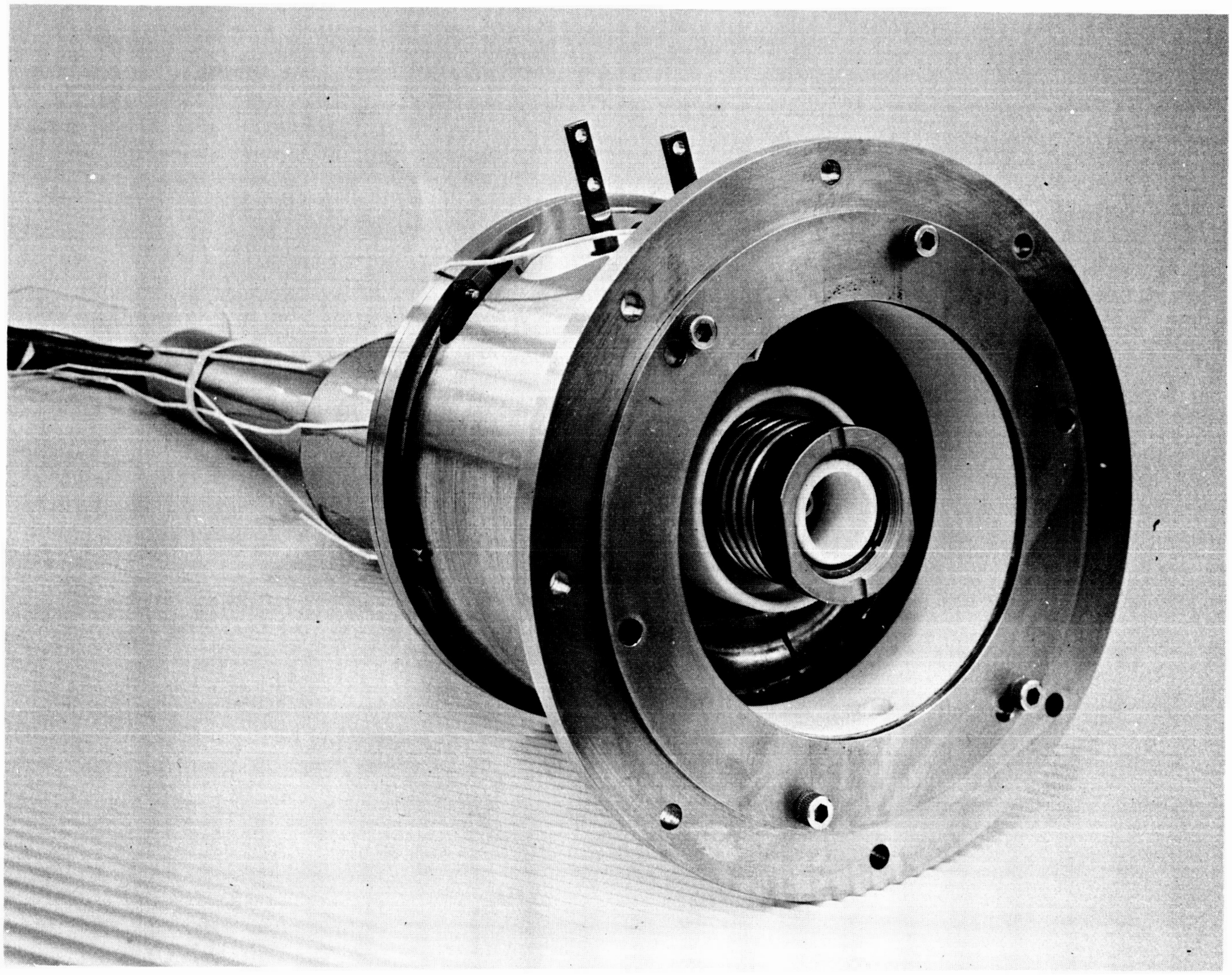


Figure 7. Actuator End of D.C. Interrupter Unit Showing Electrical Diaphragm and Contact Compression (Wipe) Spring.

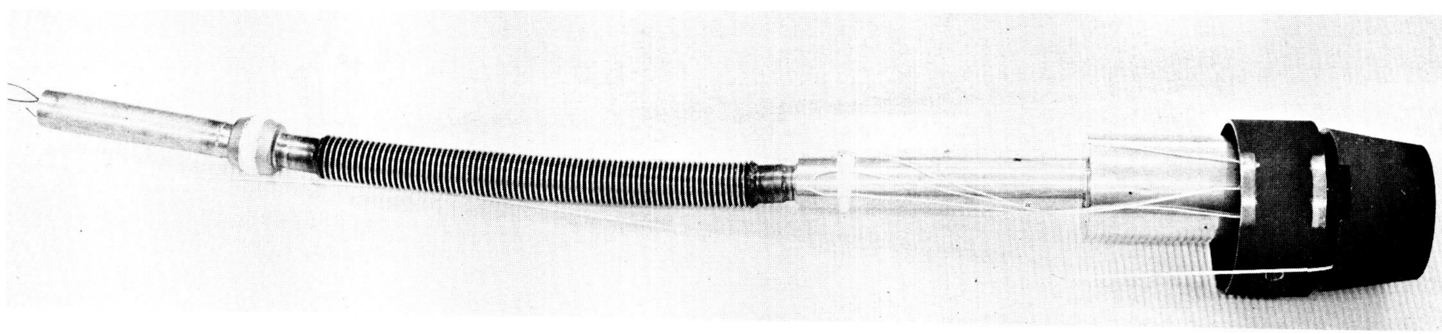


Figure 8. Vacuum Capsule for A.C. Breaker with Radiators Attached, and Ion Pump Shield and Co-axial Air Line Welded in Place.

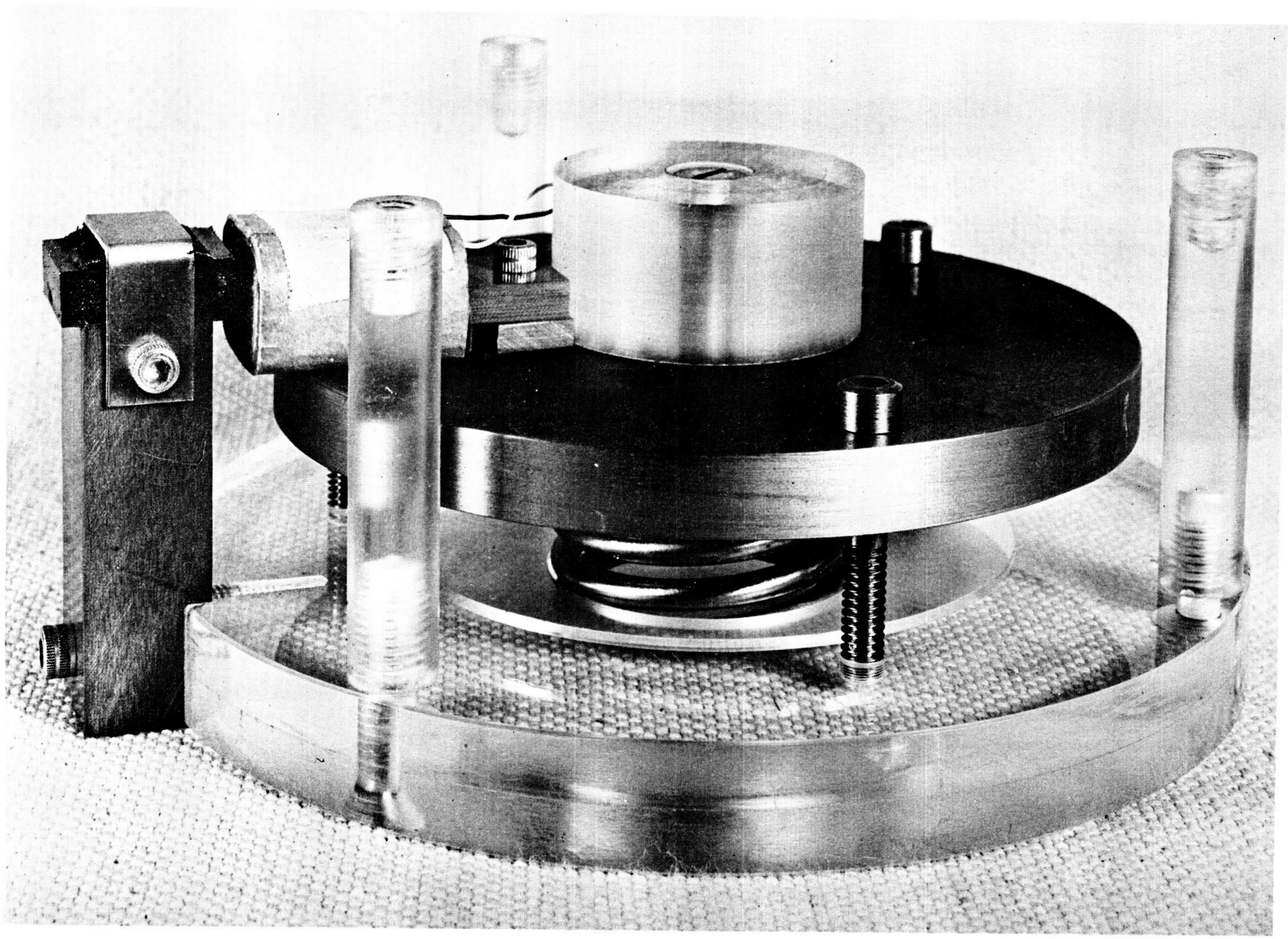


Figure 9. Fixture Being Developed for Checking Actuator Operating Characteristics, Showing Three Supports for Attaching Actuator and Center Block for Transmitting Plunger Force.

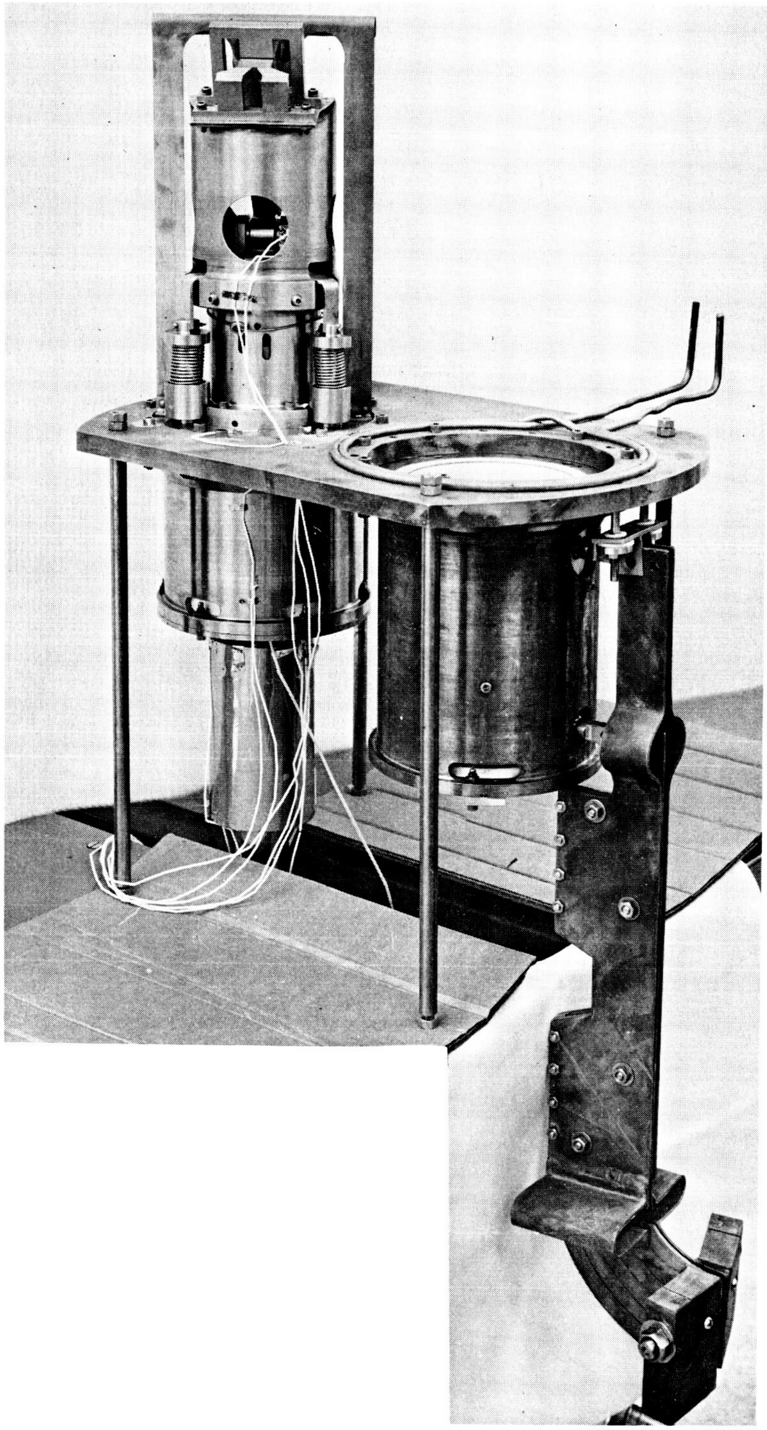
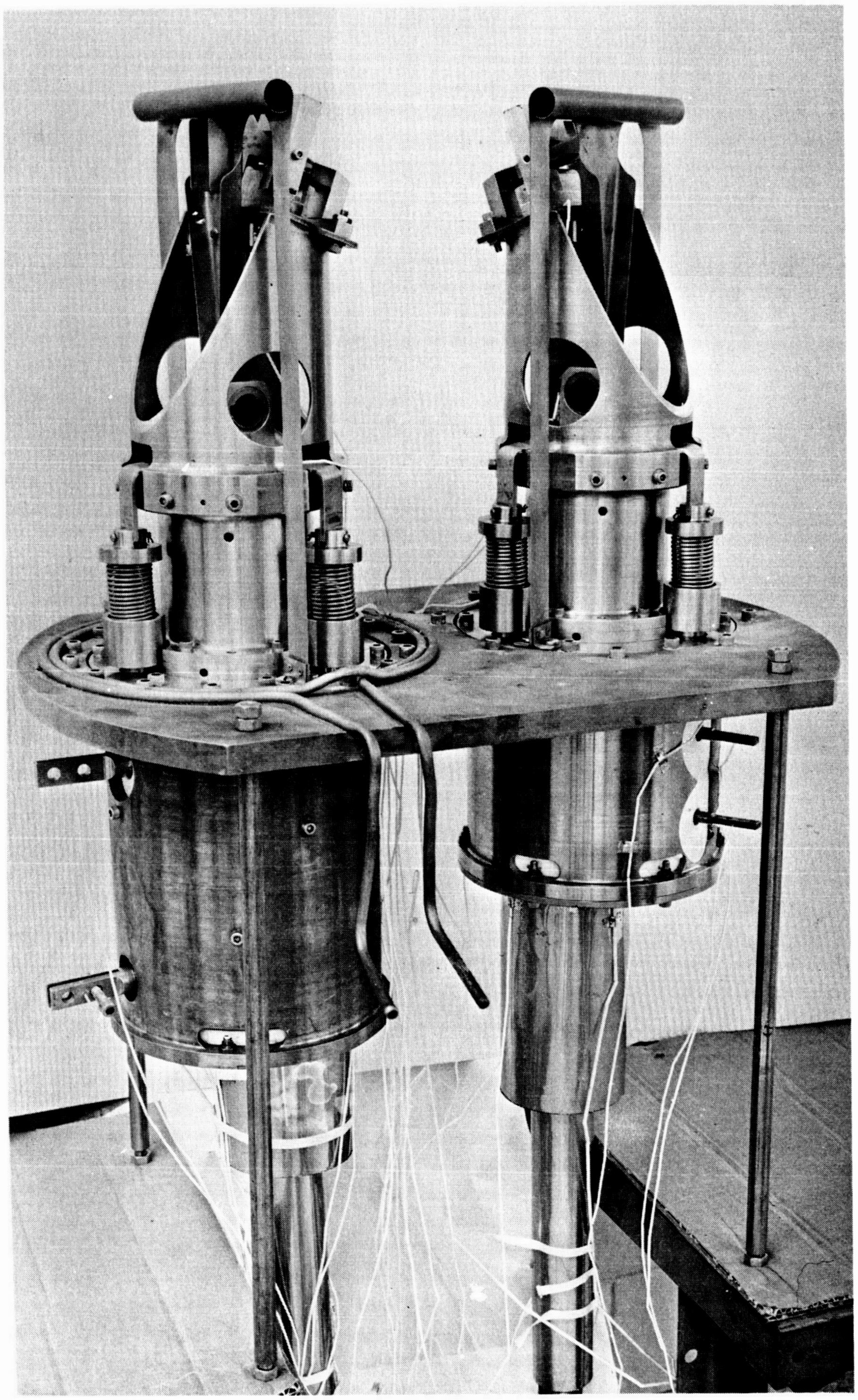


Figure 10. Complete D.C. Contactor Mounted on Heat Sink Along with Shell for A.C. Interrupter and High Current Laminated Conductor Set-up for Trial Assembly and Check-out.



gure 11. AC Breaker (Left) and DC Contactor (Right) Mounted on Heat Sink in Clean Room, Ready for Installation in Vacuum Tank for Test.

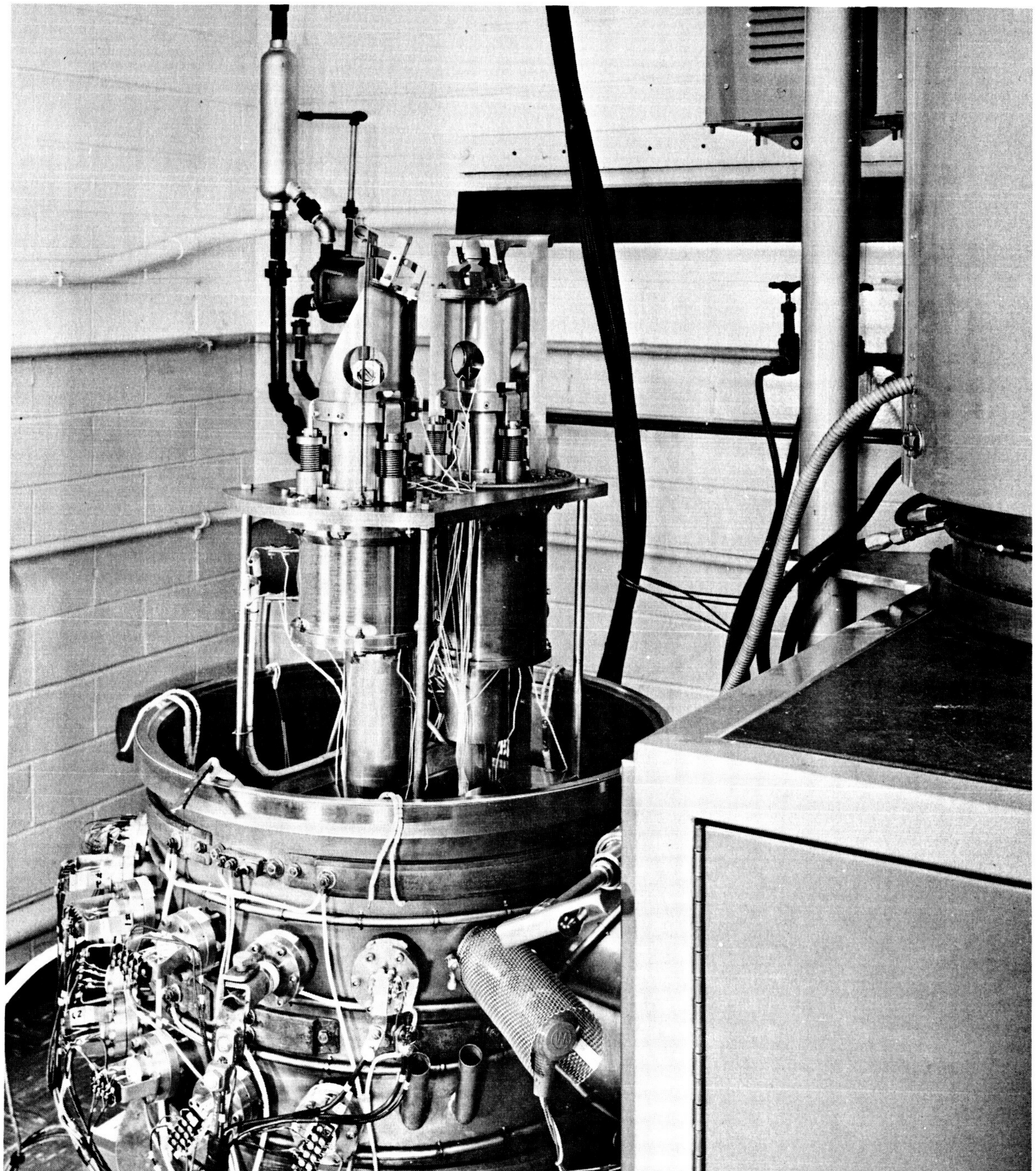


Figure 12. AC Breaker and DC Contactor, on Heat Sink, Mounted in Ultra-High Vacuum Tank Just Prior to Installing Oven Top for Heat Run Test.

Figure 13. Close-Up of AC Breaker (left) and DC Contactor (right) Set Up in Vacuum Tank, with Heat Sink Supported on Oven Bottom, Just Before Closing Oven for Heat Run Test.

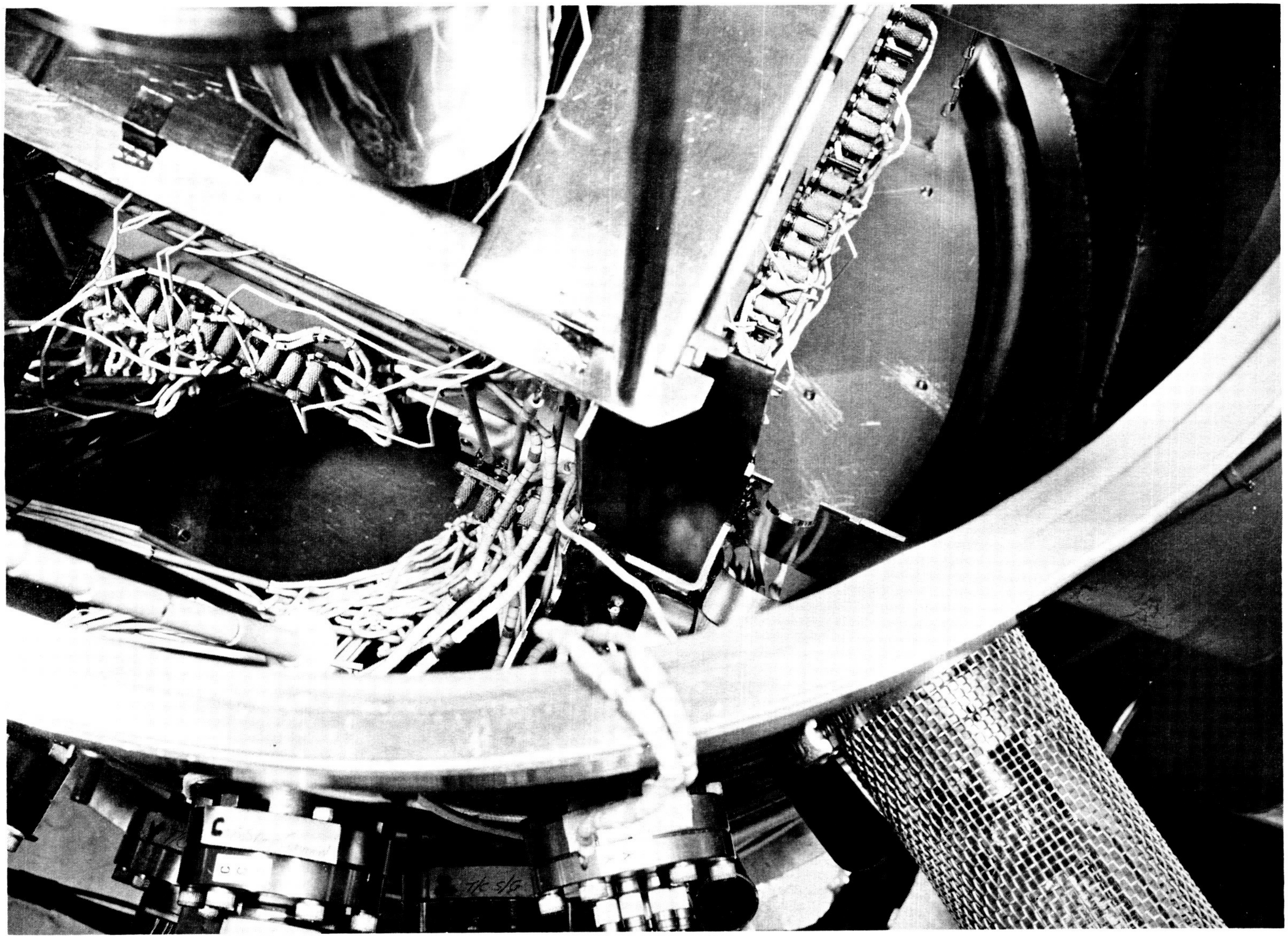


Figure 14. View Downward Toward Base of Vacuum Tank, with Lamps for Oven Removed to Provide Access to Terminal Boards and Thermocouple Connections.

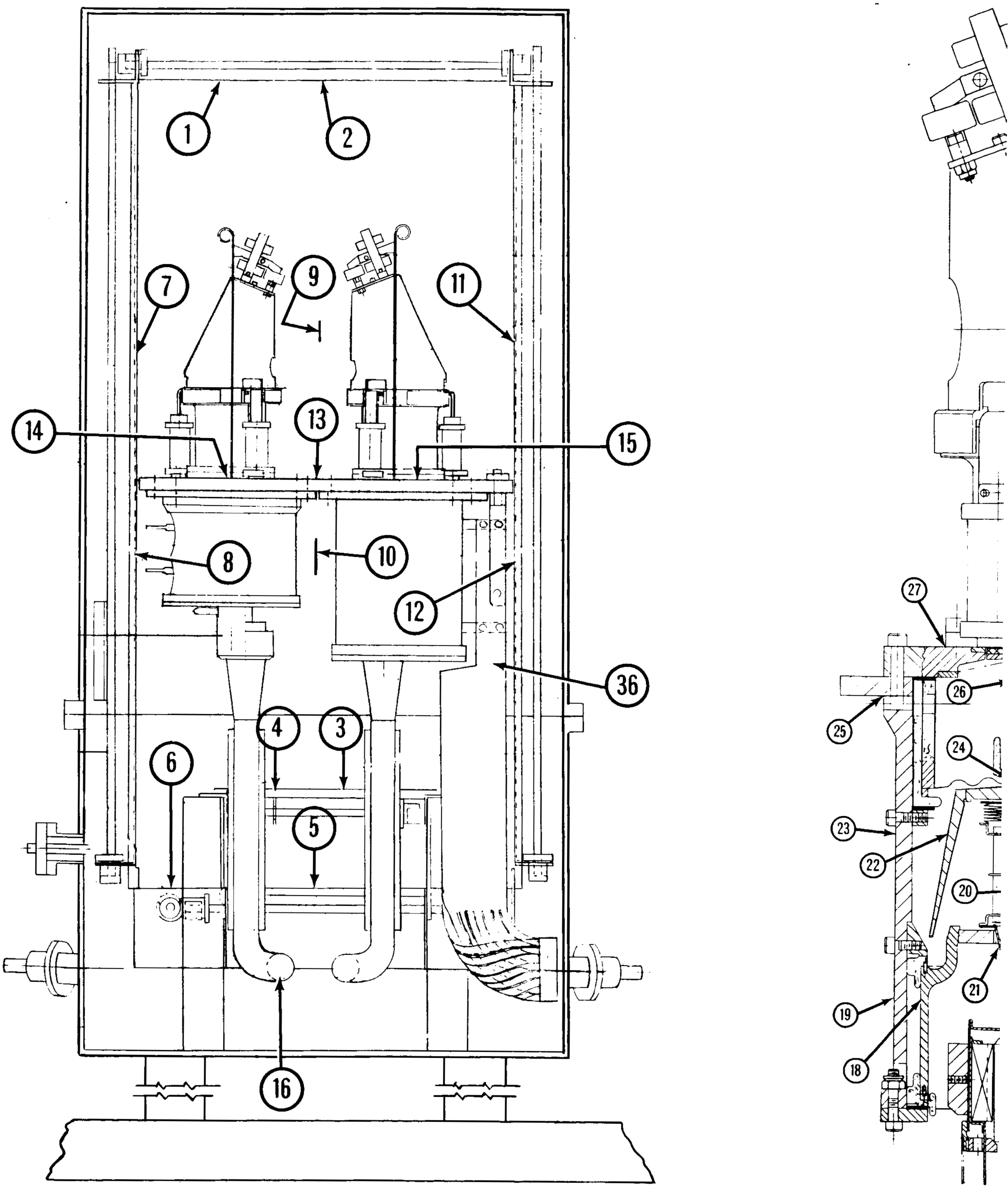
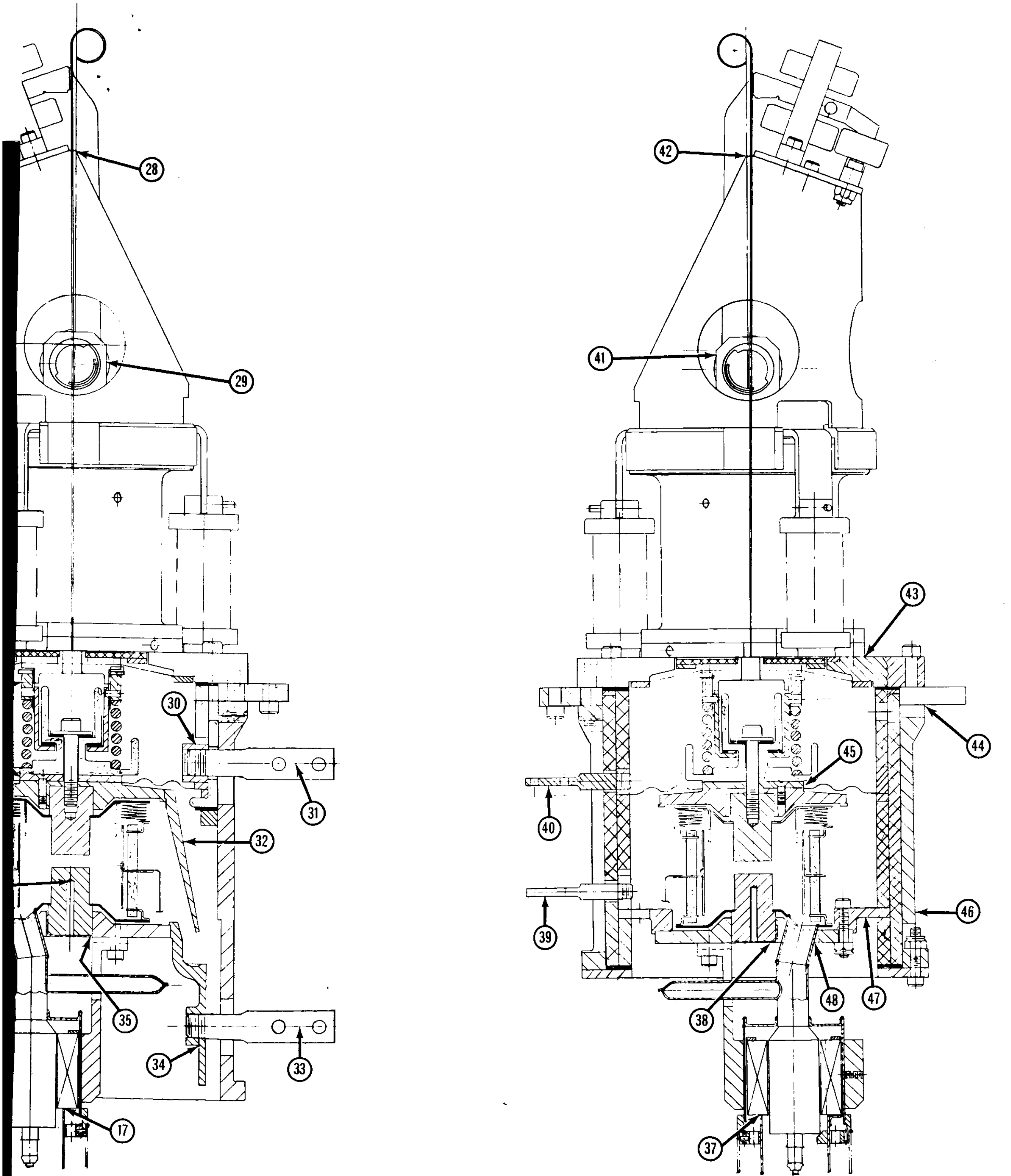


Figure 15. Location of Thermocouples in S
Breaker (center view), and DC
for the Heat Run and Endurance



pecial Oven (left view), AC
Contactor (right view) Used
Tests.

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