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MASTER

SNAP 7 Program
Quarterly Progress Report No. 4
Task 8--Strontium-90 Fueled Thermoelectric Generator Development

August 1, 1961 through October 31, 1961

MND-P-2483-4

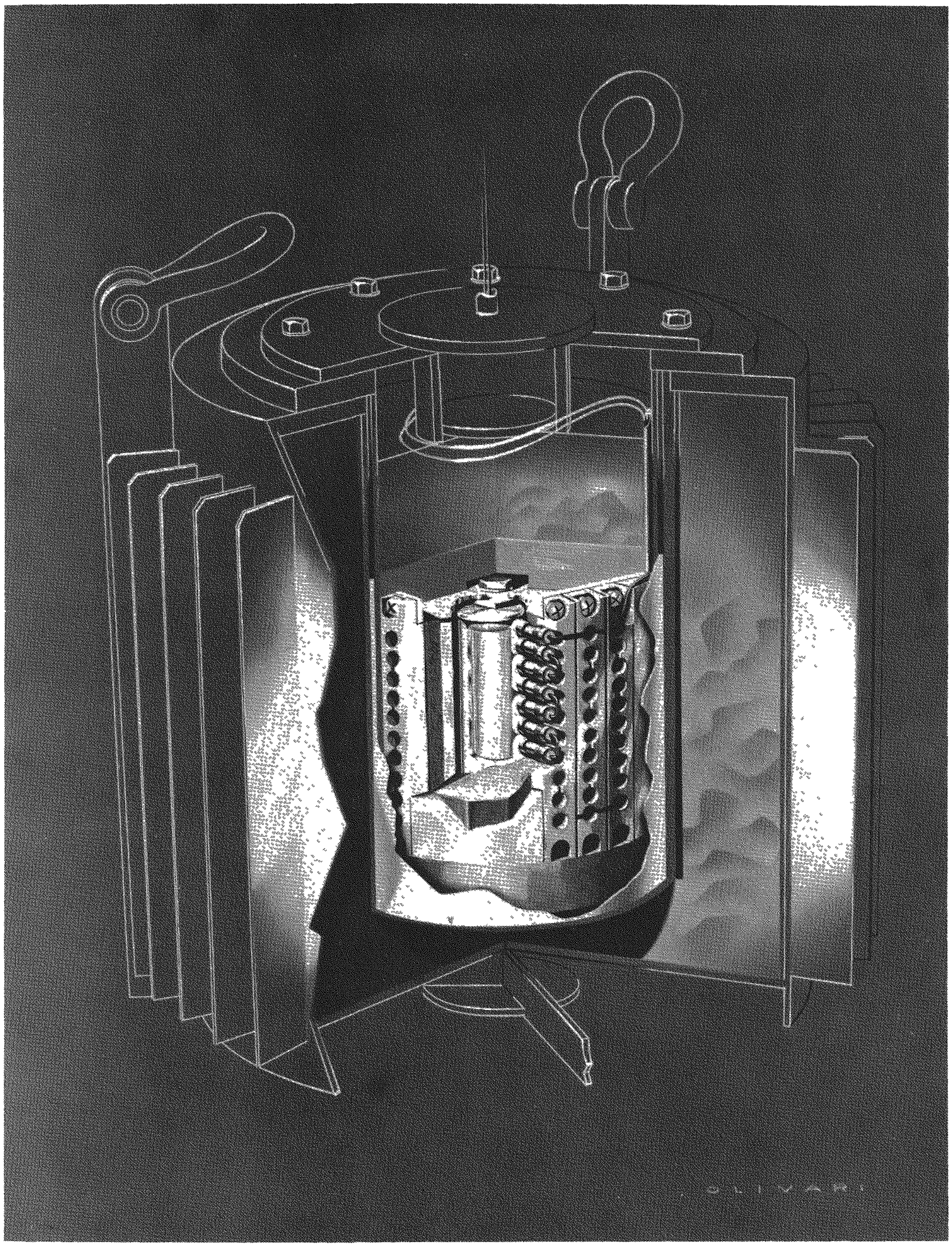
NUCLEAR MARTIN DIVISION

Prepared by

W. S. West
Ass't. Project Engineer

Approved by

J. J. Keenan
Ass't. Project Engineer



The 10-Watt Thermoelectric Generator

FOREWORD

This quarterly report covers the period from August 1 through October 31, 1961. It has been prepared by Martin Marietta Corporation according to the requirements of Contract AT(30-3)-217, Task 8, with the U. S. Atomic Energy Commission.

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SUMMARY

The SNAP 7 program is being conducted by Martin Marietta Corporation for the purpose of developing four radioisotope-fueled thermoelectric power generation systems. An important phase of this program is the processing of strontium-90 heat sources for these systems.

I. INTRODUCTION

The SNAP 7 program covers:

(1) Design, fabrication, test and delivery of four radioisotope-fueled thermoelectric generator systems to meet the rigorous environmental requirements of field use by the United States Coast Guard and the United States Navy.

(2) Fabrication of the strontium-90 fuel for two of the aforementioned generators.

The four deliverable generator systems under the contract are as follows:

(1) SNAP 7A: 5-watt electric generation system for U. S. Coast Guard light buoy, Subtask 8.1.

(2) SNAP 7B: 30-watt electric generation system for U. S. Coast Guard fixed light station, Subtask 8.2.

(3) SNAP 7C: 5-watt electric generation system for U. S. Navy weather station, Subtask 8.3.

(4) SNAP 7D: 30-watt electric generation system for U. S. Navy boat-type weather station, Subtask 8.4.

Fuel processing was isolated as a separate subtask, Subtask 8.5, after initiation of the program, to permit a more detailed surveillance of this aspect of the program. This report has been divided into three major sections: one covering Subtasks 8.1 and 8.3, one for Subtasks 8.2 and 8.4 and one for Subtask 8.5; however, it should not be overlooked that this is a highly interrelated program where variations in any subtask may produce significant effects in one or more of the others.

II. SNAP 7A AND 7C FIVE-WATT ELECTRIC GENERATION SYSTEMS--SUBTASKS 8.1 AND 8.3

A. INTRODUCTION AND SUMMARY OF SIGNIFICANT TECHNICAL ACHIEVEMENTS

The SNAP 7A and 7C systems were designed and analyzed during the first quarterly report period (Ref. 1); components and subassemblies were manufactured during the second quarterly report period (Ref. 2); during the third quarterly report period (Ref. 3), the assembly of a reliability model, the assembly of an operating model, and the final installation details for the SNAP 7A and 7C systems were completed. The significant achievements for the current report period were:

(1) The completion of the SNAP 7C system tests.

(2) The final assembly, integration with the NRL weather station, and shipment of the SNAP 7C system.

(3) The completion of safety analysis for the SNAP 7A and 7C systems.

(4) The assembly of the SNAP 7A generator and the initiation of SNAP 7A system tests.

(5) The assembly of the modified reliability model.

(6) The assembly of the third 10-watt generator.

B. ENGINEERING--EQUIPMENT DESCRIPTION, DESIGN TECHNIQUES AND PROCEDURES, AND TEST FOR SNAP 7A AND 7C

1. Objectives

The engineering objectives of Subtasks 8.1 and 8.3 for the current report period were:

(1) To assemble and check out the final SNAP 7C system, to verify the system handbook, and to package and ship the SNAP 7C system.

(2) To assemble, fuel and system-test the SNAP 7A system.

(3) To test the modified reliability model.

(4) To complete the safety analysis for the SNAP 7A and 7C systems.

(5) To complete the environmental testing of the operating model generator.

2. Discussion of Objectives

The results of analysis and design of the SNAP 7A and SNAP 7C generators and a discussion of their installation procedures were reported previously (Refs. 1, 2 and 3). System tests (simulated), environmental tests, component tests, generator tests (simulated) and fueled generator tests were conducted throughout this report period. The results of these tests are recorded in this report.

Prior to acceptance of the SNAP 7C system, the installation portion of the instruction manual for the system (Ref. 4) was verified by assembling the entire weather station according to the written instructions.

The SNAP 7C system was completed and packaged, and was transported to and loaded aboard the USS ARNEB for shipment to Antarctia.

The reliability test model has been reassembled. Thermoelectric modules having higher figures of merit than those of the previously used modules were used in the reassembled test model. Tests of the model will begin during the next report period.

The safety analysis for the SNAP 7A and 7C systems has been completed and the results of the analysis are reported in Refs. 5 and 6.

3. Handbook Verification

The instruction manual for the system (Instruction Manual for the SNAP 7C Systems) was verified by assembling the entire weather station according to the written instructions. Figure 1 shows the insulation being installed in accordance with the instructions. As a result of this verification effort and to facilitate installation of the station, alignment arrows were painted on the housing to indicate proper points of alignment for the two sections of the field installation tube (see arrows in Figs. 2, 3 and 4); a section of the outrigger and the attachment face were painted the same color to facilitate the assembly procedure (matched colors indicate a correctly assembled unit--see Fig. 5); also, holes were drilled in the ends of the outriggers for attaching the antenna guys (see Fig. 6). As a result of discussions with Martin Marietta employees with experience on the Antarctic continent, it was decided to paint certain critical items international orange to make them easily seen at the field site. Also, the top deck assembly was originally scheduled to be fabricated,

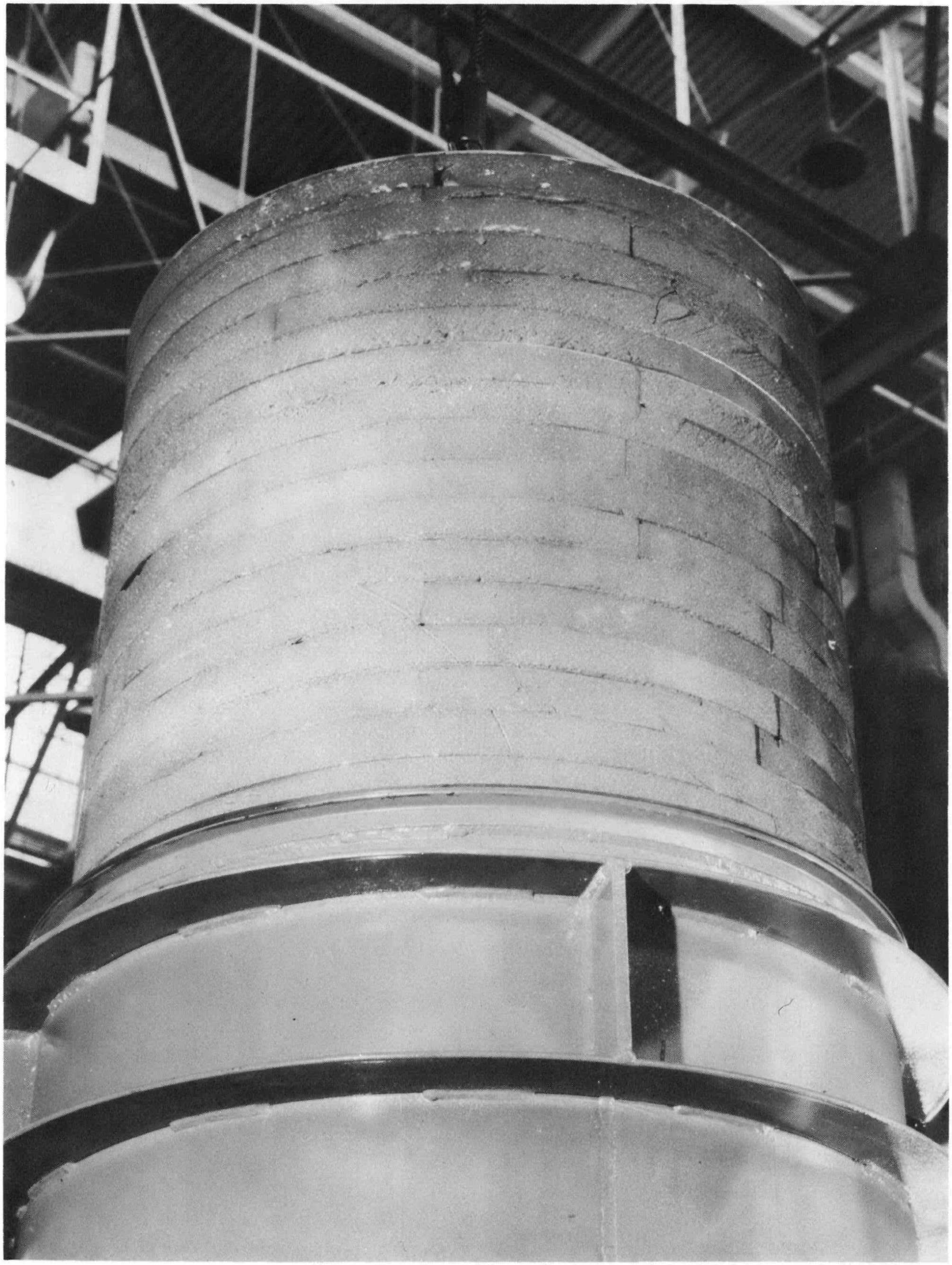


Fig. 1. SNAP 7C Weather Station--Insulation Installed According to Handbook Instructions

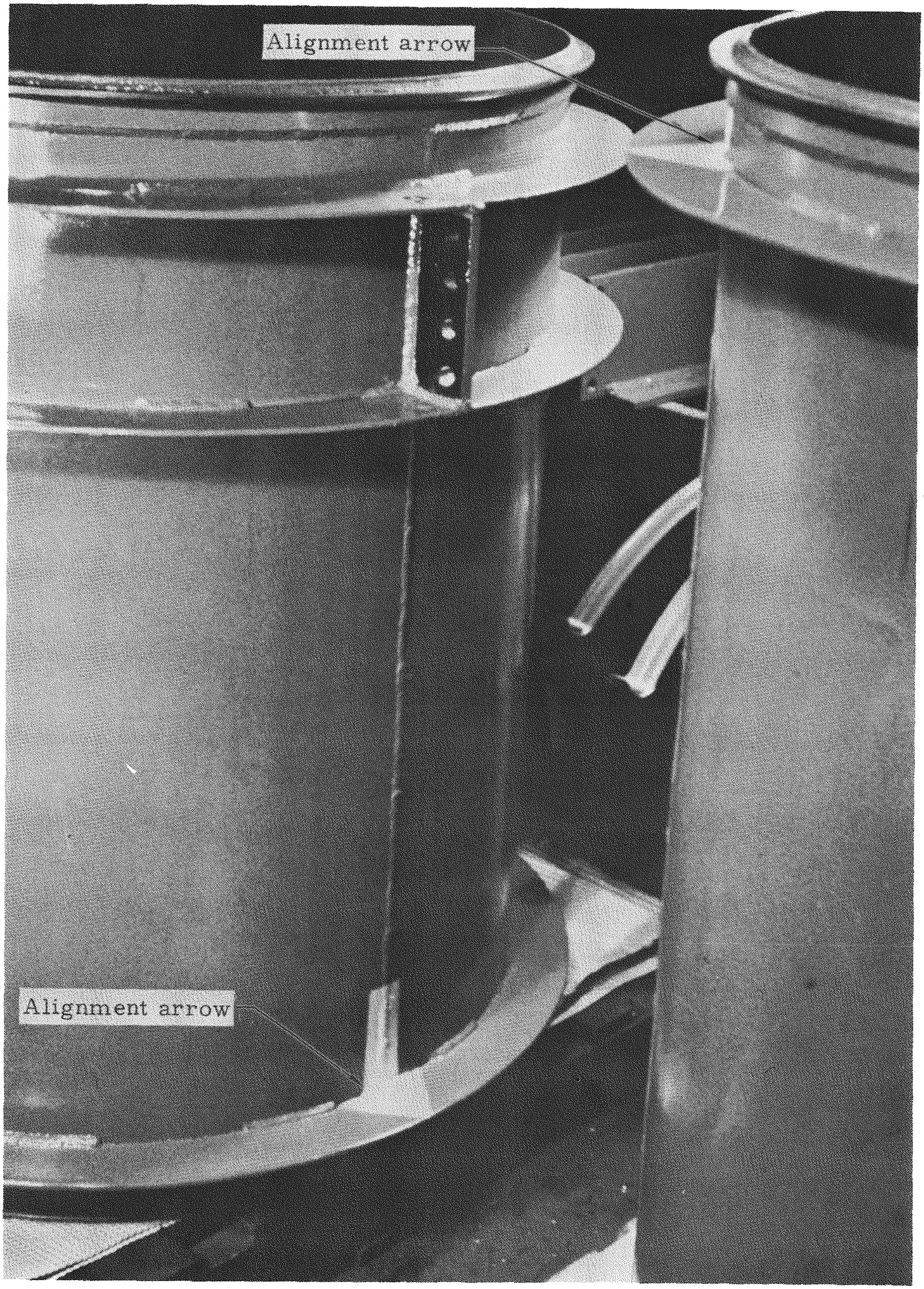


Fig. 2. SNAP 7C Weather Station Housing (2 sections)--Arrows Painted on Housing Indicate Points of Alignment

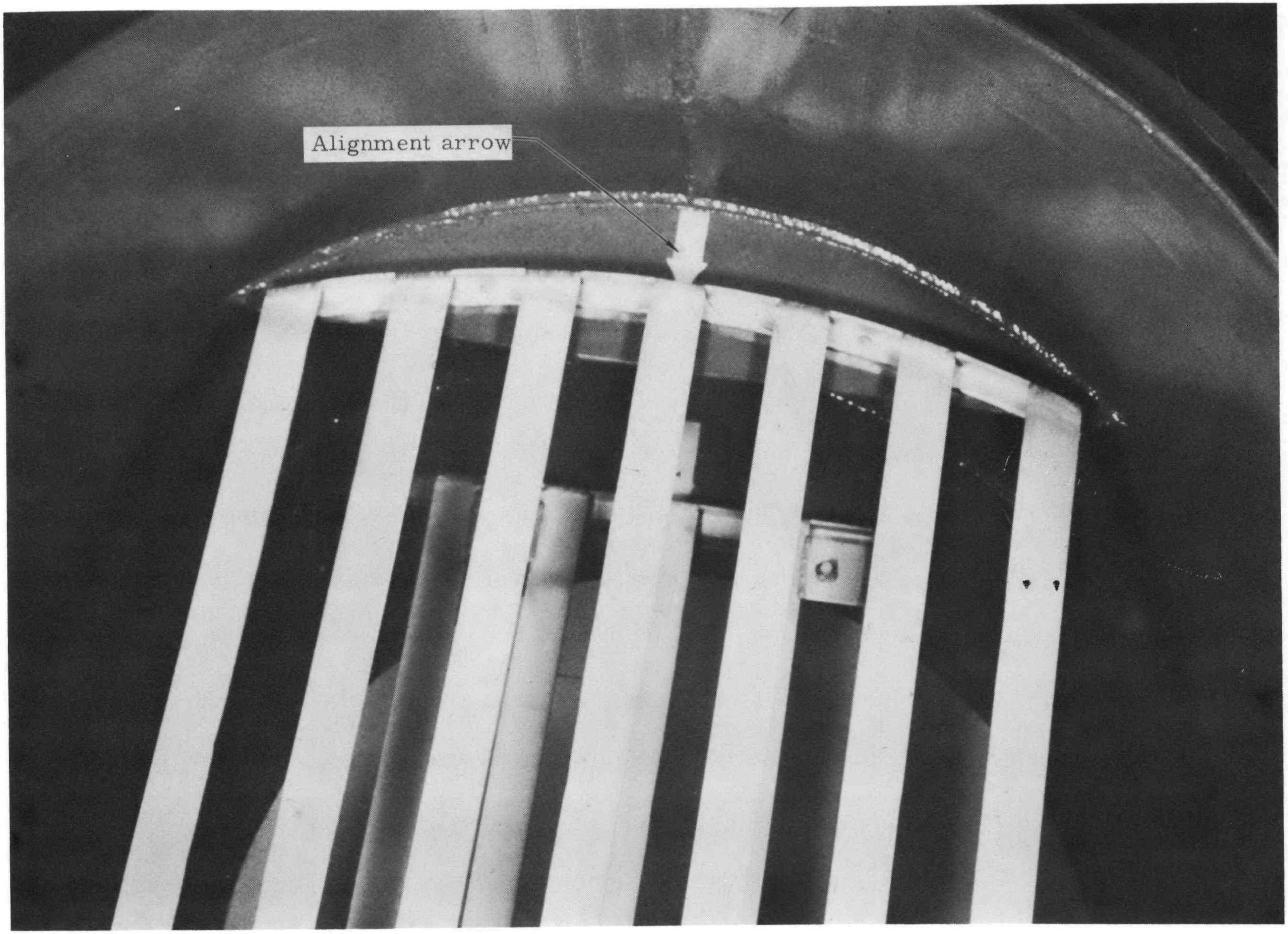


Fig. 3. SNAP 7C Field Installation Tube (inside view)--Arrow Indicates Point of Alignment for Weather Station Support Rack

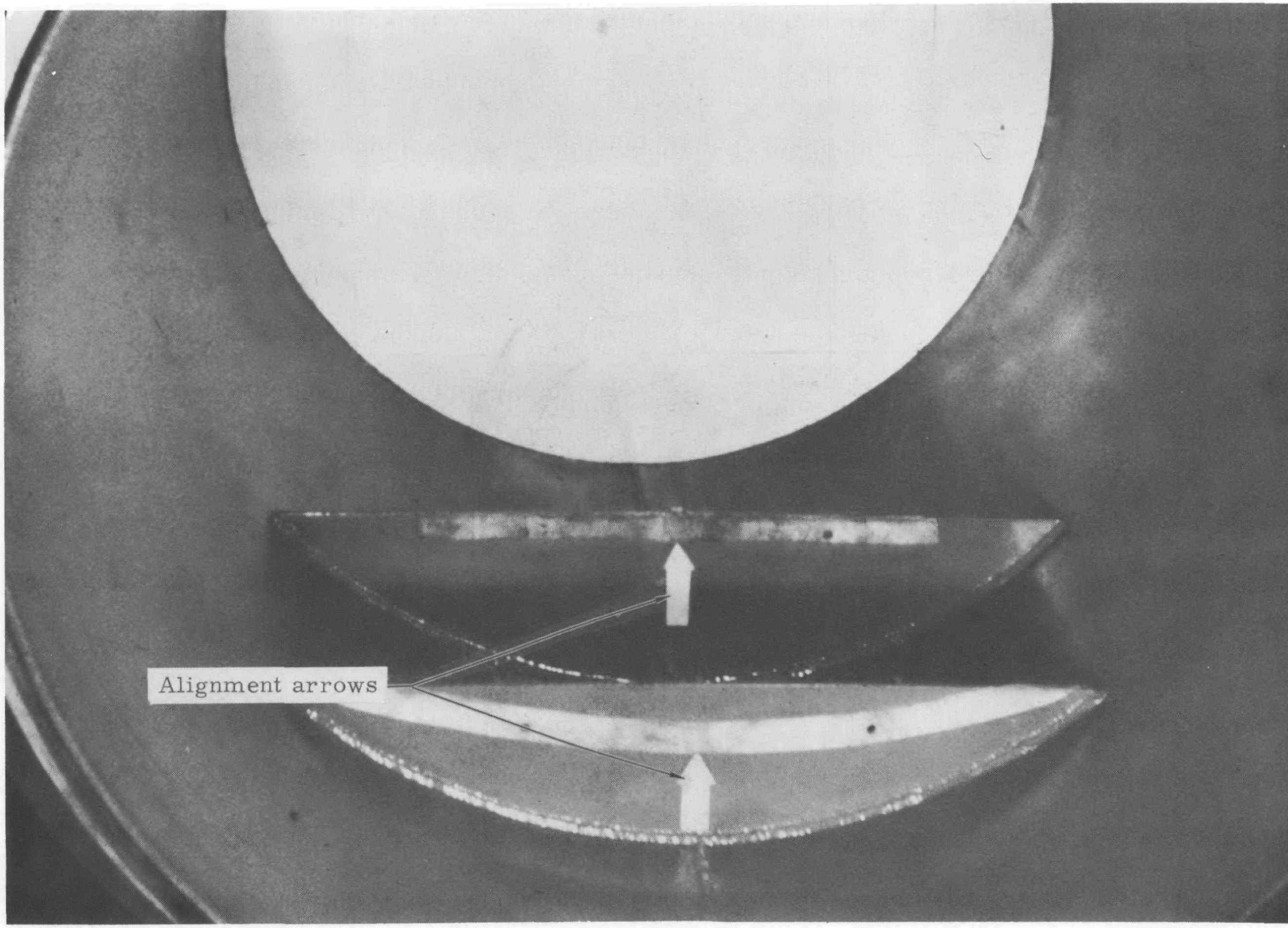


Fig. 4. SNAP 7C Field Installation Tube (inside view)--Arrows Indicate Points of Alignment for Battery Rack and Weather Station Support Rack

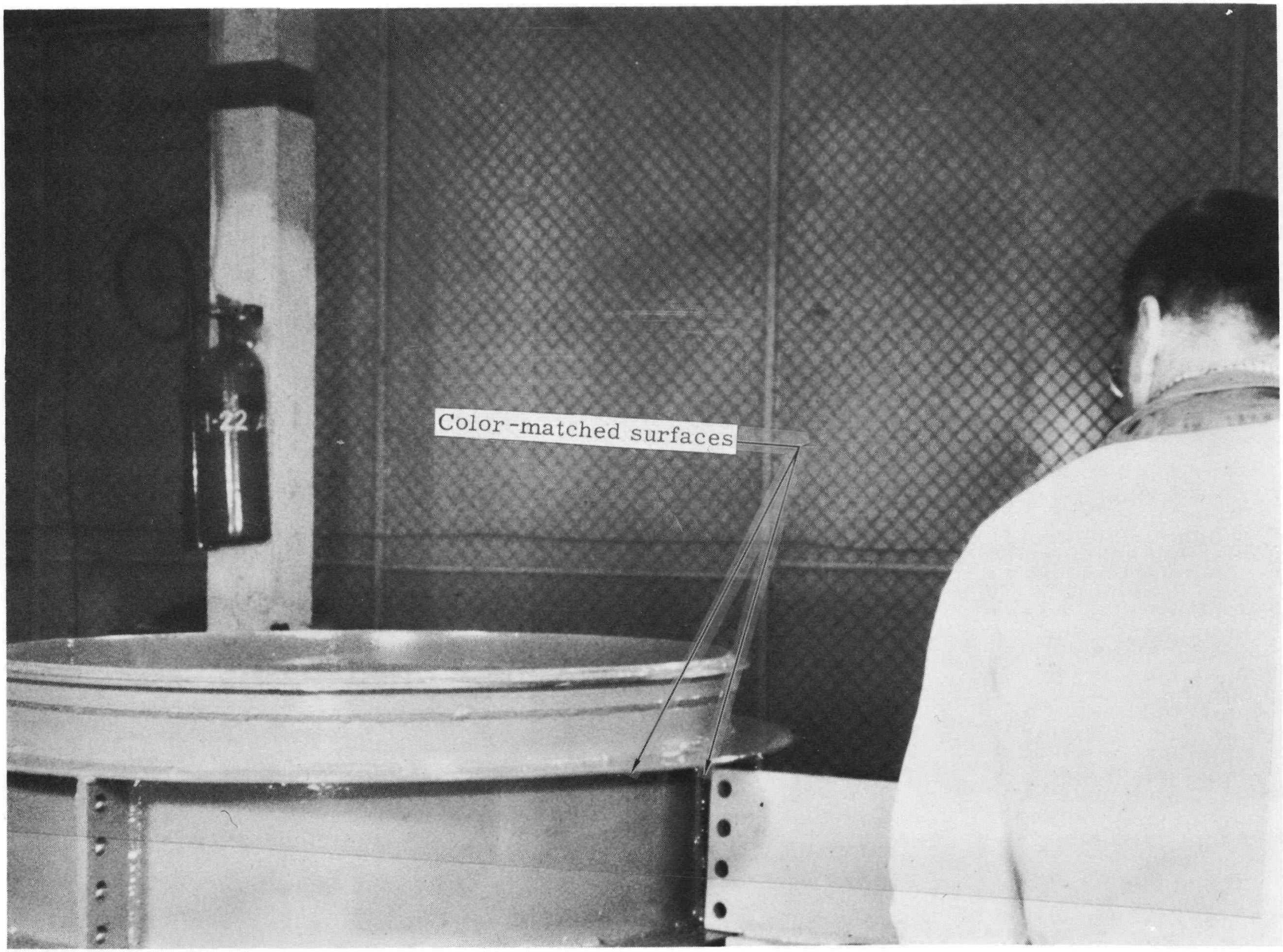


Fig. 5. Matching the Outrigger to the Attachment Face by Means of Color During Assembly of SNAP 7C Field Installation Tube

Fig. 6. Outrigger Bolted to Attachment Face of Field Installation Tube (note hole drilled in outrigger for antenna guy)

assembled and adjusted under the supervision of the Naval Research Laboratory (NRL), but was rescheduled and completed at Martin-Nuclear. The top deck assembly and assembly outlets for the SNAP 7C system are shown in Figs. 7 and 8.

4. Shipment and Installation

The SNAP 7C system was completed and shipped to Davisville, Rhode Island on October 23, 1961. An itemized description of the shipment is given in Appendix A. The packaged generator and other packaged components of the SNAP 7C system are shown in Fig. 9. At Davisville, the system was loaded aboard the USS ARNEB for shipment to Antarctica. (Fig. 10 shows the USS ARNEB on a previous trip at McMurdo Sound, Antarctica.)

The SNAP 7A system installation, as proposed by Martin Marietta, was approved by the U. S. Coast Guard with the following requested changes:

(1) The lantern conduit is to be located opposite the battery compartment.

(2) The elimination of connectors at the top of the battery-converter rack by the use of connections at the terminal block.

The final schematic diagram of the SNAP 7C antenna coupler is shown in Fig. 11; schematic diagrams of the battery and converter compartment and of the dc-to-dc converter are shown in Figs. 12 and 13, respectively.

5. Generator Assembly and Instrumentation

The SNAP 7C, the SNAP 7A, and the operating model generators were assembled with simulated heat sources for extensive generator and system testing prior to actual isotope fueling (of SNAP 7C and SNAP 7A) at the Quehanna Hot Cell Laboratory facility. All thermoelectric elements were pretested prior to assembly in order to eliminate thermoelectric couples with electrical resistance exceeding 12 milliohms; after the elements were assembled, total resistance measurements were made for each couple and its soldered connection. The identity of each element, couple and module was maintained and recorded during assembly.

Instrumentation for the generators was accomplished by attaching 36-gage chromel-alumel thermocouples to the hot shoes of Couples Nos. 1 and 5, the "P" cold cap of No. 1 couple and the "N" cold cap of No. 5 couple in Modules 5 and 6. The thermocouples in the hot shoes were spot-welded to the center of the shoe and then strapped with wires welded to the shoe. The thermocouples were insulated and a layer of Sauereisen No. 1 applied to the thermocouple and shoe for additional

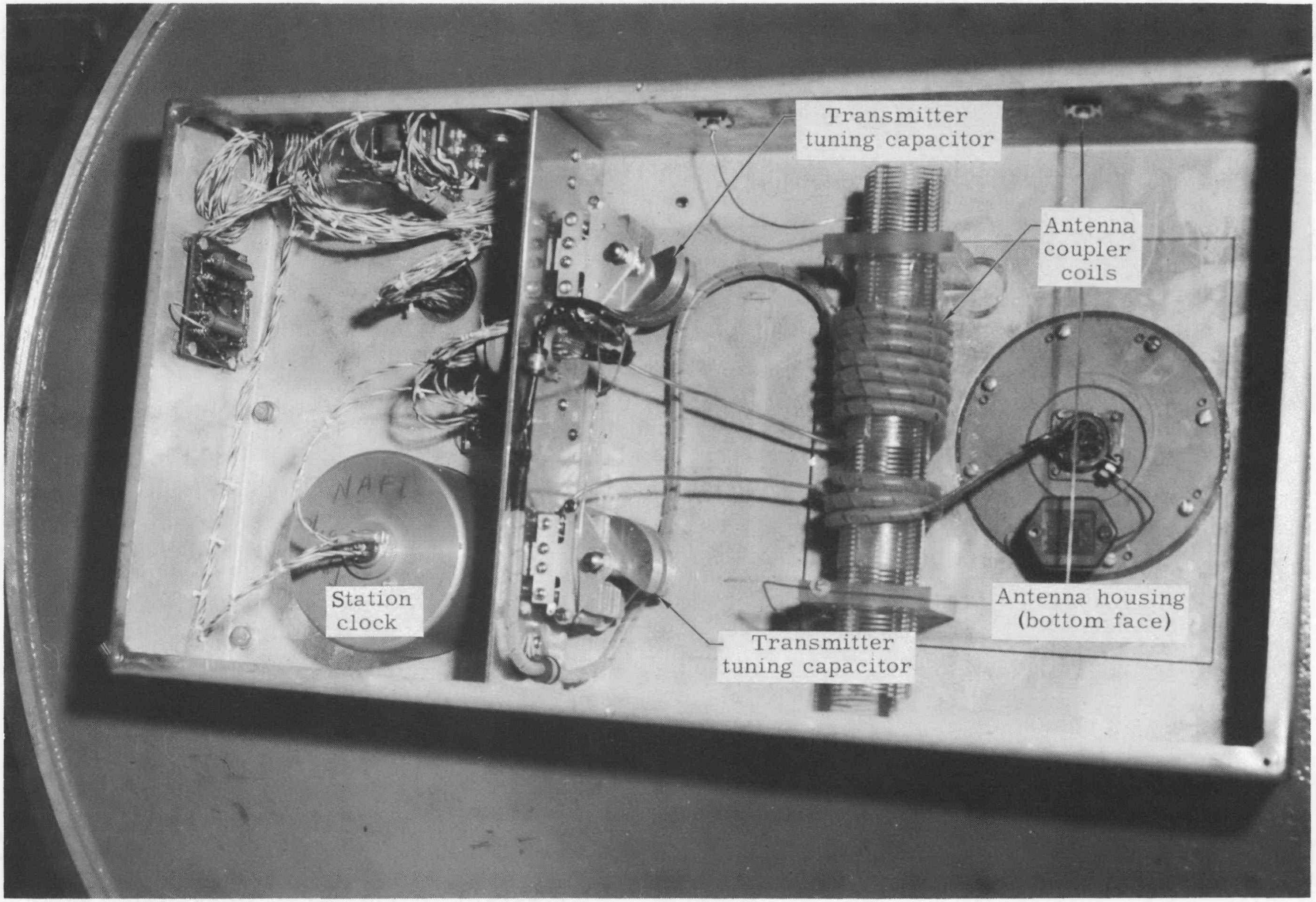


Fig. 7. Bottom View of Top Deck Assembly

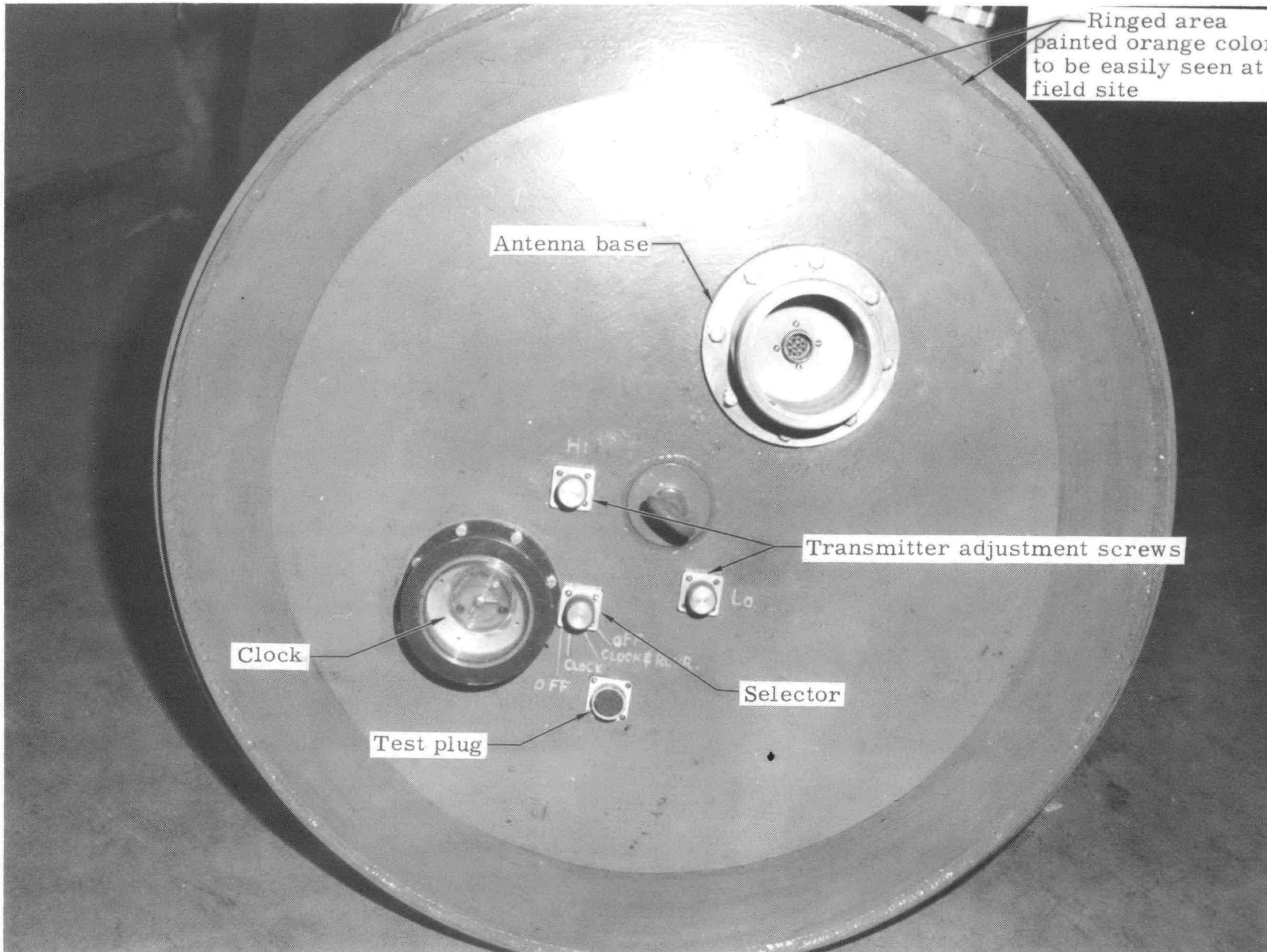
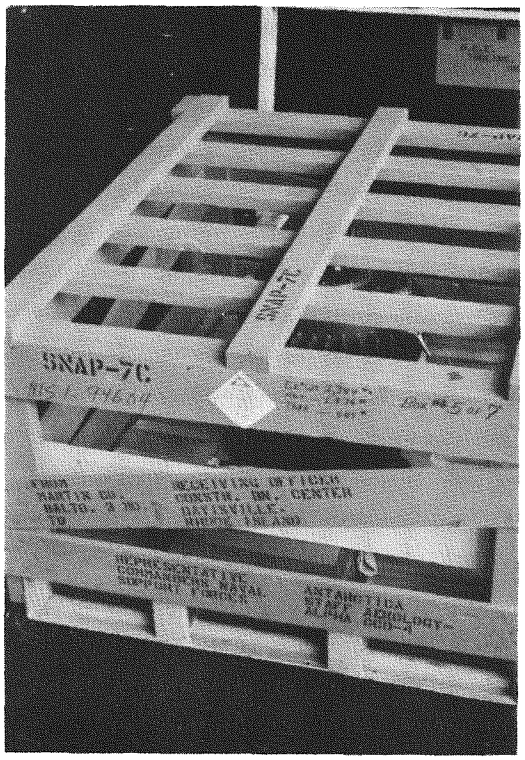
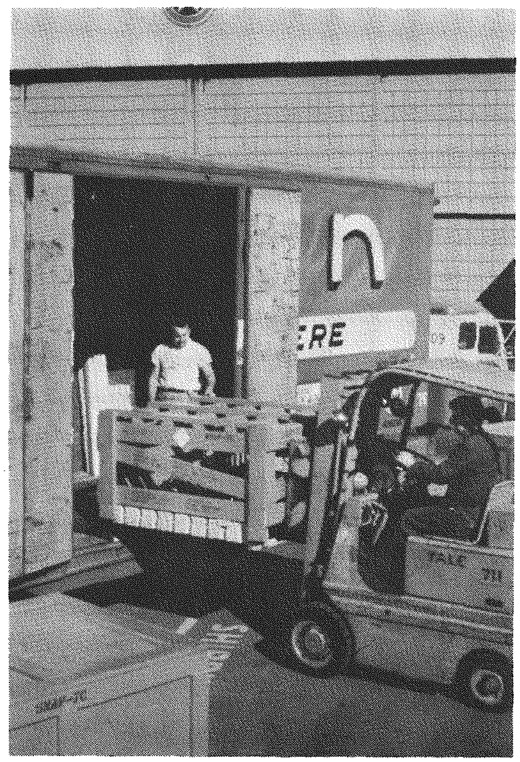


Fig. 8. Top Deck Assembly Outlets Through Top Deck Cover Plate

(A) Shipped as Seven Separate Packages



(B) Generator in Shipping Package



(C) Packages Being Loaded for Shipment

Fig. 9. The SNAP 7C System--Packaged for Shipment to Davisville, Rhode Island

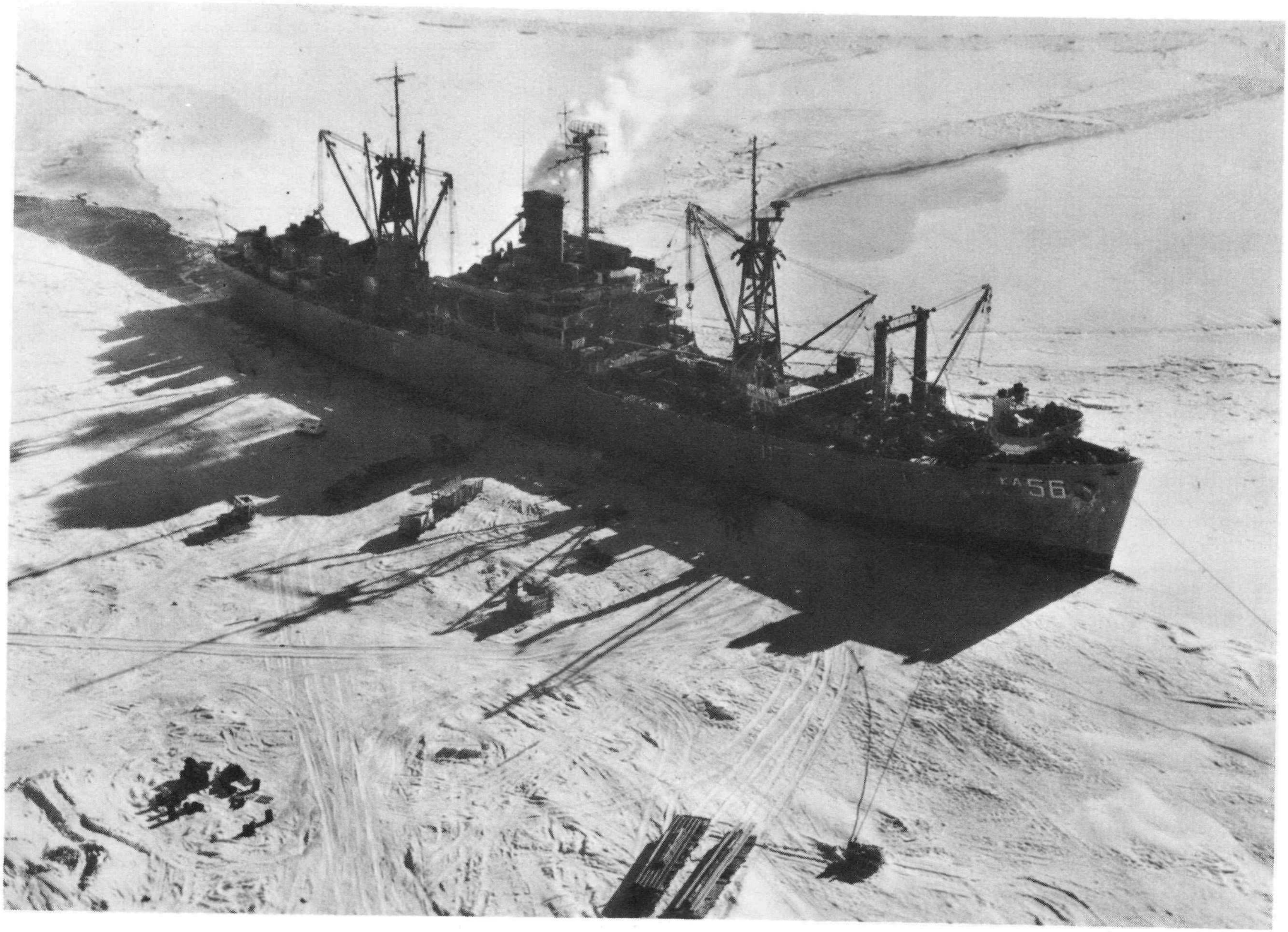


Fig. 10. The USS ARNEB--Unloading Equipment in Antarctica

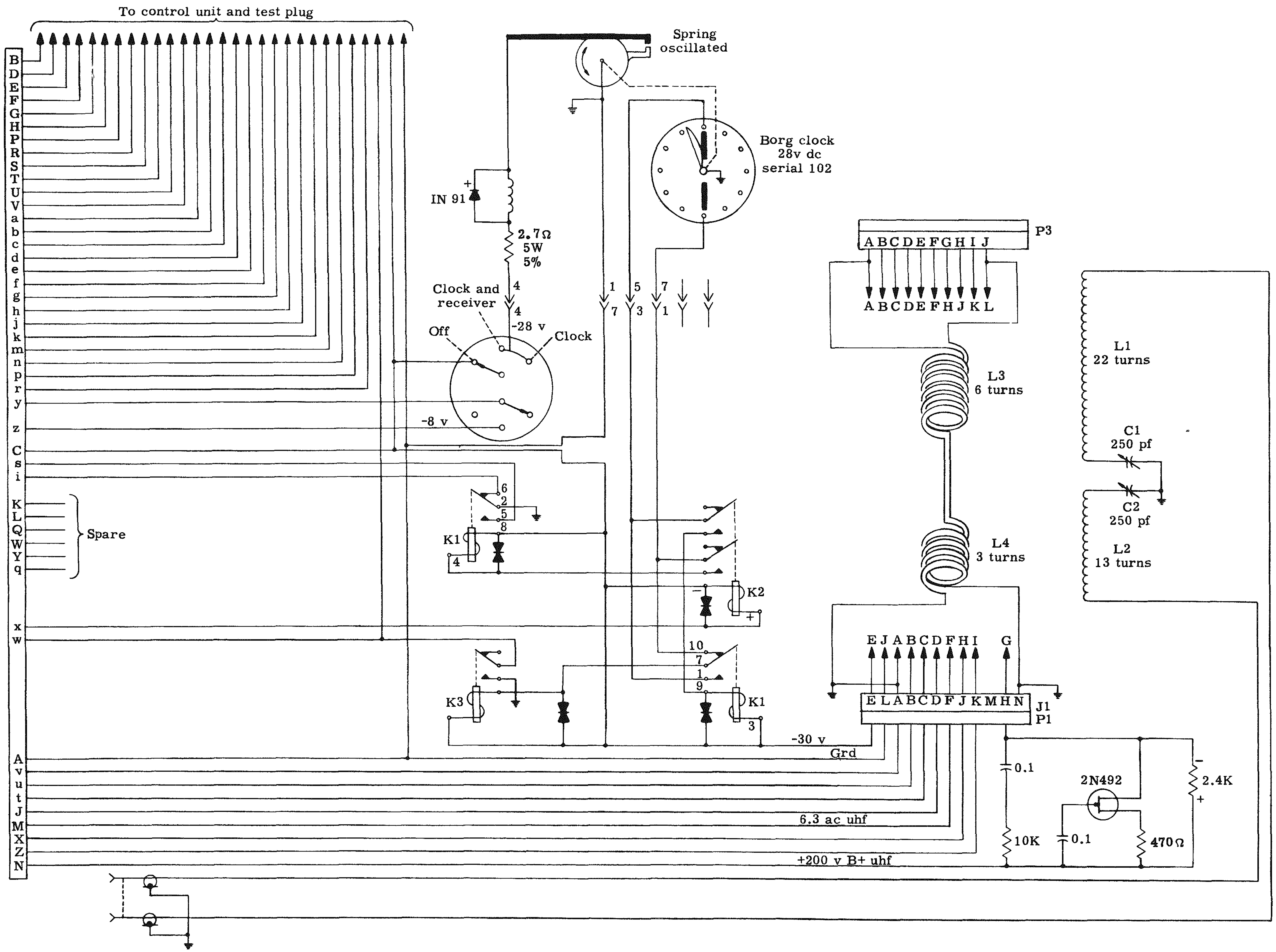


Fig. 11. Schematic Diagram of SNAP 7C Antenna Coupler

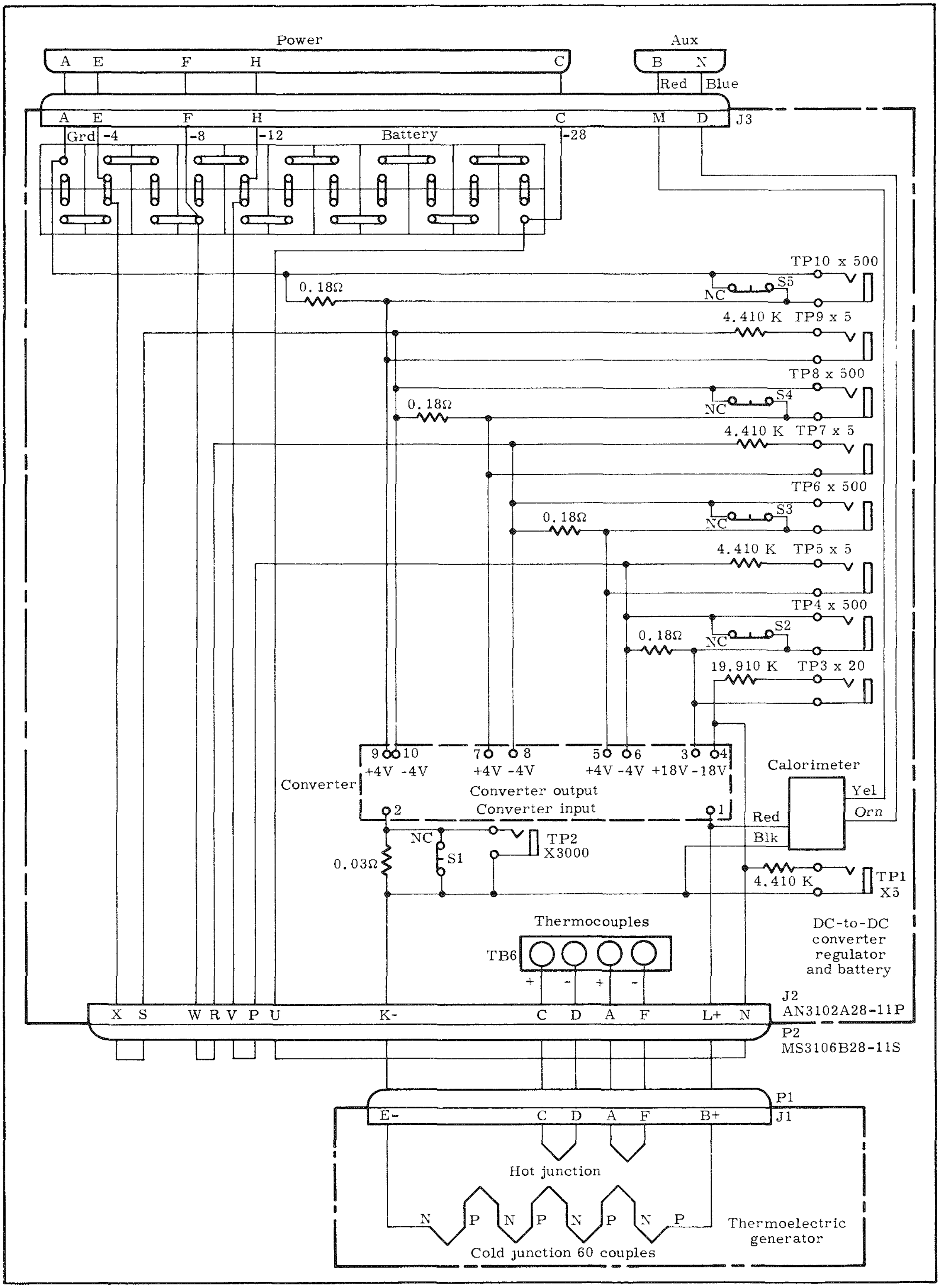
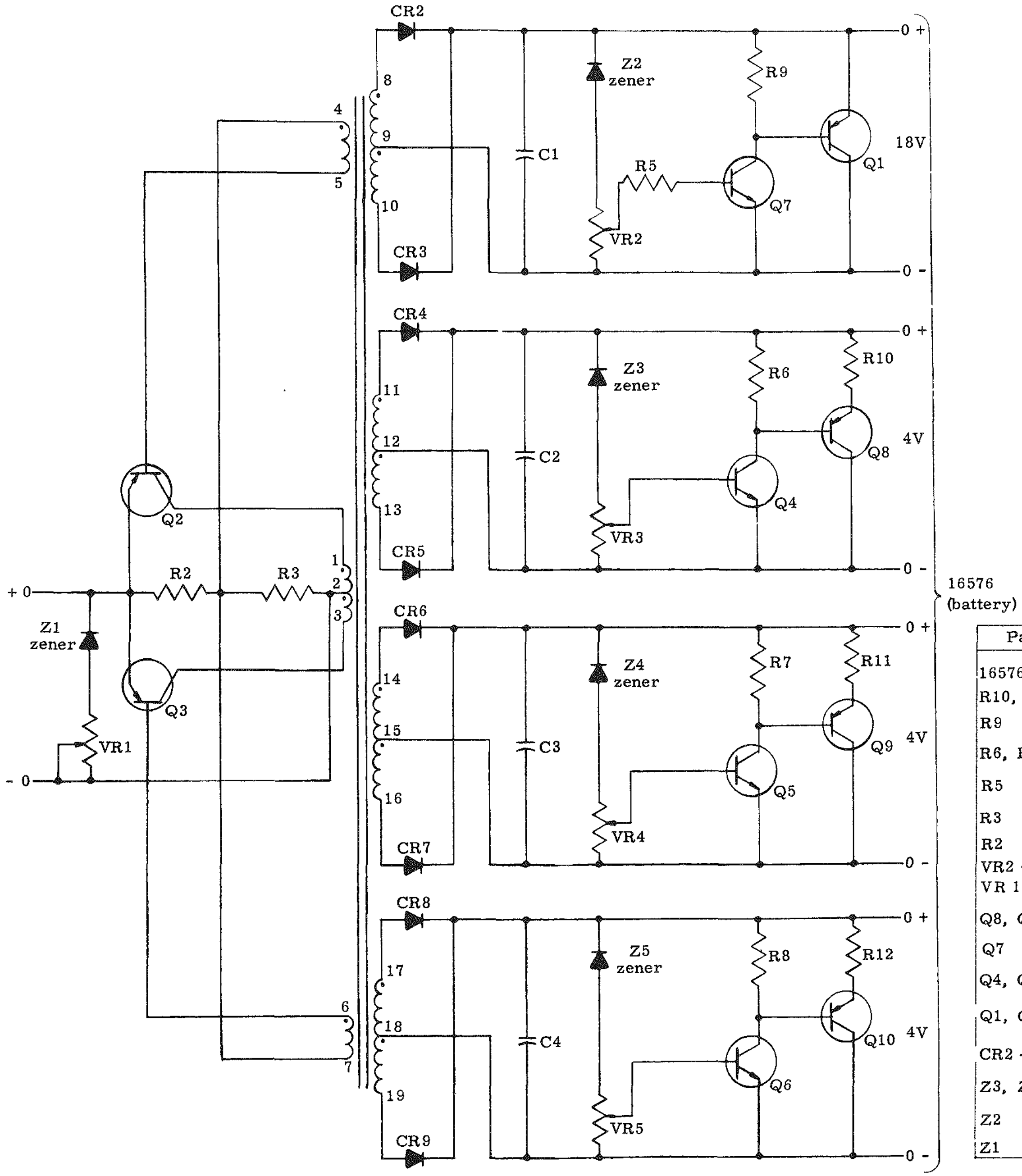


Fig. 12. Schematic of Battery and Converter Compartment



Part No.	Description
16576	Battery
R10, R11, R12	Resistor, 22 Ω, 1W, 5%
R9	Resistor, 680 Ω, 1/2W, 5%
R6, R7, R8	Resistor, 1200 Ω, 1/2W, 5%
R5	Resistor, 820 Ω, 1/2W, 5%
R3	Resistor, 220 Ω, 1/2W, 5%
R2	Resistor, 12.1 Ω, 1/2W, 1%
VR2 - VR5	Potentiometer 0-250 Ω, 2W carbon
VR 1	Potentiometer, 0-6 Ω, 2W wire wound
Q8, Q9, Q10	Transistor, PNP
Q7	Transistor, NPN
Q4, Q5, Q6	Transistor, NPN
Q1, Q2, Q3	Transistor, PNP
CR2 - CR9	Rectifier diode
Z3, Z4, Z5	Zener diode, 3.9V
Z2	Zener diode, 18V
Z1	Zener diode, 4.7V

Fig. 13. Schematic Diagram of the SNAP 7C DC-to-DC Converter

protection. Thermocouples were attached to the fuel block and to the top of the heat sink. Figure 14 shows thermocouple locations on both the SNAP 7A and the SNAP 7C generators. Figures 15, 16 and 17 are views of the 10-watt generator.

The biological shields were assembled during a prior quarter but not previously reported in detail. The first step in the assembly process was tinning both the inside and the outside cover of the depleted uranium of the biological shield (see Fig. 18). Next, the outer Hastelloy-C shell (with fins), the tinned depleted uranium and the inner Hastelloy-C shell were positioned on a dolly (see Fig. 19) and assembled one inside the other. A weight is positioned in the center so that as the assembly is heated in the furnace, the inner core and depleted uranium settle down to the proper position. Figure 20 shows the depleted-uranium shield being positioned for insertion into the outer Hastelloy-C shell. Figure 21 shows the furnace weight being inserted into the shield. Figure 22 shows both 10-watt shields prior to their insertion into the furnace. Figure 23 shows the assembly (without the furnace weight) after removal from the furnace. Figure 24 shows both units after sandblasting.

The assembled and instrumented generators were then installed in their respective Hastelloy-C cans, the O-rings inserted, the cover plates bolted to the containers and the units delivered for testing.

At the completion of prefueling tests, the SNAP 7C generator was disassembled to remove the heat simulators and shipped to the Quehanna facility. On September 14, 1961, the SNAP 7C generator was fueled and assembled within the biological shield. The unit was purged of air and filled with hydrogen for shipment to Baltimore. The total time required to complete the remote fueling and closure of the unit was thirty minutes. Figure 25 shows the unit upon its arrival at Martin Marietta Corporation in Baltimore where it was immediately placed under a postfueling check-out test. Figure 26 shows the generator on its shipping pallet with the tool box.

6. SNAP 7C--Generator, System and Component Tests

a. Generator tests

The prefueled generator tests were conducted at various temperatures, and electrical heaters were used during the tests to obtain initial and end-of-life power parameters. Also, various combinations of internal gas were used.

The generator output power, internal atmosphere, and hot and cold junction temperatures are shown in Table I.

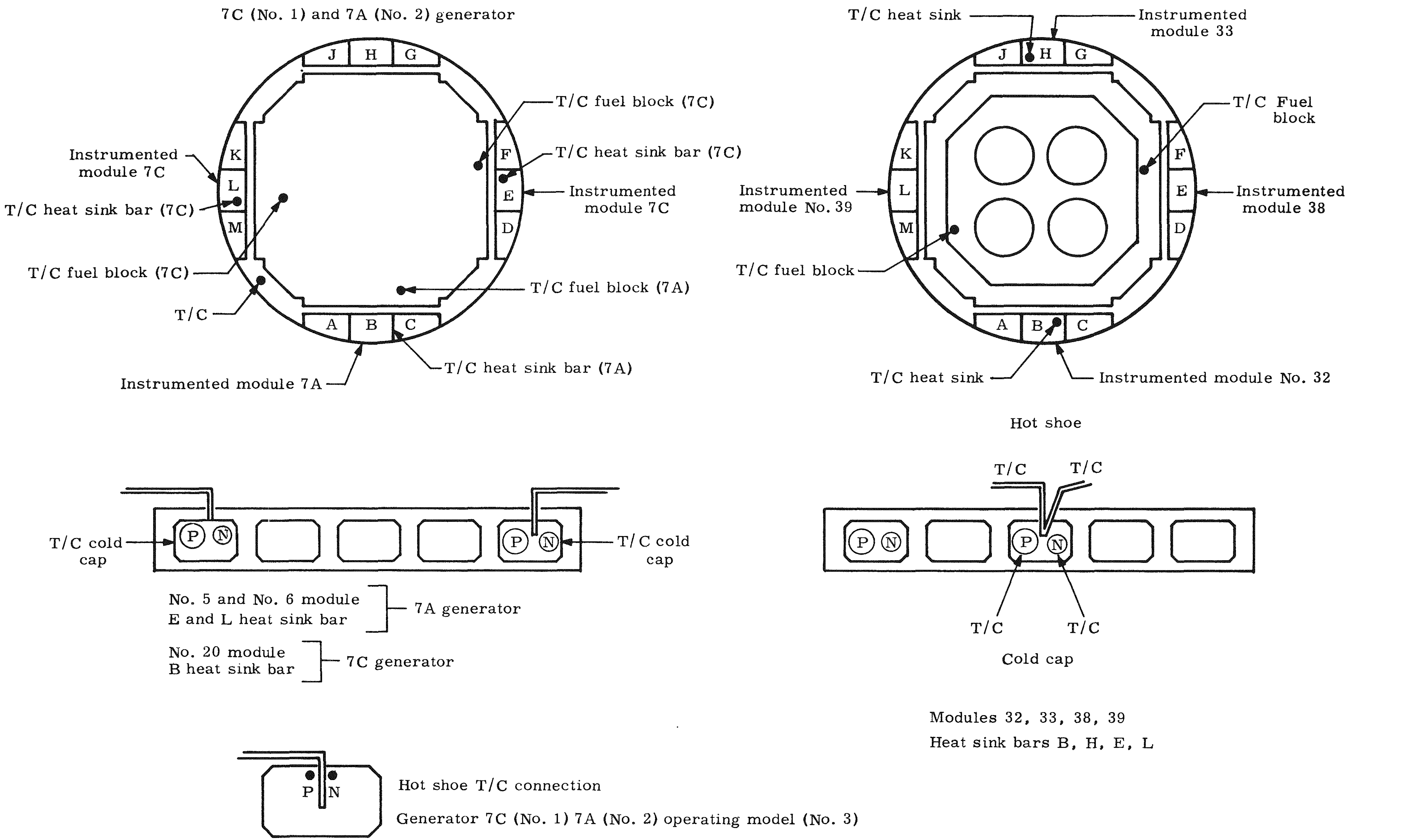


Fig. 14. Thermocouple Locations on the SNAP 7A and SNAP 7C Generators

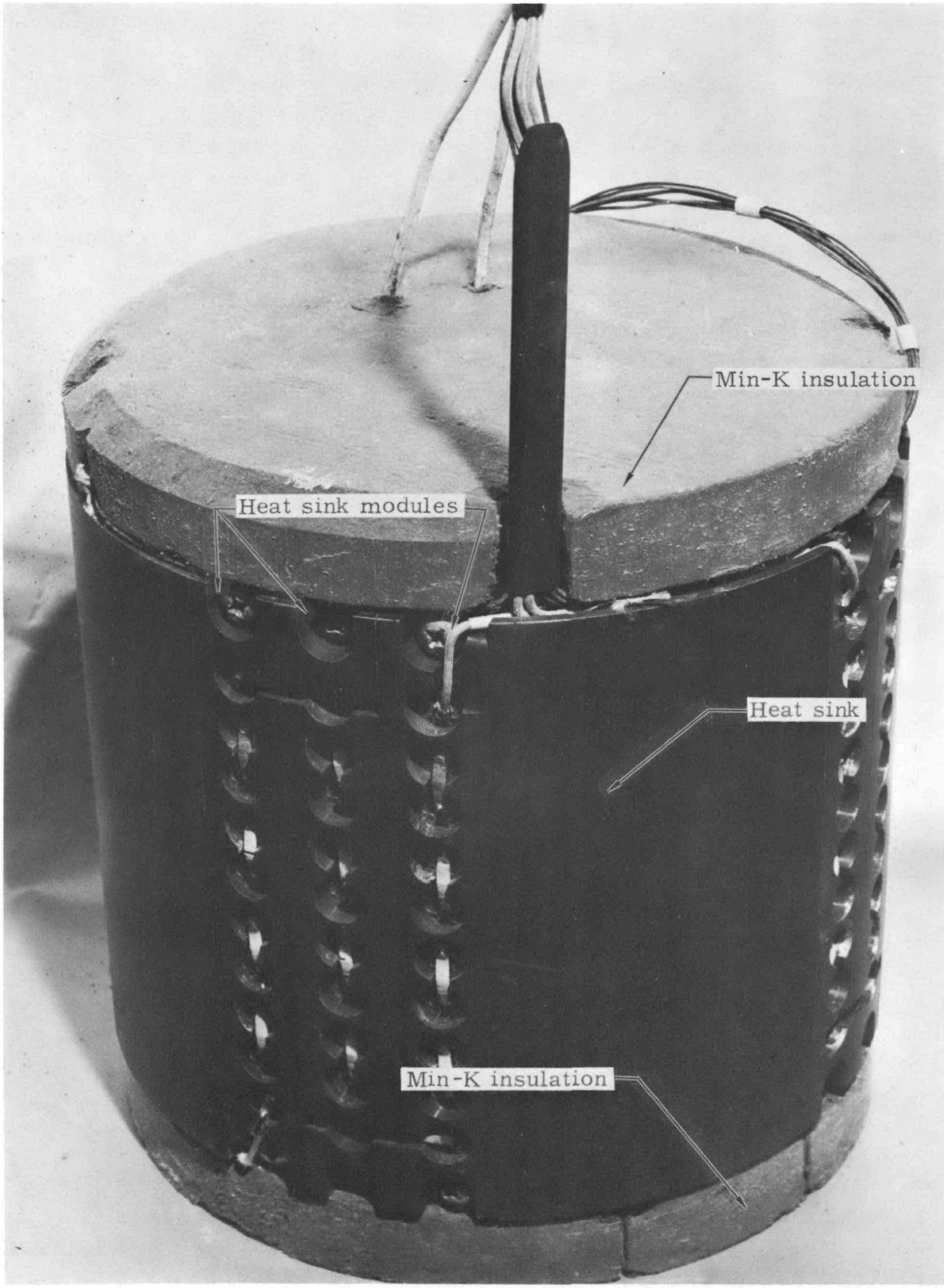


Fig. 15. Top View of the 10-Watt Instrument Generator--Min-K Insulation in Position

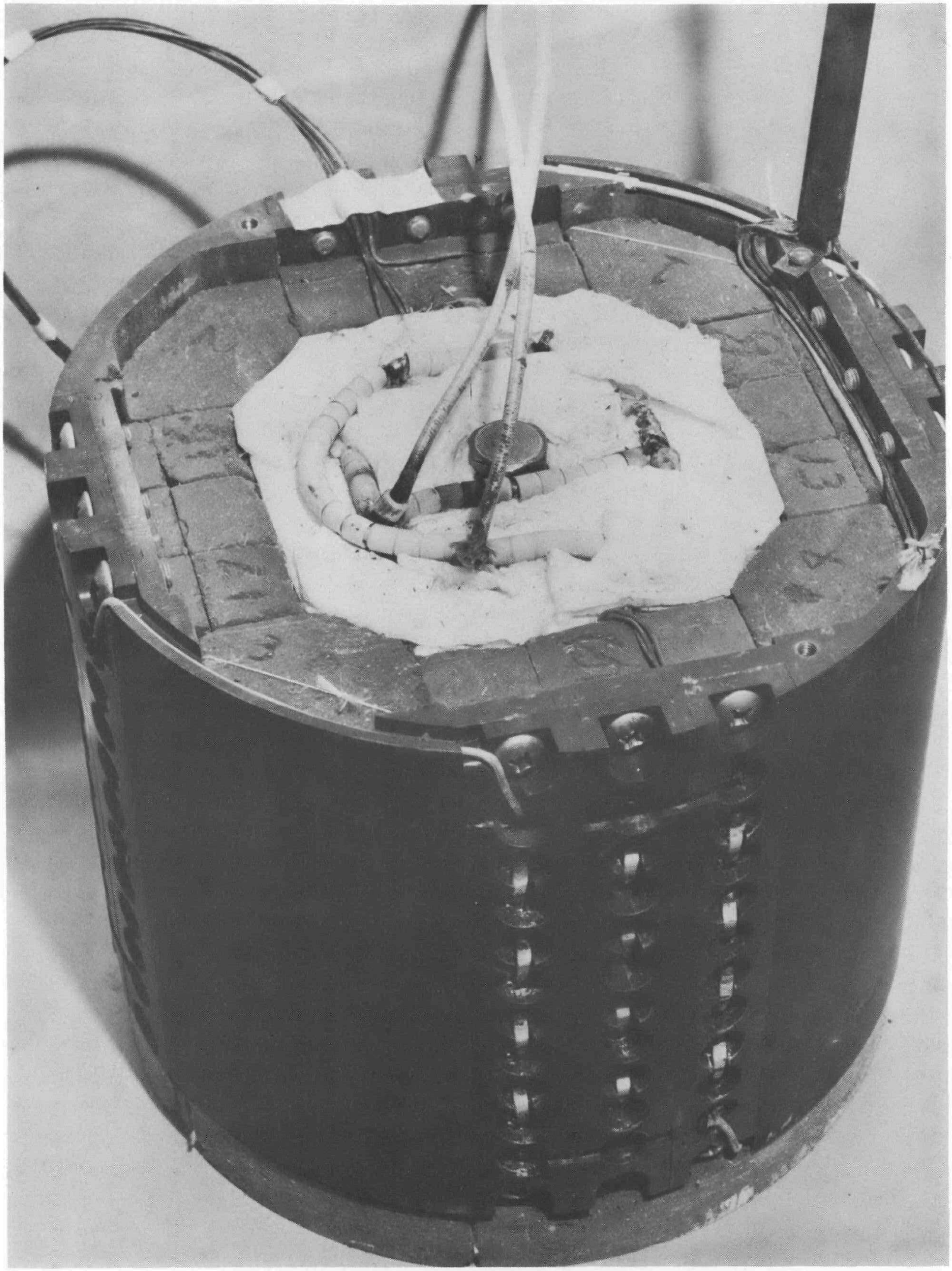


Fig. 16. Top View of the 10-Watt Instrument Generator--Min-K Insulation Cover Removed

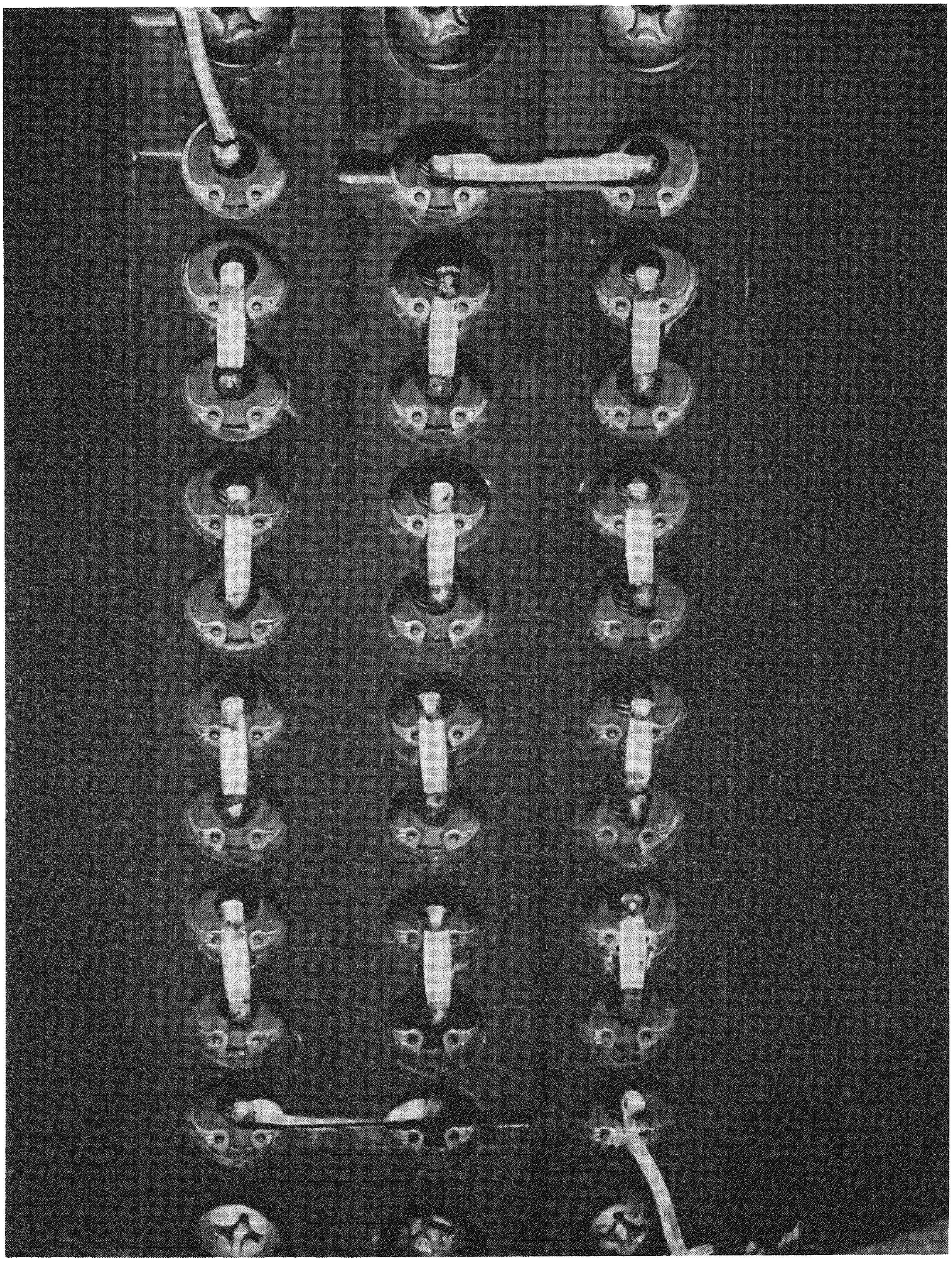


Fig. 17. Side View of the 10-Watt Generator--Thermoelectric Couple Outlets

Fig. 18. Tinning the Inside Wall of the Depleted-Uranium Biological Shield

Fig. 19. Biological Shield Assembly

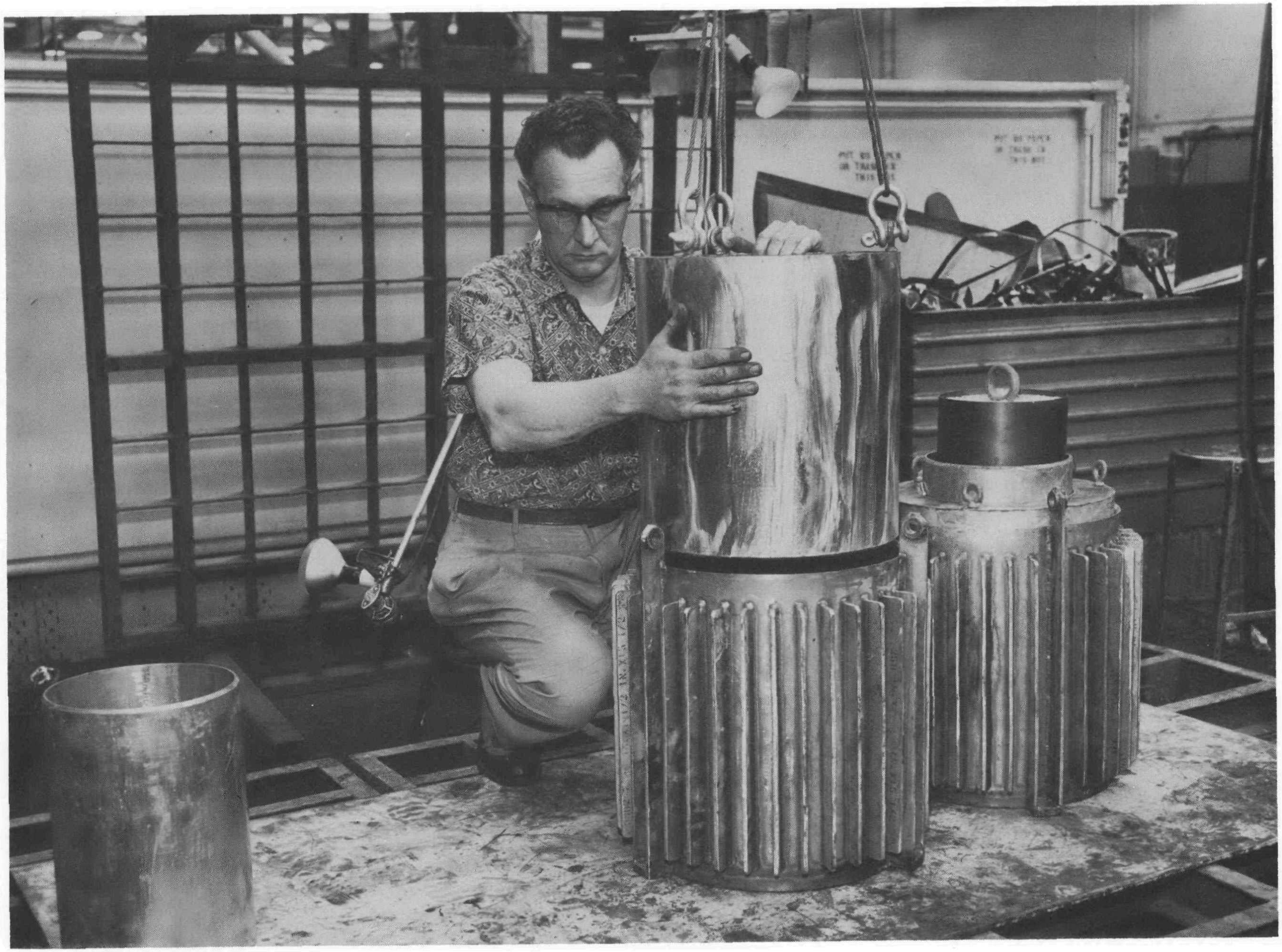


Fig. 20. Depleted-Uranium Shield Being Positioned for Insertion into Outer Hastelloy-C Shell

Fig. 21. Inserting Furnace Weight into Shield

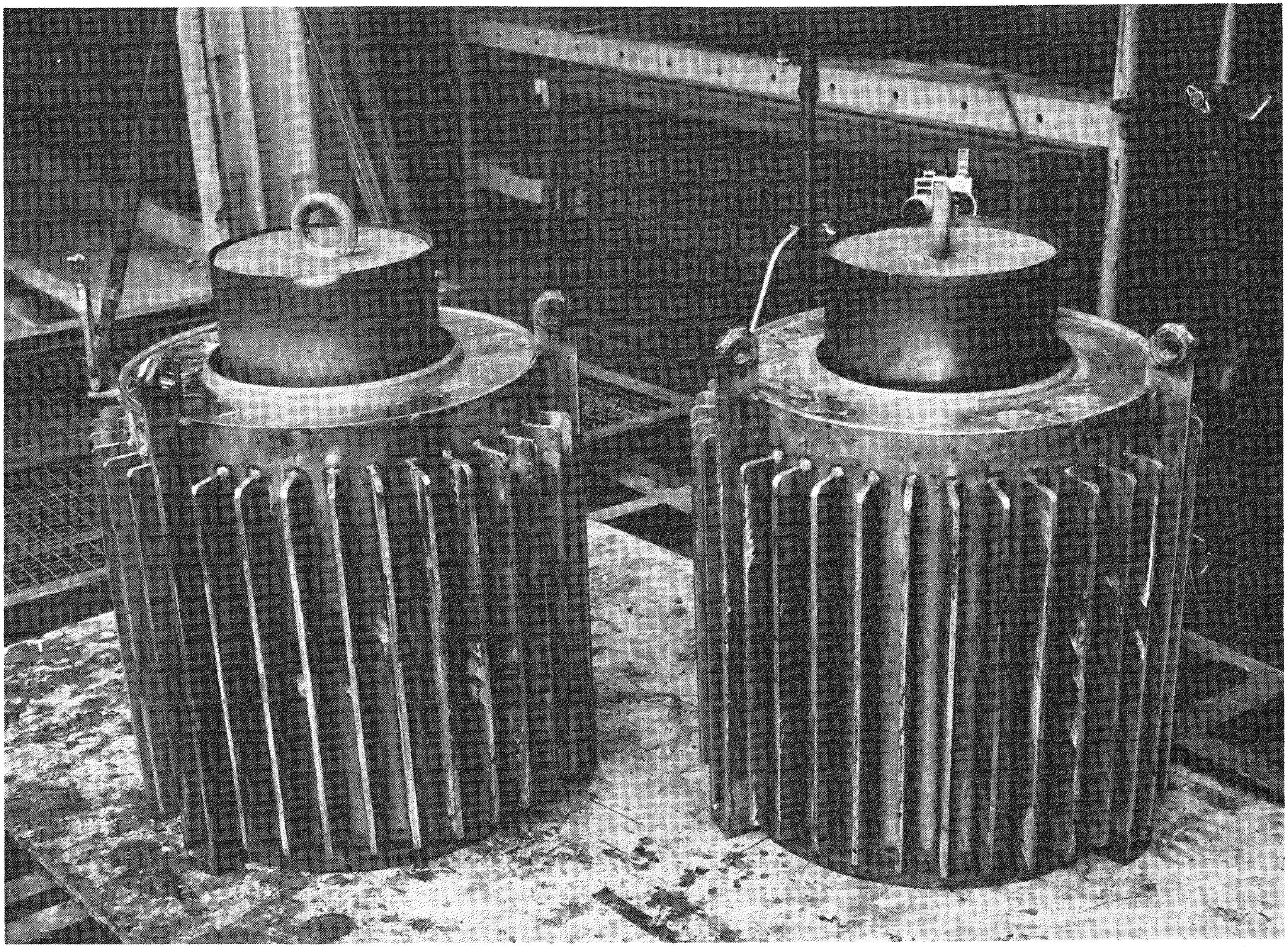


Fig. 22. Biological Shields After Heat Treatment in Furnace (Furnace Weight Inserted)

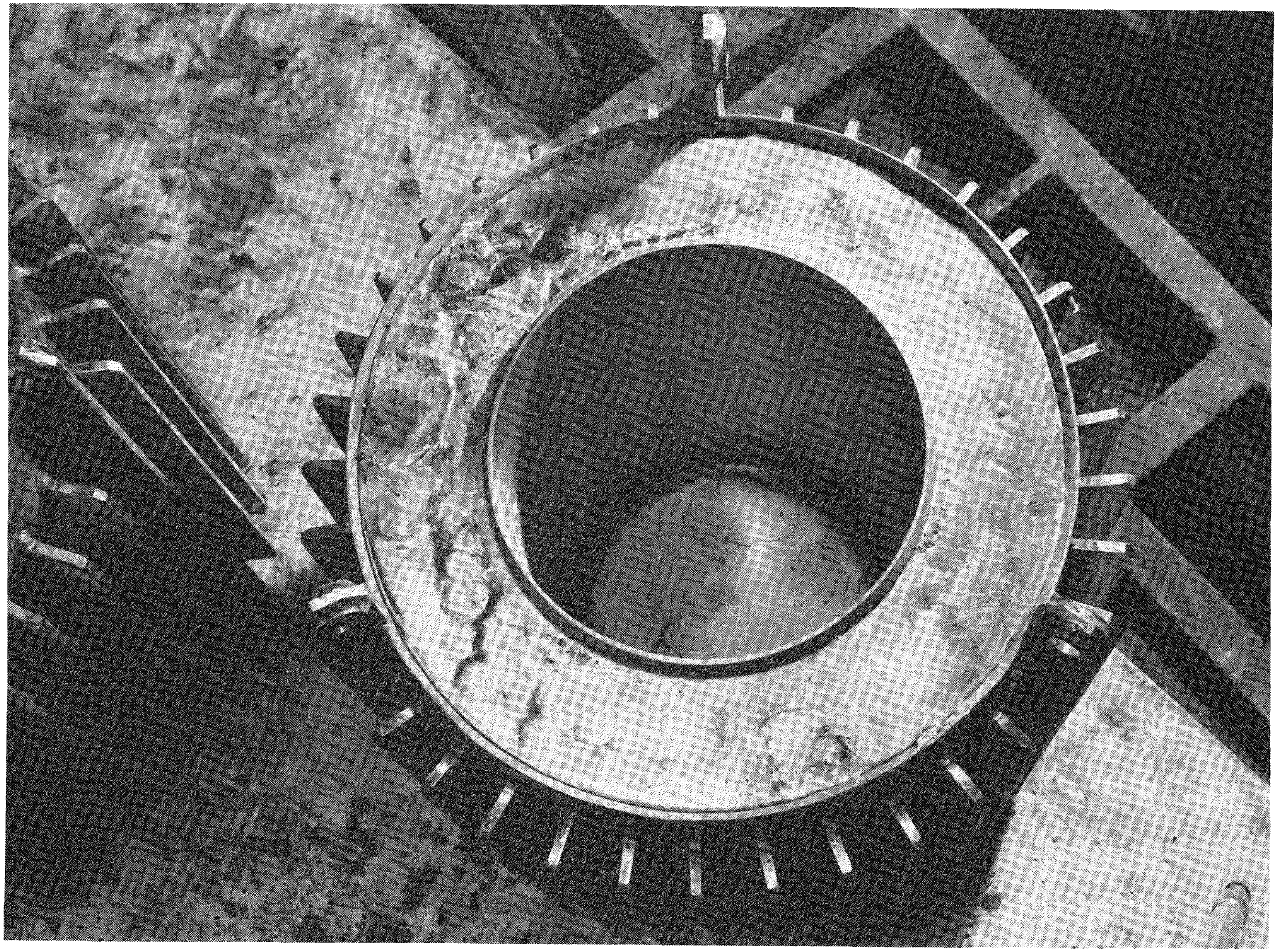


Fig. 23. Biological Shield After Removal from Furnace (furnace weight removed)

Fig. 24. Biological Shields After Sandblasting

Fig. 25. SNAP 7C Generator Arriving in Baltimore After Having Been Fueled and Assembled at the Quehanna Facility

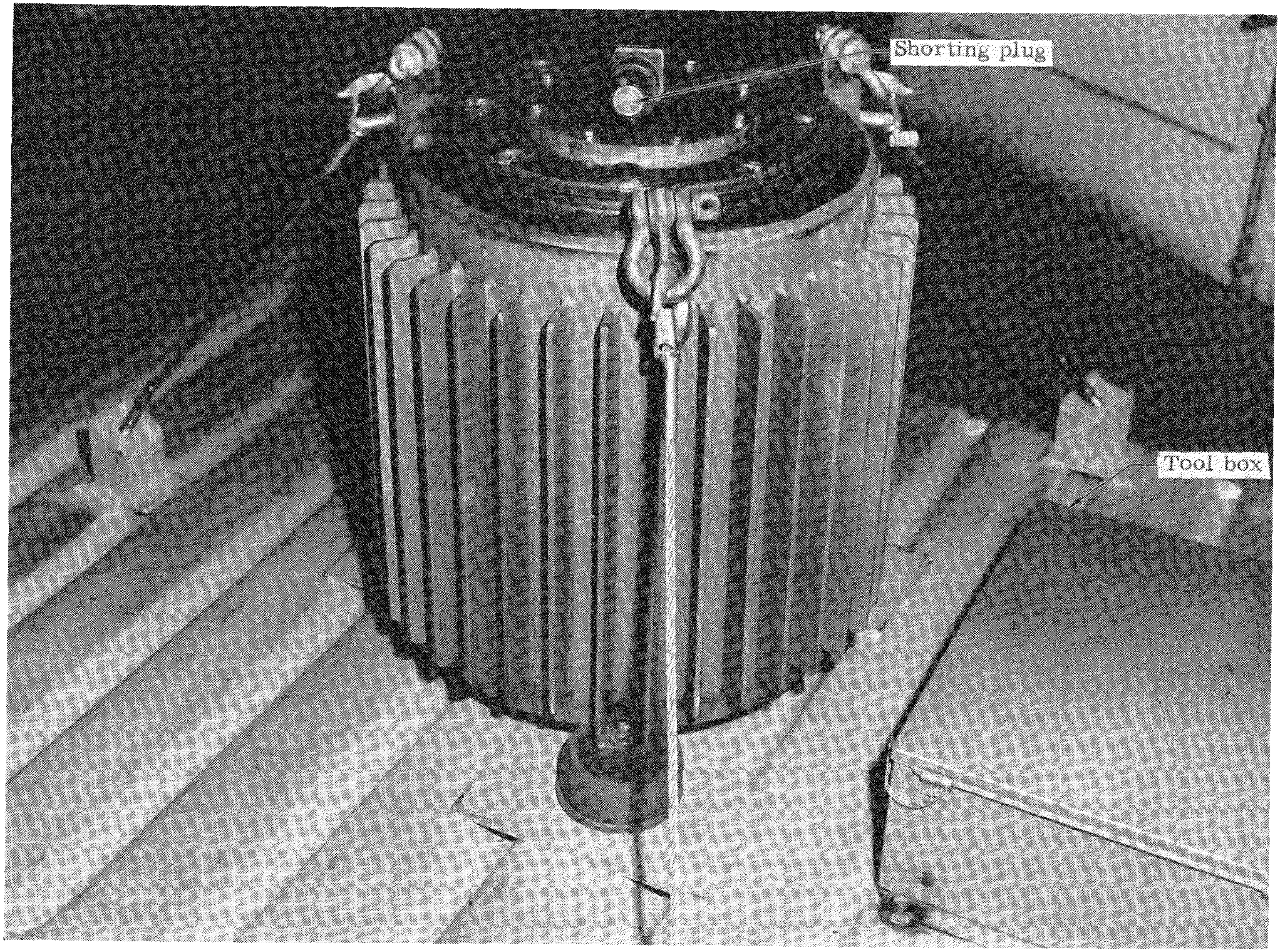


Fig. 26. Fueled SNAP 7C Generator on Shipping Pallet in Gamma Pool Area at Martin Marietta in Baltimore

TABLE I

Summary of Generator Tests*

Conditions	Power Input (watts)	Power Output (watts)	Atmosphere	Hot Junction Temperature (°F)	Cold Junction Temperature (°F)
7C--Beginning of Life	250	10.09	100% helium	924	128
7C--End of Life	210	8.3	100% argon	805	125
7A--Beginning of Life	276	11.7	100% helium	950	
7A--2 years of operation	240	9.7	100% helium	860	
7A--2 years of operation	240	11.8	25% helium 75% argon	950	
7A--8 years of operation	210	9.4	25% helium 75% argon	850	
7A--8 years of operation	210	10.2	100% argon	900	
7A--10 years of operation	200	9.3	100% argon	845	
Third generator Beginning of Life	256	9.97	100% helium	895	

*Ambient temperature--room temperature

Figures 27 through 32 represent typical parameters of generator performance. A varying power input and gas composition were used to simulate beginning- and end-of-life conditions.

b. System tests

System tests on a fueled SNAP 7C generator, actual converter and battery, and a simulated transmitter were initiated September 29, 1961. The test resulted in a decision to change the internal gas composition of the generator from argon-hydrogen to helium. The change resulted in a stabilization of the hot junction temperatures and internal gas pressures. The change was brought about by the fact that a hydrogen-argon atmosphere caused a fluctuation of gas composition and pressure, which resulted in increasing hot junction temperatures as a function of time. This effect was attributed to the absorption of the hydrogen by the uranium component of the top shield.

The shunt-regulated 7C converter provided charging voltages to the batteries as shown in Table II. These voltages fall within the acceptable limits of 1.33 and 1.38 volts per cell. These limits are necessary in order to maintain trouble-free operation of the system for the long periods of time the system will remain unattended. Values below 1.33 volts will result in a deficiency of power delivered to weather station components. A value higher than 1.38 volts will result in increased electrolyte loss due to dissociation and subsequent outgassing.

TABLE II

Converter Charging Voltages

Cycle (hr)	4-Volt Sections		18-Volt Sections (volts)
	Minimum	Maximum	
3	4.10	4.12	17.67
6	4.10	4.13	17.84

c. Component acceptance tests

The tests specified in Ref. 7 as acceptance tests were successfully conducted. The total battery output was measured after loads were applied to the respective battery sections. The transmitter was cycled three times in succession, which resulted in a battery voltage of 28.3 volts with acceptable ripple values. The minimum acceptable voltage was 26.0 volts.

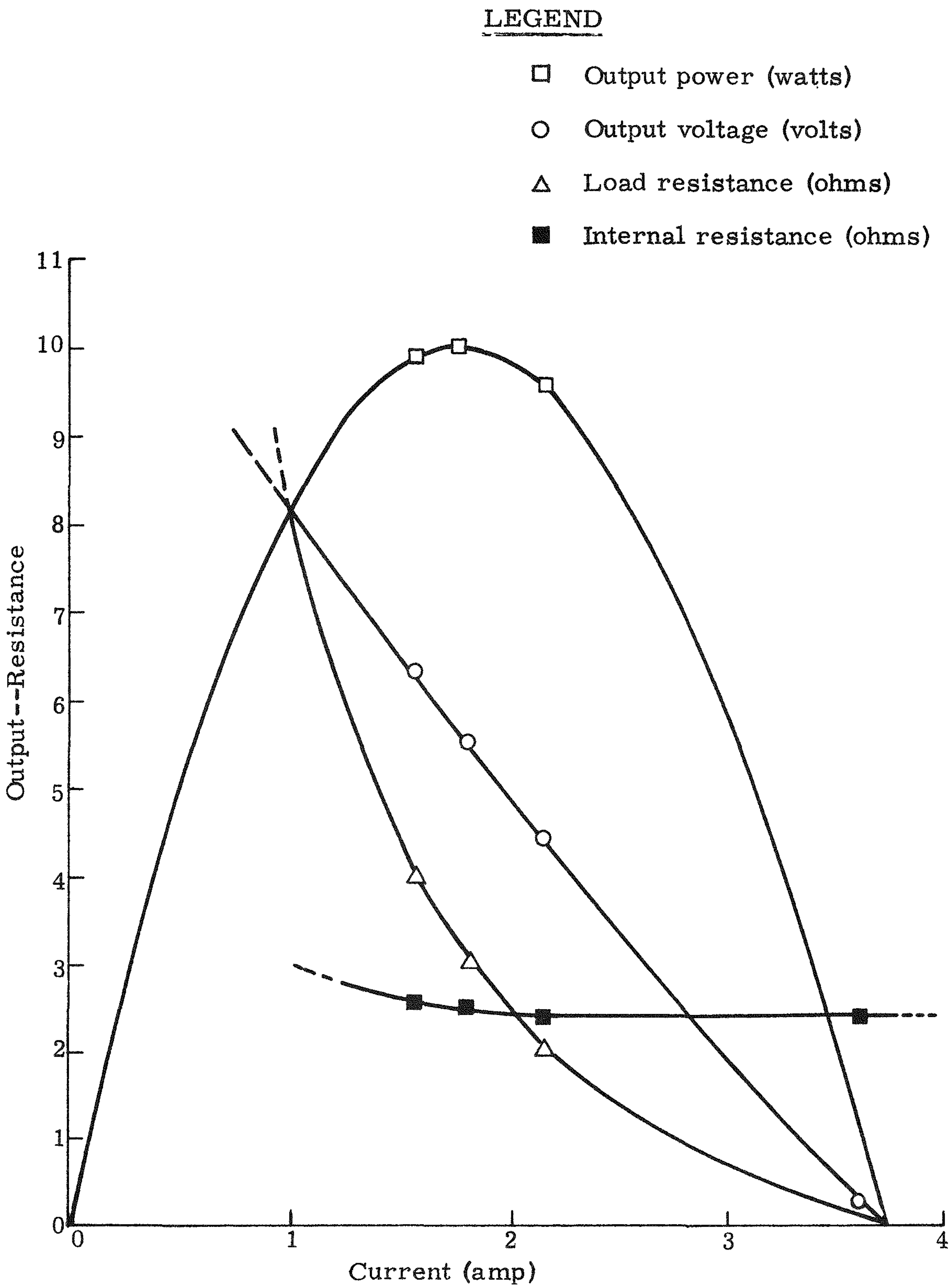


Fig. 27. Plot of Parametric Data for SNAP 7A and SNAP 7C Test Generator (Operating Model), Where Power Input was 266 Electrical Watts and Internal Gas Composition was 100% Helium (1.05 atm)

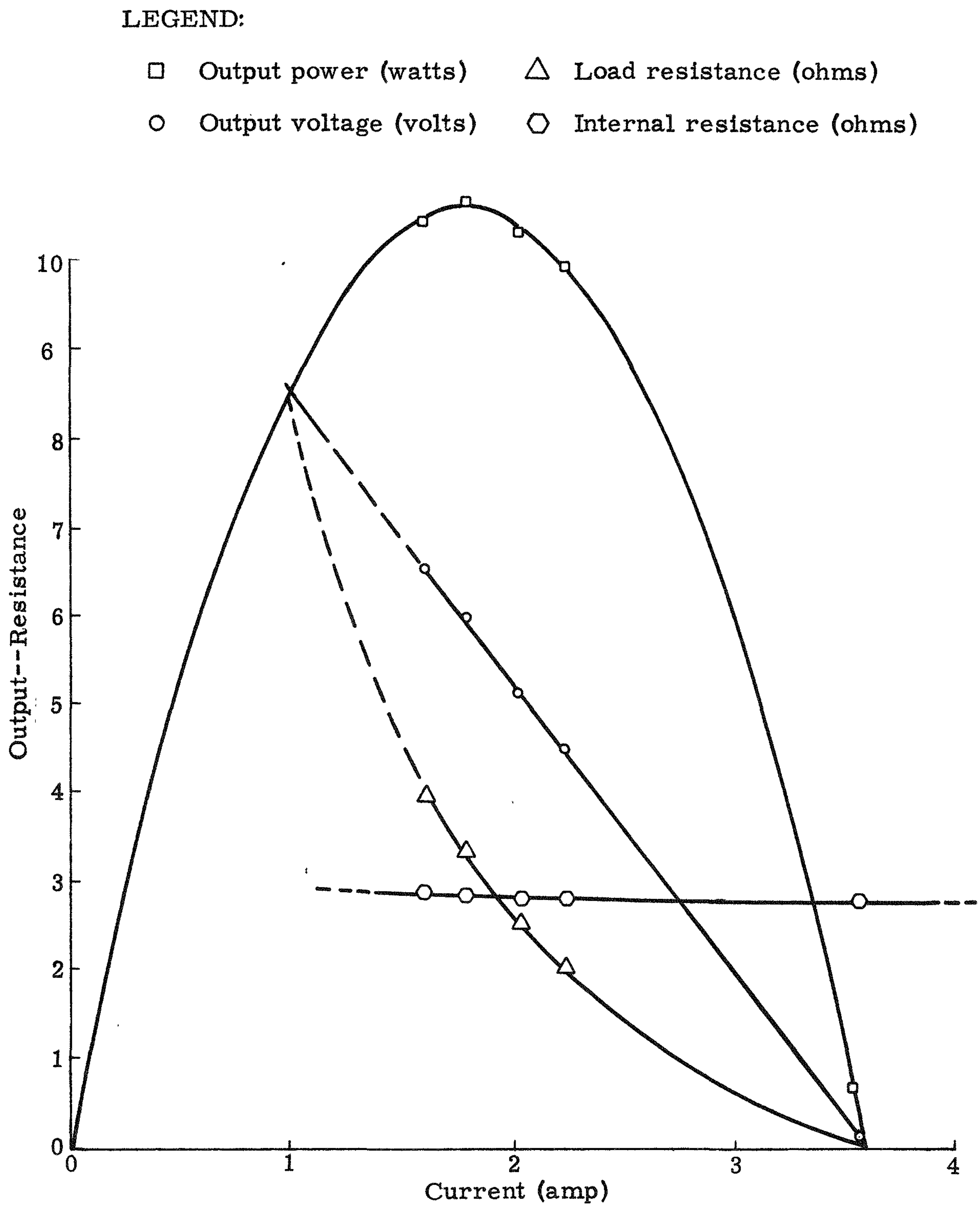


Fig. 28. Plot of Parametric Data for SNAP 7A Generator, Where Power Input Was 266 Electrical Watts and Internal Gas Composition Was 100% Helium (1.05 atm)

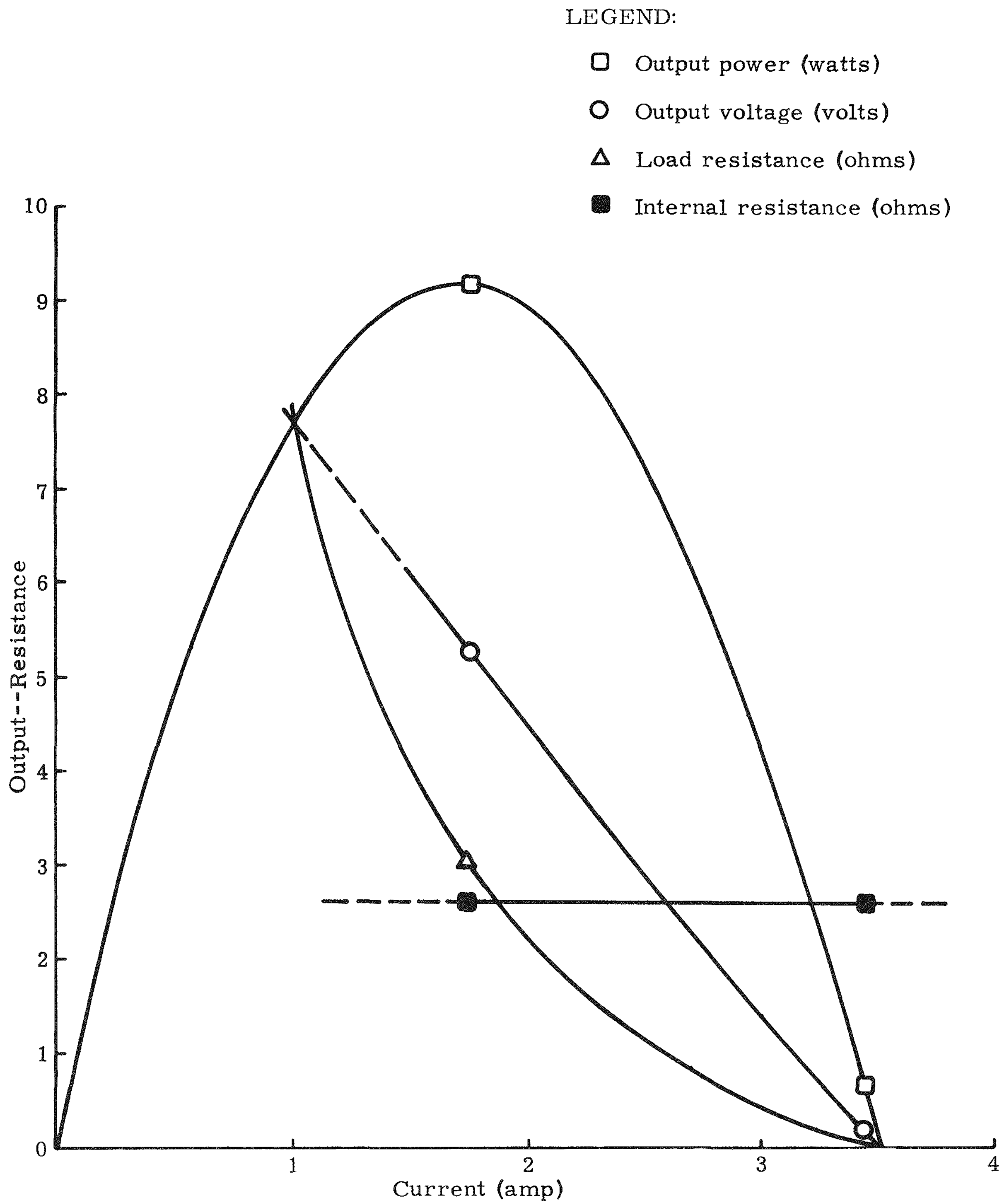


Fig. 29. Plot of Parametric Data for SNAP 7A Generator, Where Power Input Was 248 Electrical Watts and Internal Gas Composition Was 100% Helium (1.05 atm)

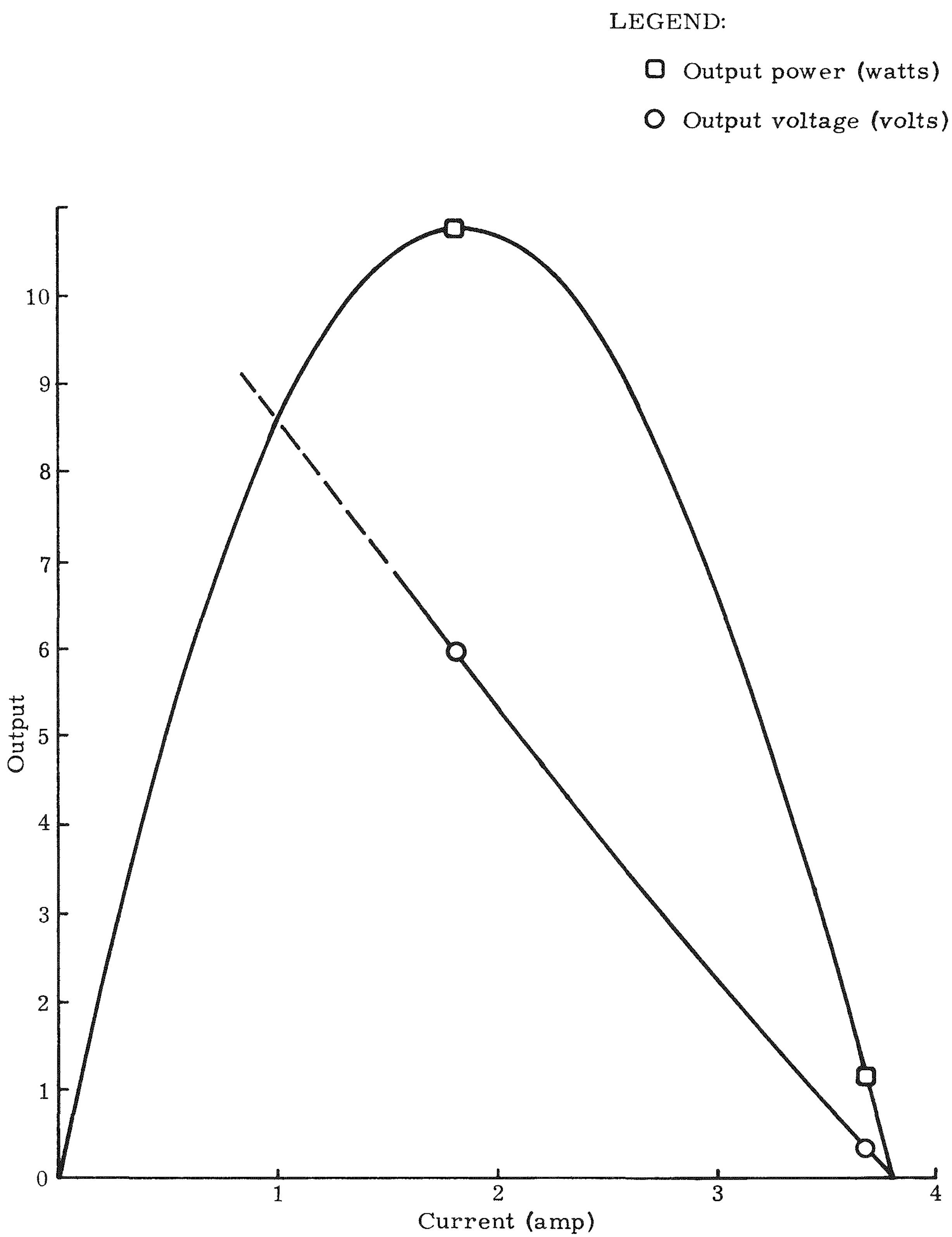


Fig. 30. Plot of Parametric Data for SNAP 7A and SNAP 7C Test Generator (operating model), Where Power Input Was 278 Electrical Watts and Internal Gas Composition Was 100% Helium (1.05 atm)

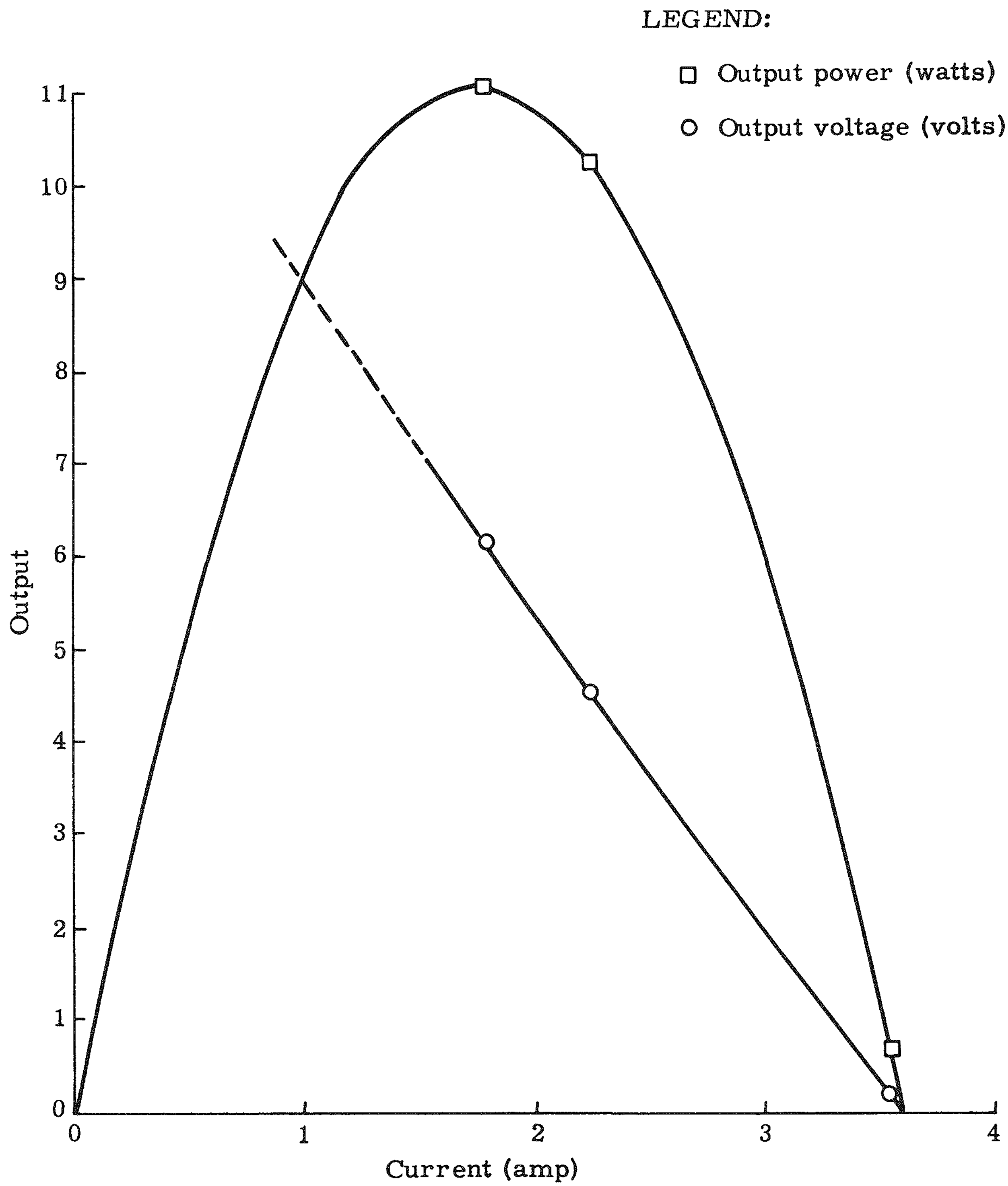


Fig. 31. Plot of Parametric Data for SNAP 7A Generator, Where Power Input Was 240 Electrical Watts and Internal Gas Composition Was 75% Argon and 25% Helium (1.05 atm)

LEGEND:

□ Output power (watts) △ Load resistance (ohms)

○ Output voltage (volts) ■ Internal resistance (ohms)

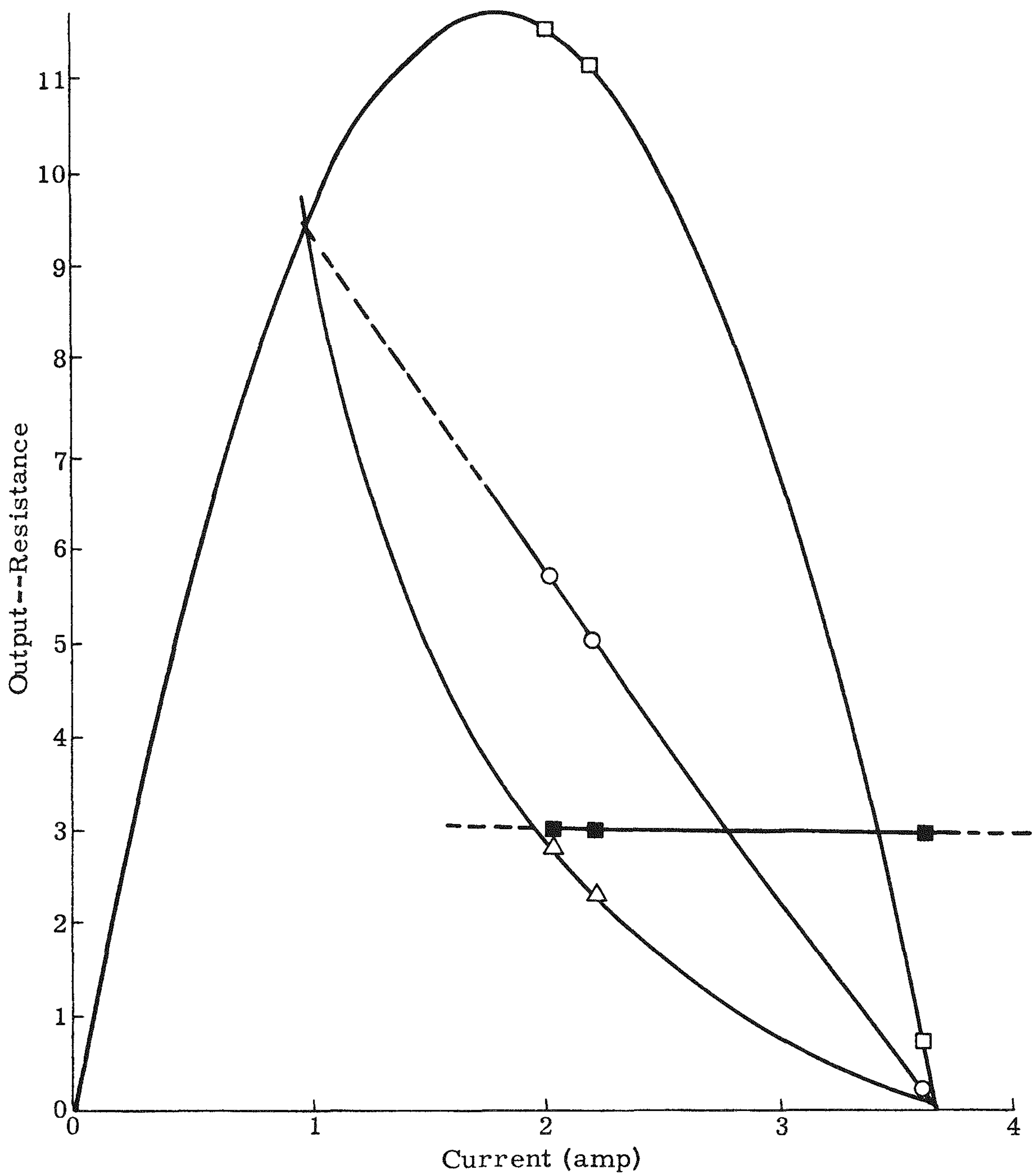


Fig. 32. Plot of Parametric Data for SNAP 7A Generator, Where Power Input Was 252 Electrical Watts and Internal Gas Composition Was 75% Argon and 25% Helium (1.05 atm)

d. Environmental test

Environmental qualification of the SNAP 7C system is primarily a result of the following considerations:

(1) The equipment, after exposure to normal accelerations and vibrations, must be operable and undamaged from shock or resonant oscillations.

(2) The equipment must be capable of operation in the installation environment.

The SNAP 7C thermoelectric generator, converter and battery were subjected to vibration, shock and temperature environments as follows:

(1) Vibration

(a) Vertical plane

(i) Increase in frequency from 5 to 33 cps in discrete intervals of 1 cps. Hold at each frequency for three minutes at a level of 3 g or an amplitude of 0.060 ± 0.006 in., whichever is less.

(ii) A frequency sweep of 5 to 300 cps and a return to 5 cps in fifteen minutes at a 3 g level or an amplitude of 0.060 ± 0.006 in., whichever is less.

(b) Repeat (a) above for the two remaining principal orthogonal axes.

(c) Dwell for a period of two hours at the most severe resonant condition with an input level consistent with the frequency.

The battery and converter were also subjected to the vibration tests described in (a) (ii) above.

(2) Shock

Subject components to two 6 g shocks, having a 6-millisecond half-sine wave pulse in each of the three principal orthogonal axes.

(3) Temperature

(a) Generator

Measure performance and specimen temperatures after stabilization at the following conditions:

Temperature	Pressure
0° F*	Sea level
+28° F	Sea level
+70° F*	Sea level
+125° F**	Sea level

(b) SNAP 7C battery and converter

Measure performance and component temperatures after stabilization at the following conditions:

Temperature	Pressure
+20° F*	Sea level
+60° F*	Sea level

(4) Test results

(a) Vibration

Figure 33 shows the generator mounted to the test fixture and positioned on an MB-C25 Electrodynamic Shaker for excitation in the vertical plane. Figure 34 shows the generator and fixture mounted to a slide plate resting on an oil table for excitation in the horizontal plane. Figure 35 shows the results of the vibration test in a horizontal plane for the thermoelectric generator.

Battery and converter were tested simultaneously for conditions (1)-(a)-(ii) and (1)-(b)-(ii) (see Fig. 36). Primary battery and converter functions were monitored throughout the test.

The generator functioned throughout all vibration tests. Discontinuities in generator output were noted at 90 and 250 cps. The 250-cps frequency was chosen for a vibration

---

* Anticipated extreme of ambient temperature.

** Maximum anticipated ambient temperatures during shipment. The generator is short-circuited to take advantage of the Peltier cooling effect.

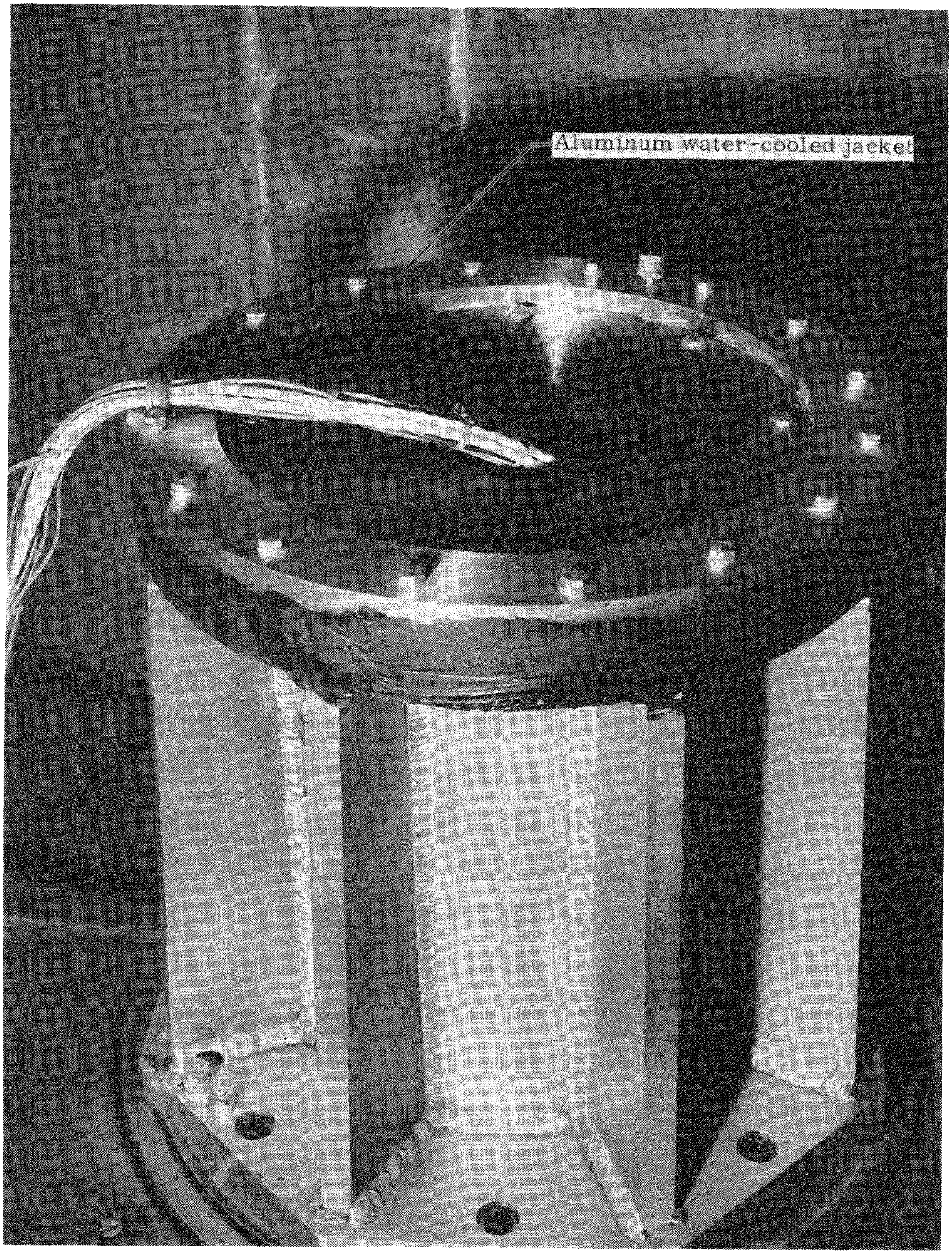


Fig. 33. Generator Mounted to Test Fixture and Positioned on Electrodynamic Shaker for Excitation in Vertical Plane

Fig. 34. Generator and Fixture Mounted to Slide Plate of Electrodynamic Shaker for Excitation in Horizontal Plane

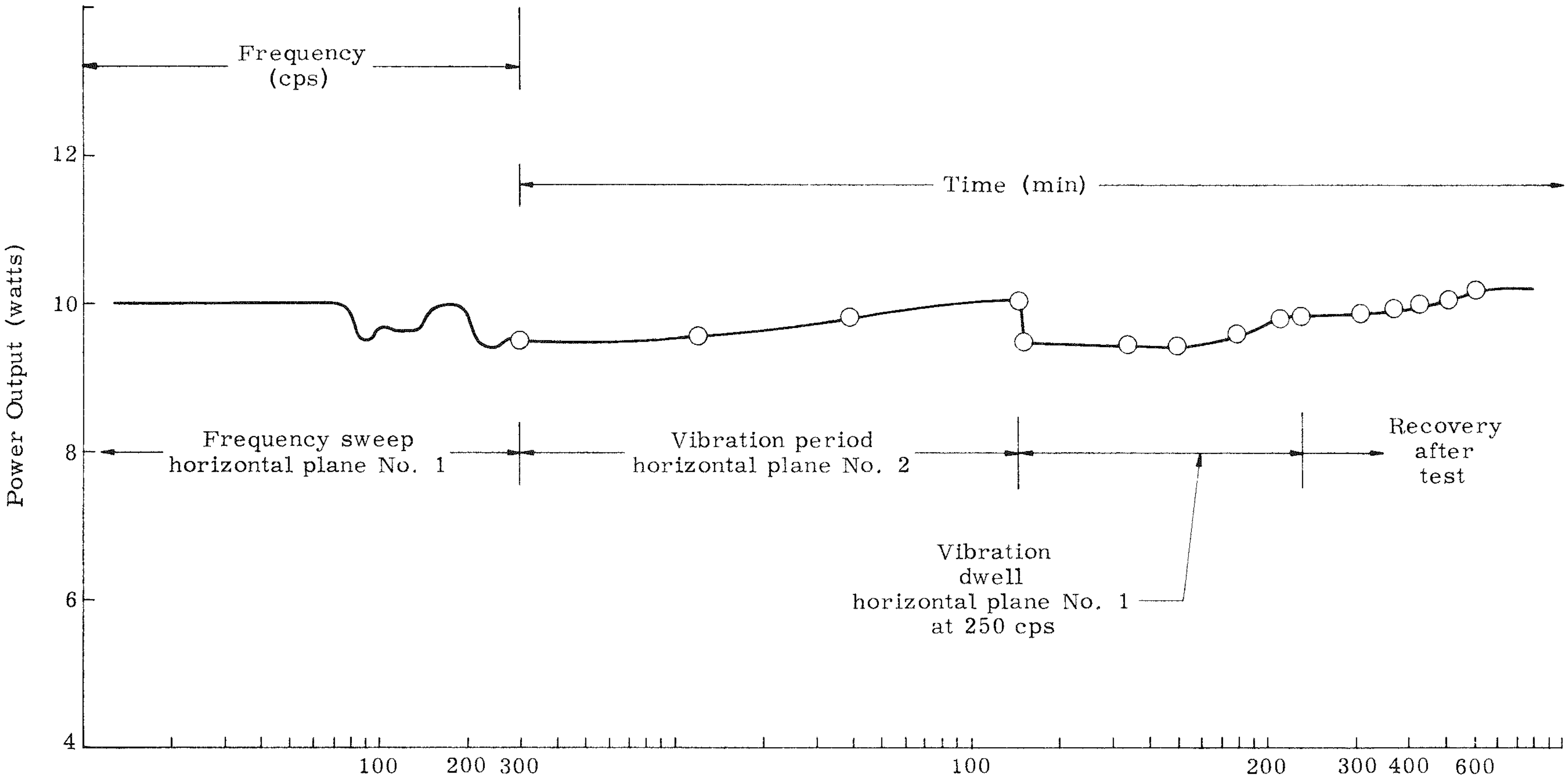


Fig. 35. Time History of Thermoelectric Generator Output During and After Horizontal Vibration

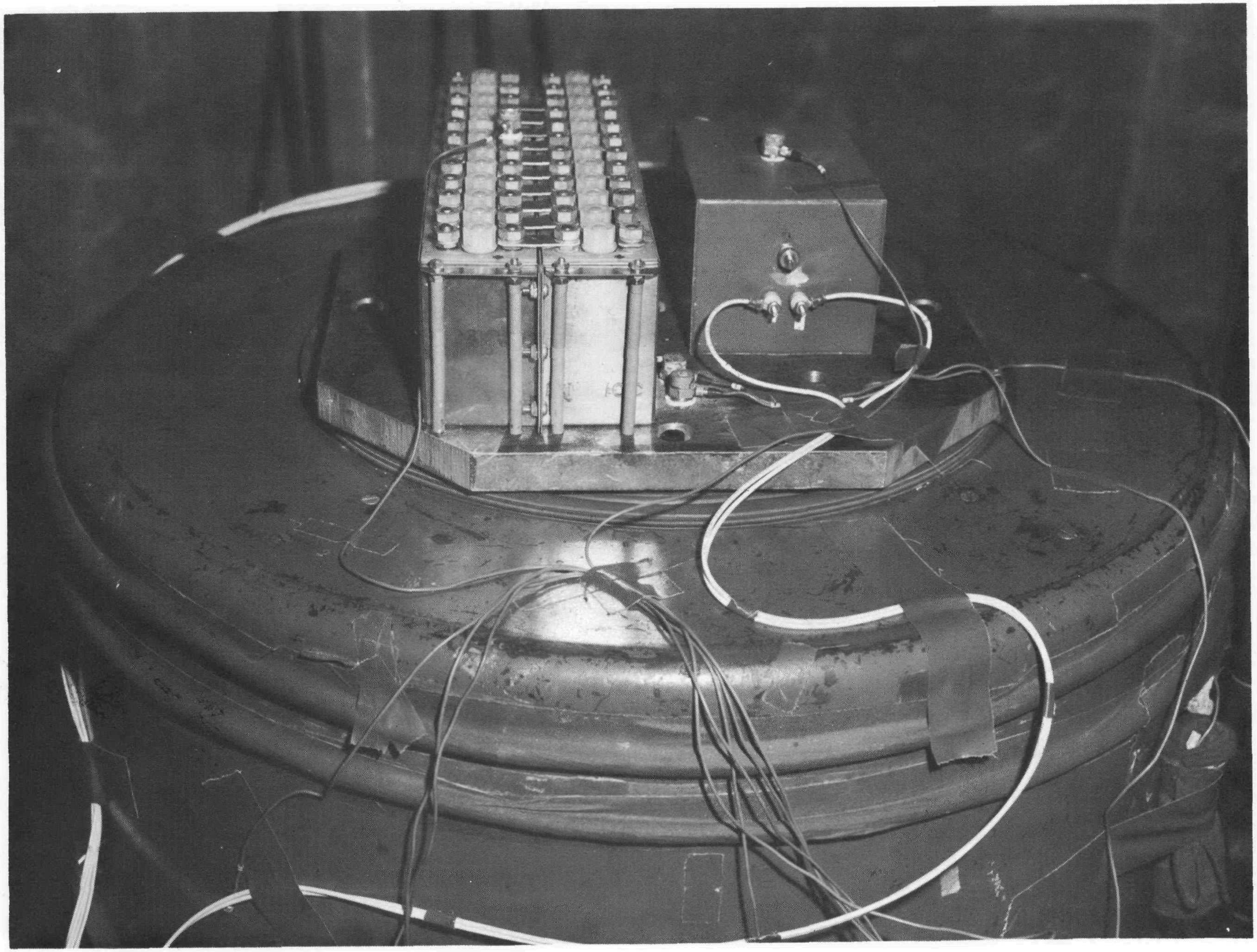


Fig. 36. SNAP 7C Batteries and Converter in Position on Electrodynamic Shaker to Test the Conditions: (1)-(a)-ii and (1)-(b)-ii

dwell in the horizontal plane because of the broad output response characteristics in that frequency range. The dwell resulted in the gradual restoration of generator output to 9.8 watts. The output power returned to 10 watts during the six-hour recovery period. Table III summarizes all vibration testing.

(b) Shock

During the shock tests in the first horizontal plane, a sudden decrease of 15% in output was noted. This occurred several minutes after the second shock. However, the output returned to maximum during the shock testing in horizontal plane No. 2. This decrease in output was also noted after handling of the input-output plug; as a consequence, output decrease was attributed to a loose electrical connection at the plug rather than the generator. Discrepancies in shock machine behavior were also noted, and, upon investigation, the actual load to which the generator was subjected was found to be 18 g rather than 6 g. This positively demonstrated the shock survival capability of the generator. Table IV summarizes generator shock tests; Fig. 37 is a typical record of output voltage and current during the test.

(c) Temperature

Figure 38 shows the generator positioned in a temperature chamber. Power inputs were varied during the test to simulate beginning- and end-of-life characteristics. Figures 39 through 42 are typical results for this test. In all of the above tests the SNAP 7C generator is referred to. However, the environment was a composite of both 7A and 7C requirements, and, since both generators are identical, the testing of one model was considered sufficient. Figure 43 is a schematic of the generator test instrumentation circuitry.

The SNAP 7C battery and converter were subjected to simulated environmental tests for 12 days in order to determine stabilized voltages at 20° and 60° F. A typical curve, Fig. 44, shows charging voltage as a function of time for the No. 1 four-volt battery section at 20° F.

The SNAP 7A system was evaluated for the following temperature environments:

TABLE III

Vibration Test Results

Ref. Plane	Environment	Exposure Time (min)	Power Input Before (watts)	Power Input After (watts)	Power Output Before (watts)	Power Output After (watts)	Remarks
Vert	5-300 cps at 0.06DA & 1/2 g	7-1/2	240	240	10.05	10.05	Investigations for major resonant conditions--none noted
Vert	5 33 cps at 0.06DA & 3 g	87	240	240	10.05	10.05	Satisfactory
Vert	5-300-5 cps at 0.06DA & 3 g	15	240	240	10.05	10.05	Satisfactory
Horiz 1	5-300 cps at 0.06DA & 1/2 g	7-1/2	238	238	10.02	10.02	No resonances noted
Horiz 1	5-33 cps at 0.06DA & 3 g	87	238	238	10.02	10.02	Satisfactory
Horiz 1	5-300-3 cps at 0.06DA & 3 g	15	238	238	10.05	9.51	Discontinuity in output & ripple at 90 cps & decrease at 250 cps with ripple
Horiz 2	5-300 cps at 0.06DA & 1/2 g	7-1/2	238	238	9.89	9.82	No resonances noted
Horiz 2	5-33 cps at 0.06DA & 3 g	87	238	238	9.89	9.94	Satisfactory
Horiz 2	5-300-5 cps at 0.06DA & 3 g	15	238	238	9.94	10.05	Satisfactory
Horiz 1	250 cps at 3 g dwell	120	238	238	10.05	9.51	At start of vibration, output decreased to 9.43 watts. Ripple on output ceased after 90 min, and output increased to 10.2 watts, 6 hours after vibration was complete

TABLE IV

Shock Test Results

Ref. Plane	Required Environment**	Power Input Before (watts)	Power Input After (watts)	Power Output Before (watts)	Power Output After (watts)	Results
Vert No. 1	6 g, 6MS half sine	238	238	9.92	9.92	Satisfactory
Vert No. 2	6 g, 6MS half sine	238	238	9.92	9.92	Satisfactory
Horiz 1 No. 1	6 g, 6MS half sine	238	238	9.92	9.92	Satisfactory
Horiz 1 No. 2	6 g, 6MS half sine	238	238	9.92	9.92	Approx 5 min after drop, output was noted to have decreased to 8.3 watts
Horiz 2 No. 1	6 g, 6MS half sine	238	238	8.3	8.3	Impulse caused momentary increase to normal output
Horiz 2 No. 2*	6 g, 6MS half sine	238	238	8.3	8.3	Impulse caused momentary increase to normal output

* After the last shock test, the generator was placed in the vertical position. A slight shock impulse in this position instantly restored output power to 9.875 watts. Further handling of the generator in the vicinity of the input-output plug produced a similar decrease in power output as experienced during the shock test.

** Actual shock environment was approximately 18 g, 6MS half sine

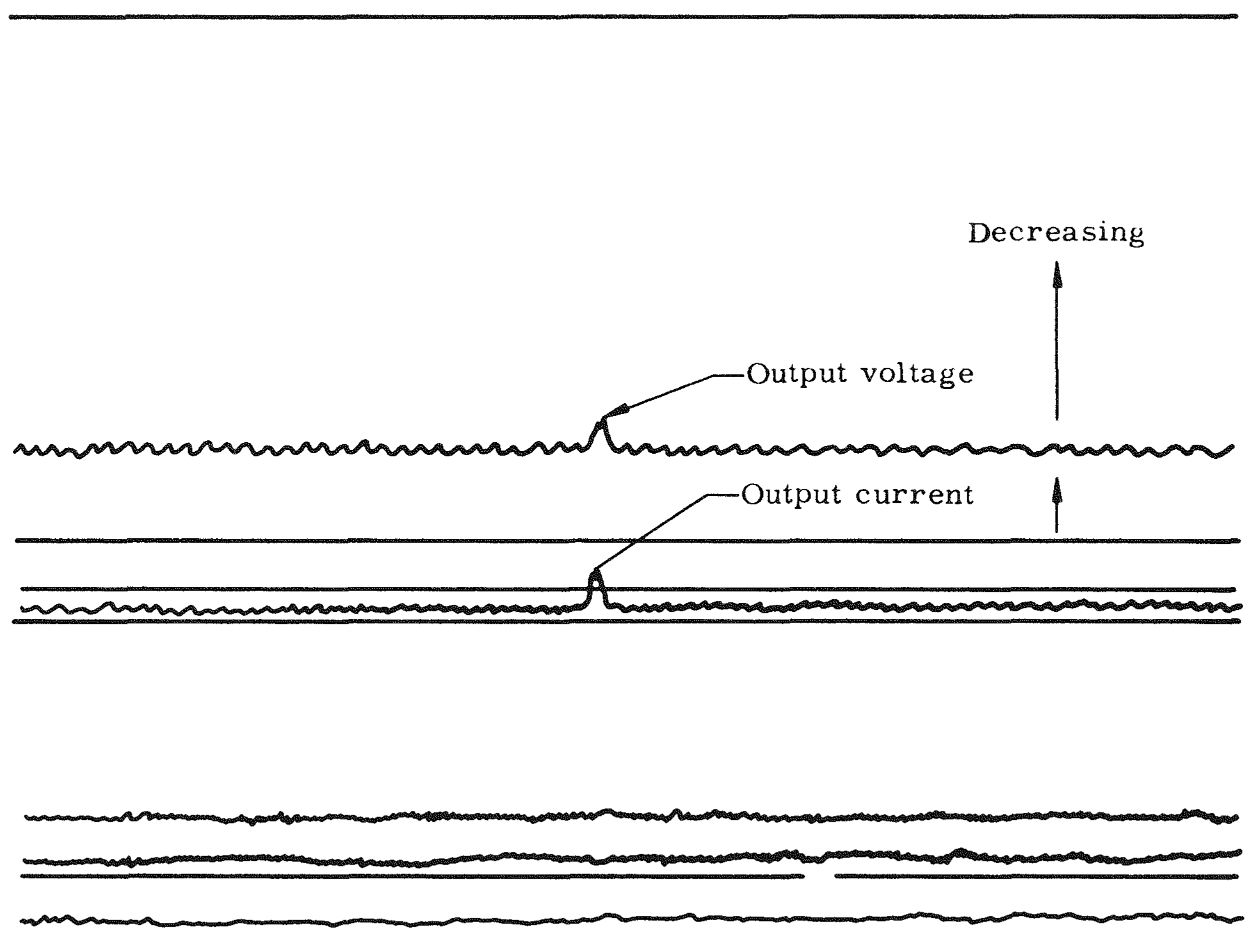


Fig. 37. Oscillograph Reproduction of SNAP 7A and SNAP 7C Generator Output During Horizontal Shock Test

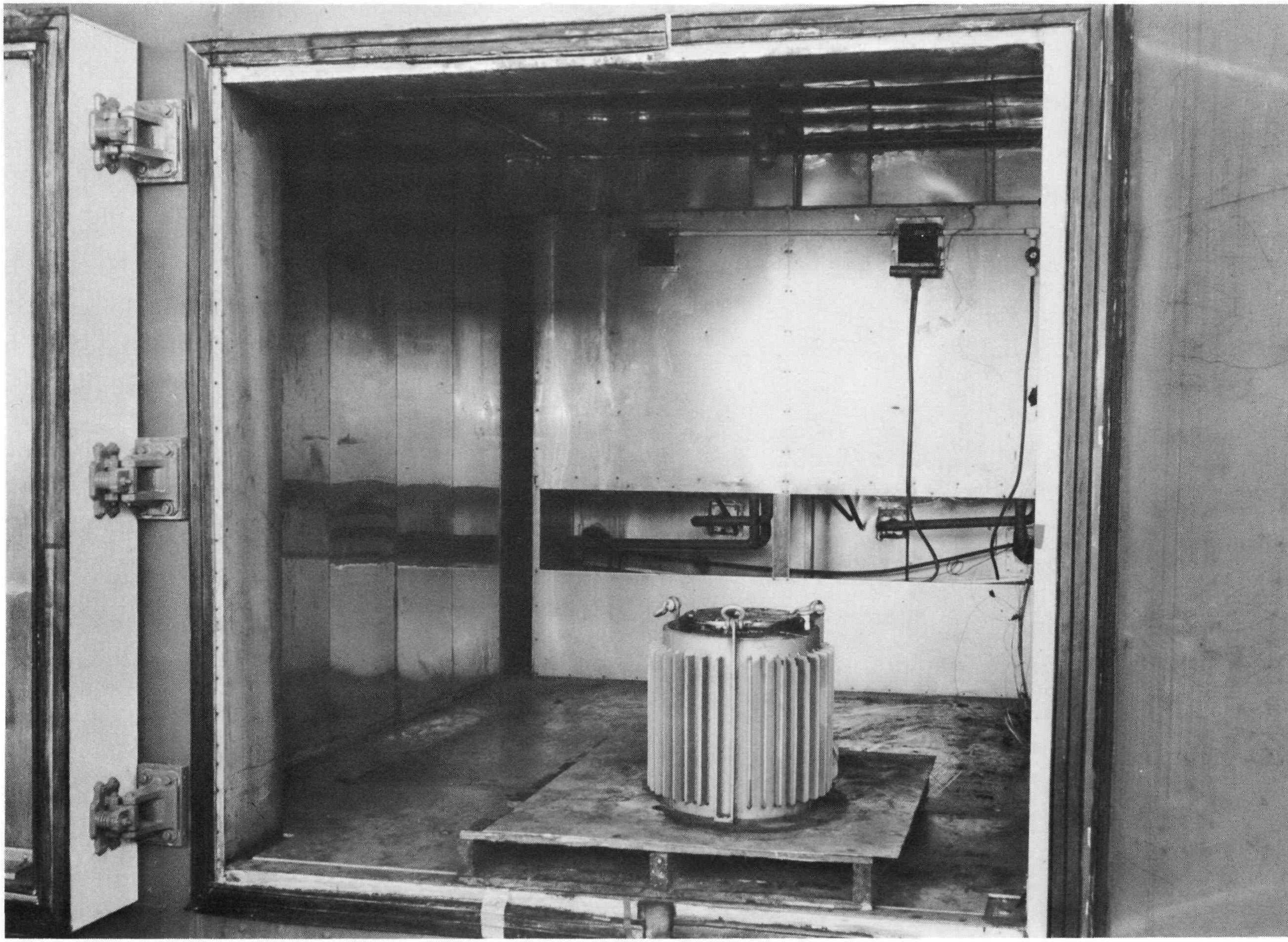


Fig. 38. Generator Positioned in a Temperature Chamber for Test to Determine Stabilized Voltages at Various Temperatures

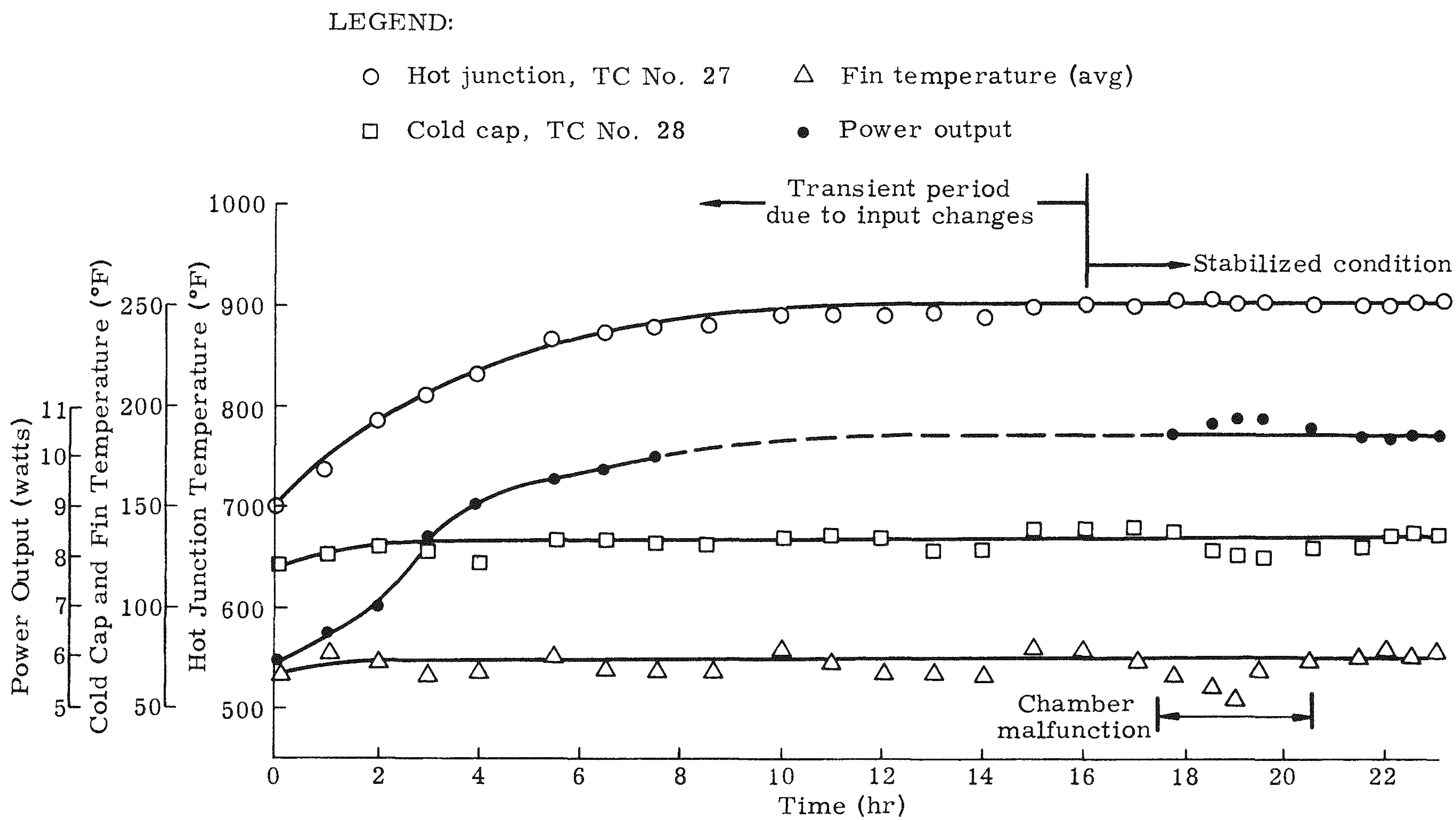


Fig. 39. Results of SNAP 7A and SNAP 7C Generator Temperature Chamber Tests, Where Nominal Power Input Was 257 Watts, Ambient Air Temperature Was 70° F, and Generator Atmosphere was 50% Argon and 50% Hydrogen

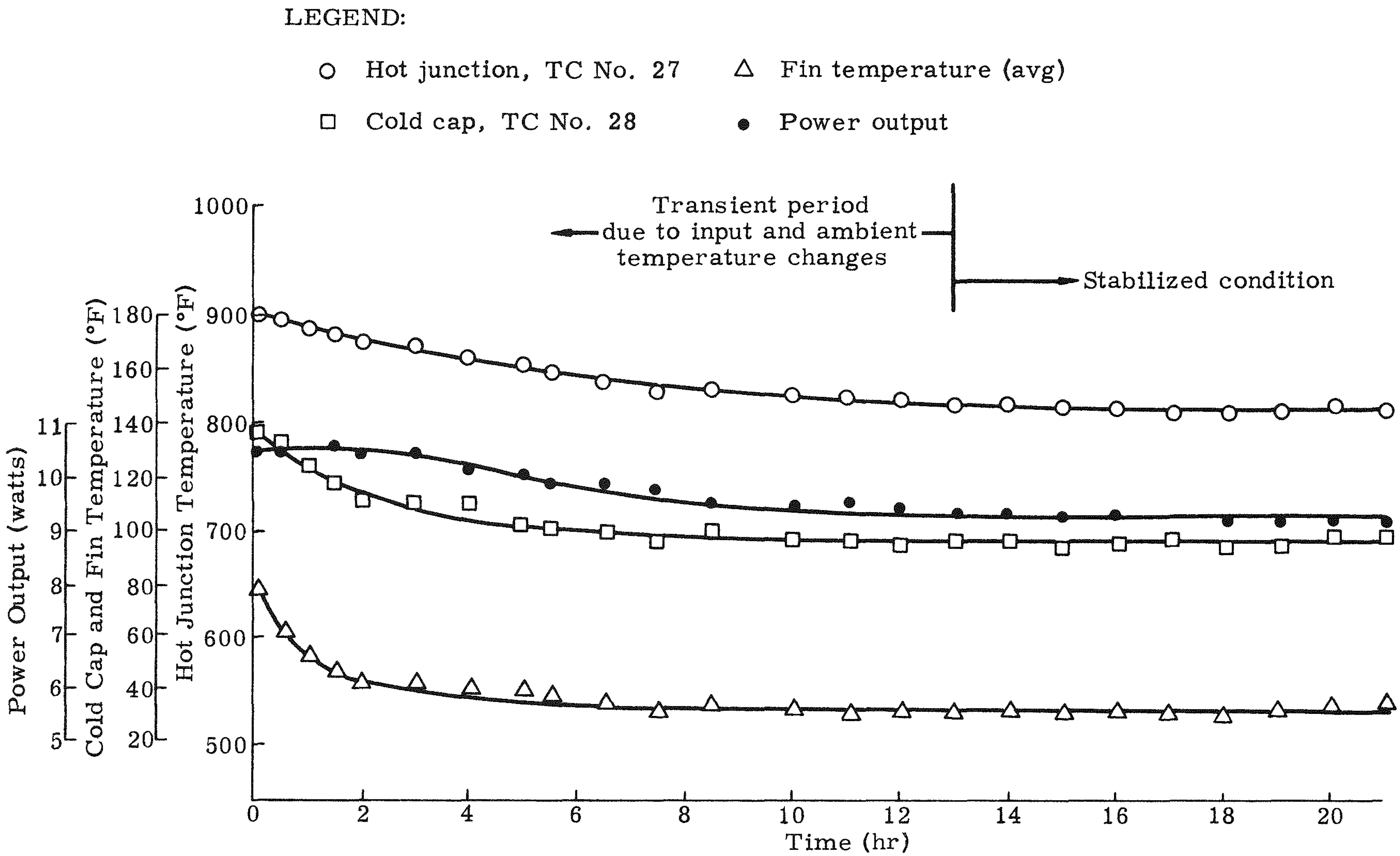


Fig. 40. Results of SNAP 7A and SNAP 7C Generator Temperature Chamber Tests, Where Nominal Power Input Was 247.5 Watts, Ambient Air Temperature Was 28° F, and Generator Atmosphere Was 50% Argon and 50% Hydrogen

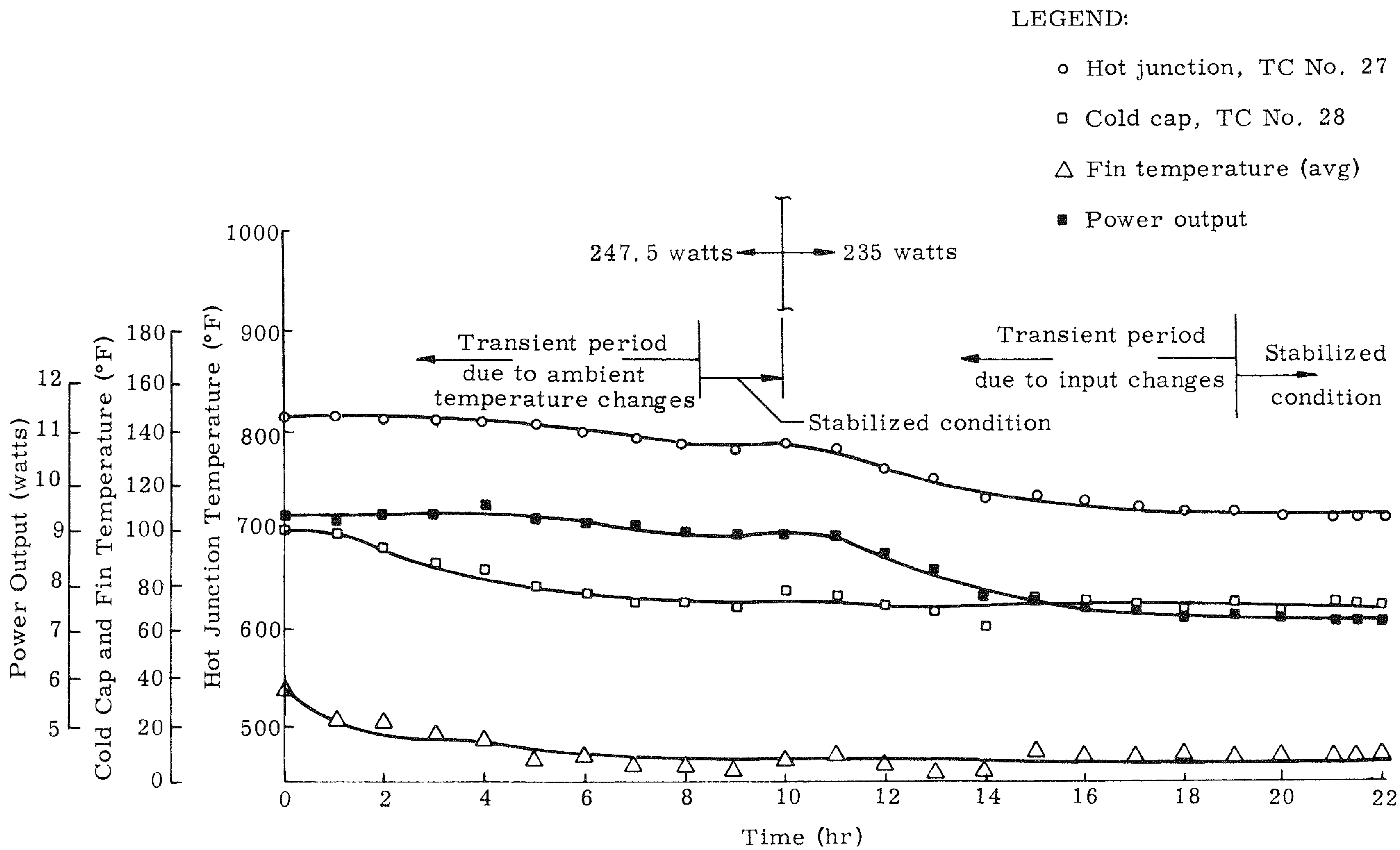


Fig. 41. Results of SNAP 7A and SNAP 7C Generator Temperature Chamber Tests, Where Nominal Power Input Was 247.5 and 235 Watts, Ambient Air Temperature Was 0° F, and Generator Atmosphere Was 50% Argon and 50% Hydrogen

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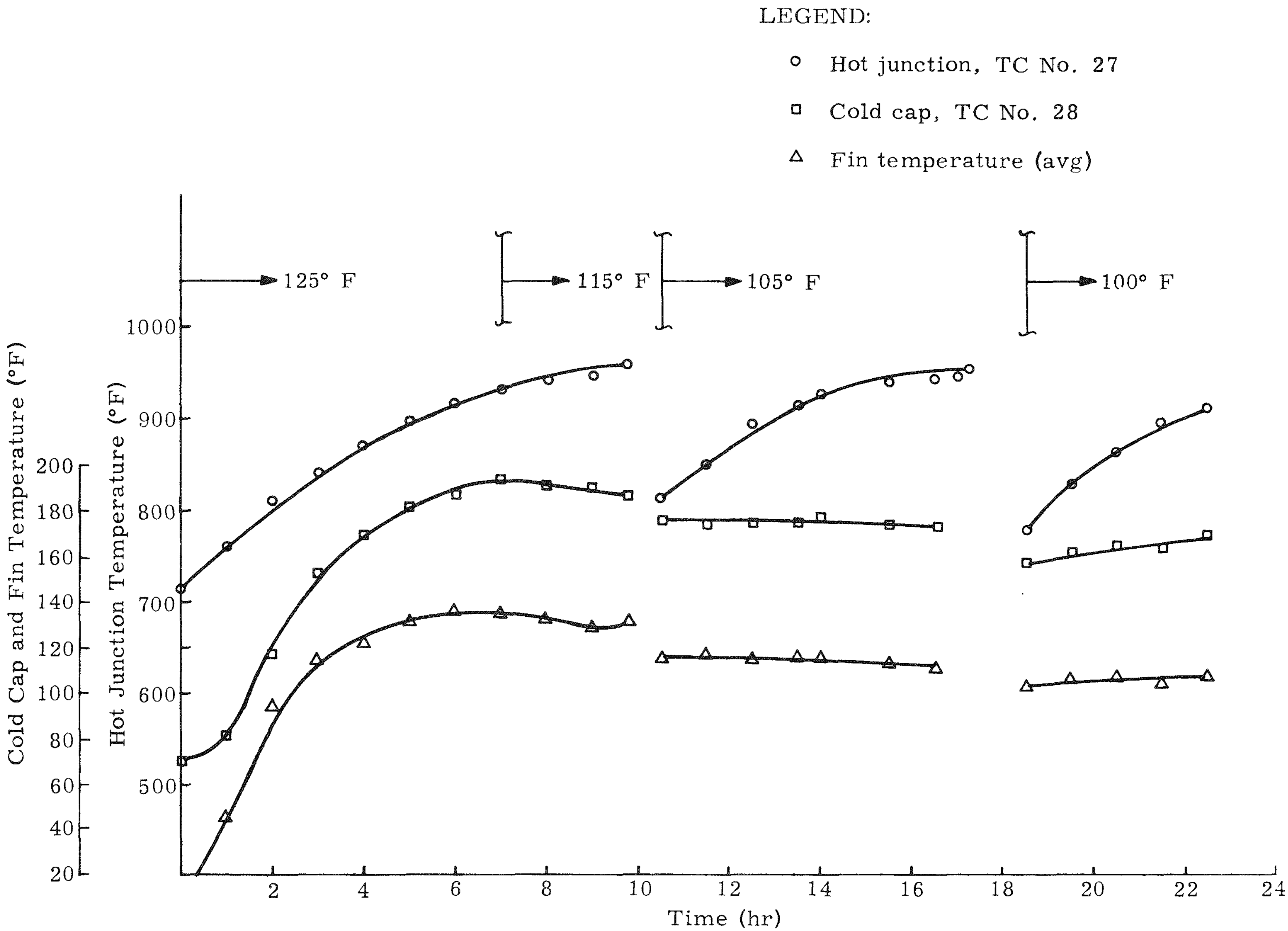

Fig. 42. Results of SNAP 7A and SNAP 7C Generator Temperature Chamber Tests (Output Short-Circuit Shipping Condition), Where Nominal Power Input Was 280 Watts, Ambient Air Temperatures Were 100° F, 105° F, 115° F and 125° F, and Generator Atmosphere Was 50% Argon and 50% Hydrogen

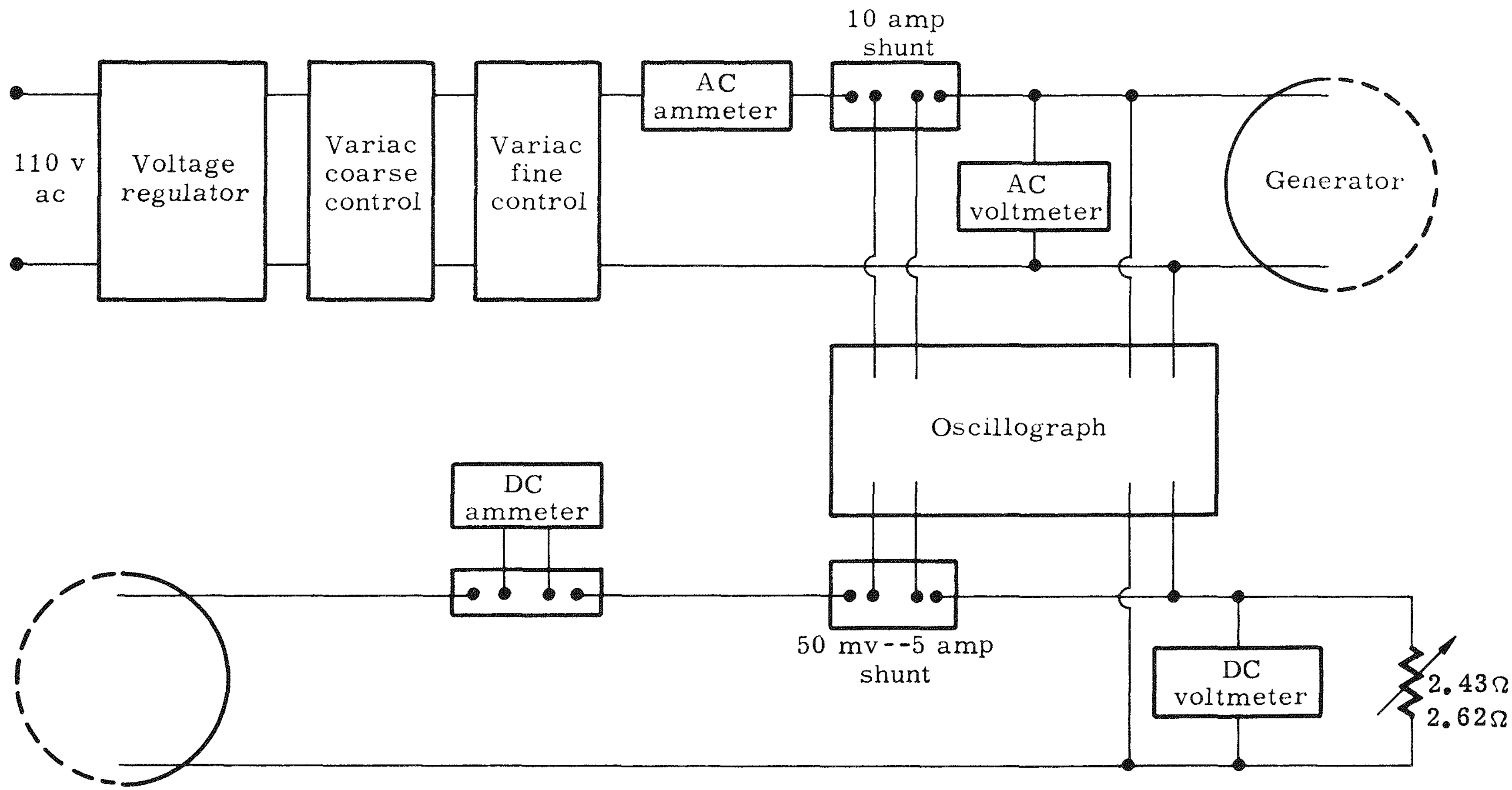

Fig. 43. SNAP 7A and SNAP 7C Generator Test Instrumentation Circuitry

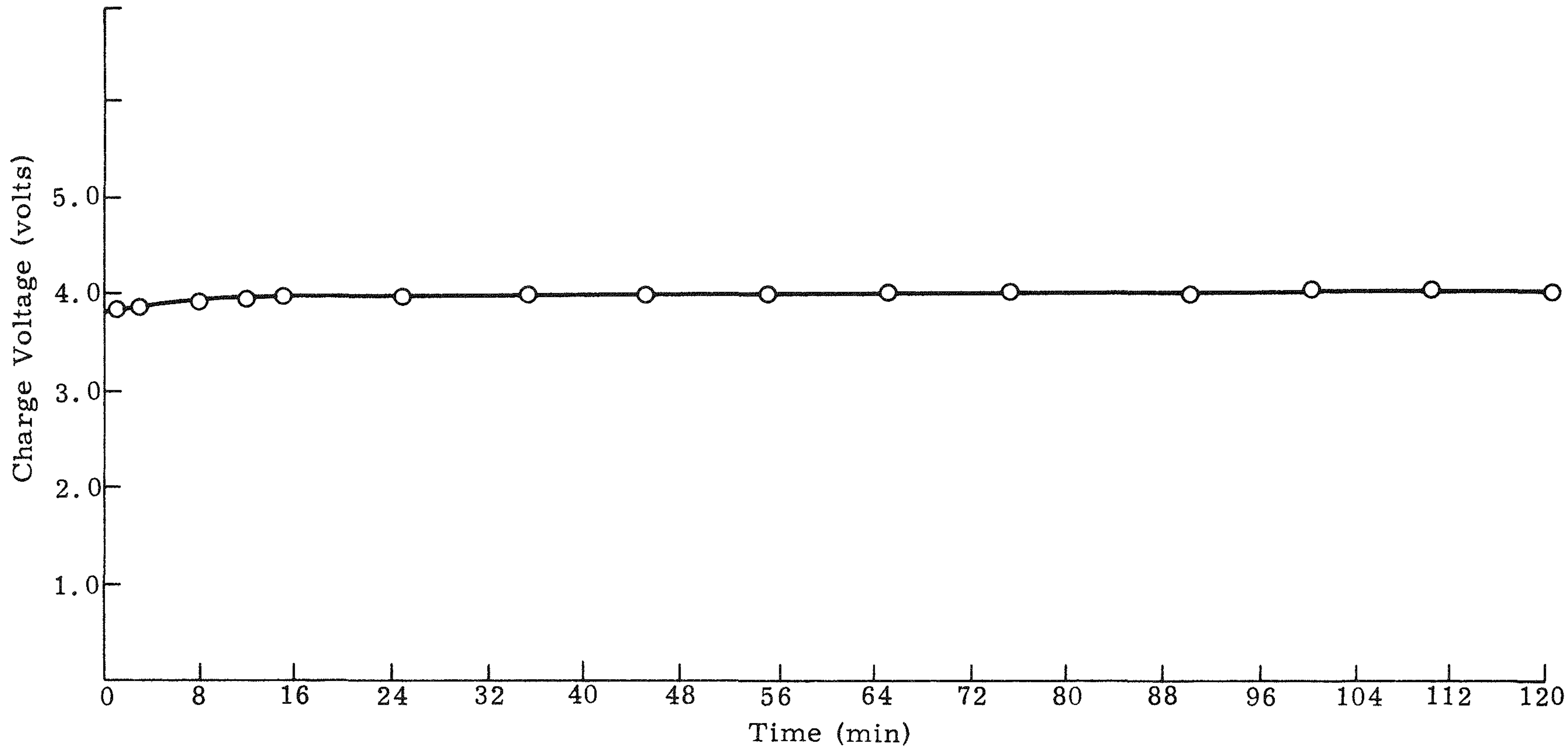

Fig. 44. Charging Voltage as a Function of Time for the No. 1 Four-Volt Battery Section at 20° F

	Low Temperature	High Temperature
Battery and converter	0° F	90° F
Buoy light and shroud	-40° F	120° F
Time	3 days	8 days

The maximum power consumed by the light and flasher unit was 4.8 watts.

7. SNAP 7C Battery Pack

The SNAP 7C battery pack (Sonotone, No. 16576) consists of 24 cells. Two of these cells are spares, and the remaining 22 are divided into four sections in order to supply the appropriate voltages to the weather station. The pack consists of three blocks of three cells in series (Block B, C and D) with a nominal voltage of 4 volts and one block (A) consisting of 13 cells in series with a nominal voltage of 18 volts. The positive terminal of Cell Block D is grounded to form the system ground. All voltages supplied to the system are negative. The diagram of the battery and converter cell block is shown in Fig. 12.

8. SNAP 7C DC-to-DC Converter

The SNAP 7C generator supplies approximately 9 watts of electrical power. This power is supplied, for an optimum operating point on the generator power curve, at approximately 4.8 volts at 1.9 amperes. In order to charge the battery at 30 volts, the generator voltage must be stepped up. This step-up is accomplished by means of the dc-to-dc converter which consists of an overdriven, push-pull, transformer coupled transistor oscillator with four rectified and regulated load windings. The output voltages are regulated to keep the voltage supplied to the batteries at between 1.33 and 1.38 volts per cell for a load current change of 30 to 150 milliamperes, and ambient temperature range of 20° to 60° F.

The schematic of the dc-to-dc converter is shown in Fig. 13. The 2N1360 switching transistors were chosen because of their low saturation voltage (typically 0.3 volt at 2 amperes collector current). The transistors have a typical current gain of 40 at 2 amperes collector current. The base drive voltage is typically 0.6 volt at a collector current of 2 amperes. A switching frequency of 500 cps was chosen, since experience has shown this frequency optimizes the core and copper losses in the transformer. The various losses in the converter are as follows:

Losses

	(watts)
Transistor losses	0.600
Base drive losses	0.120
Copper losses	0.300
Core losses	0.280
Diode losses	0.300
Total	1.600

$$\text{Efficiency } \frac{9.000 - 1.600}{10.000} \times 100 = 74\%$$

This efficiency is attainable only if components exhibit nominal losses.

There are regulators provided on each of the outputs of the converter. These regulators maintain the voltage supplied to the battery. The regulators require the following power losses:

-4 volts	0.20 watt
-4 volts	0.20 watt
-4 volts	0.20 watt
-18 volts	0.90 watt
Total	1.50 watt

The power provided at the regulators is calculated to be 7.4 watts. Therefore, the power provided to the load is 5.9 watts.

9. SNAP 7A Battery

The stability of cell voltages under the SNAP 7A system cycle has been evaluated. Individual cell voltages varied from 1.32 to 1.40 volts/cell. This battery pack has operated in the simulated system since September 15, 1961. A second set of batteries is presently operating the simulated system; the final battery pack will include cells from each set of batteries in order to obtain a smaller spread of individual cell voltages. Converter modification is being considered as an alternate method of limiting the spread of individual cell voltages. This can be accomplished by regulating the voltage output to blocks of three battery cells.

10. SNAP 7A Converter

The breadboard converter for the SNAP 7A system was tested with a simulated generator and an actual battery pack and light and flasher unit. The converter was operated at 0° F for three days and at 90° F for seven days. A maximum converter efficiency of 67.5% was obtained at 0° F. Converter stability was obtained on all tests of the SNAP 7A system.

11. Safety

Safety reports for SNAP 7A and 7C systems have been completed (Refs. 5 and 6). The generator can be transported safely and operated with the normal precautions afforded any structure containing a radioisotope. The shielding provided is adequate for protection against direct radiation exposure.

Integrity of the system is maintained under most conceivable accident conditions. An aircraft accident resulting in a terminal velocity impact might destroy the biological shield around the fuel capsules. The fuel capsules would still remain intact. The analysis used to postulate this conclusion is based on a rigid impact of the generator assembly. Since there are only a few areas on the surface of the earth where such an impact is possible, the probability of the loss of the shield is small. Most of the possible incidences of impact would occur on nonrigid materials and, as a consequence, would result in the burial of the unit.

The insolubility and chemical stability of the radioisotope strontium-90 titanate is incidental as long as containment is maintained. However, if fuel release should occur, the fuel will not readily enter the biological cycle because of the physical properties of the compound.

III. SNAP 7B AND 7D 30-WATT ELECTRIC GENERATION SYSTEMS--SUBTASKS 8.2 AND 8.4

A. INTRODUCTION AND SUMMARY OF SIGNIFICANT TECHNICAL ACHIEVEMENTS

The SNAP 7B and 7D 60-watt thermoelectric generators were designed and the associated engineering drawings released during the second quarterly report period (Ref. 2). In the third quarterly report period (Ref. 3), preliminary design investigations for SNAP 7B and 7D installations were continued and fabrication of components was initiated.

The significant achievements for the current report period were the completion of the thermal and safety analyses for the SNAP 7B and 7D generators.

B. ENGINEERING--EQUIPMENT DESCRIPTION, DESIGN TECHNIQUES AND PROCEDURES, AND TEST FOR SNAP 7B and 7D

1. Objectives

The major engineering objectives of Subtasks 8.2 and 8.4 for the current report period were:

(1) To complete the thermal and safety analyses for the SNAP 7B and 7D generators.

(2) To prepare the conceptual installation drawings for the SNAP 7D system.

(3) To test the "P" thermoelements.

2. Safety Analysis

A preliminary draft of the SNAP 7B safety report was completed and issued for internal review during the previous report period. The results of the investigation for typical credible accidents are as follows:

(1) With one exception, the biological shield can withstand impact from all possible collisions during transport. The exception is the rather remote occurrence of a maximum credible accident in which a transporting aircraft reaches a terminal velocity of 700 ft/sec and impacts upon a rigid surface. The fuel, fuel capsule, and fuel block will remain as in integral

unit with a combined weight of 150 lb. The kinetic energy developed by this unit at a terminal velocity of 700 ft/sec is 1, 140, 000 ft-lb. This is less than the 1, 650, 000 ft-lb determined by analysis to be the limit for integrity of this unit.

(2) The structural integrity of the generator can be maintained from a free fall of 100 ft.

(3) The generator can withstand deep sea pressures equivalent to depths of 18, 000 ft. A release below this depth would not present a hazard.

(4) The maximum temperature that can occur from accidental burial in soil would be 1200° C at the capsule surface. Since 1200° C is below the melting temperature for the capsule the fuel will be retained.

3. Thermal Analysis

A detailed thermal analysis for the surface temperature of the 7D generator under operating conditions and an analysis and design of the containment tank of a land-based 7B generator are given in Appendix B. This analysis indicates that the cold junction of the generator will not exceed 187° F (an acceptable value) when the generator is installed as described herein.

4. SNAP 7D Installation

The 7D system will be installed on a weather vessel of the Nomad I class. Detailed engineering is not available on the boat at this time, since the specific boat has not been selected. However, our analysis has been based on the conceptual design reported in the previous quarterly progress report.

5. Generator Design

Minor changes have been made in the design of the generator in order to facilitate fabrication and assembly. Some of these changes resulted from the experience gained with SNAP 7C. It was found that chamfering the fuel block cover screws facilitated assembly within the hot cell during fueling. Steel test containers and covers have been designed to reduce handling problems during the testing of the 7B and 7D generators with simulated heat sources. The seal for the container cover was changed from a static O-ring to a larger dynamic O-ring.

6. "P" Element Testing

The "P" element life test has accumulated 4305 hours of testing with only slight variations in thermoelectric properties.

IV. FUEL PROCESSING FOR SNAP 7B AND 7D GENERATORS--SUBTASK 8.5

A. INTRODUCTION AND SUMMARY OF SIGNIFICANT TECHNICAL ACHIEVEMENTS

The conversion of strontium-90 feed material into a useful strontium titanate fuel form, fuel process engineering, fuel process equipment fabrication, nuclear chemistry audits and hot cell safety and shielding analysis have been reported in Refs. 1, 2 and 3.

Significant achievements for the current report period were:

(1) The completion of all the basic engineering fuel process equipment designs and the fabrication and installation of a portion of this equipment.

(2) The completion of the shielding and safety analysis for the hot cell operations.

B. FUEL PROCESSING ENGINEERING

1. Objectives

The major engineering objectives of Subtask 8.5 for the current report period were:

(1) To complete all fuel process equipment design, to continue the manufacture and installation of process equipment, and to continue the procurement of all items necessary for the complete installation and checkout at the hot cell facility.

(2) To conduct the safety review of process equipment and equipment designs for failures that could result in the release of radioactive material from primary containment vessels.

(3) To analyze and review strontium-90 process shielding requirements for the Quehanna Hot Laboratory facility.

2. Equipment Design and Installation

Process equipment and installation have been described in previous quarterly reports (Refs. 1, 2 and 3). Certain modifications and revisions have been made which do not affect the basic process previously described. The revisions are as follows:

(1) Feed tanks have been relocated to the roof of the isolation rooms in order to assure gravity flow of material into Cells No. 1 and No. 2. This installation has been completed.

(2) The HAPO II cask will be transferred into the cell by an electric-powered pallet lift truck rather than on a Jake's cart.

The height of the Jake's cart limited the access to the cask top. Therefore, the placing of the cask on a pallet will remedy this situation.

(3) The HAPO II cask will be shipped with blind semiremote disconnects designed at Hanford. Since it is necessary to provide containment while removing the disconnects and attaching process lines, a cask cupola glove box has been designed. This box will mate and seal with the top of the shipping cask; the process lines will pass through the top of the glove box. The removal of disconnects and the installation of process line disconnects will be accomplished manually through the glove ports. A pass-through air lock on the box will facilitate the handling of the leakage test wipes. The box is suspended by a counterweight and pulley system over the cask in Cell No. 1 in order to facilitate cask removal after emptying.

(4) A lead brick shield has been provided for the shielded storage tank in Cell No. 1.

(5) The effort planned in designing and fabricating equipment for the process has been progressing at a satisfactory rate. A list of released equipment drawings is given in Appendix F. The status of some of the more pertinent items is given below:

(a) Capsule loading tray. A capsule loading tray has been designed to aid in stacking the finished pellets and spacers, and loading them into the capsule prior to welding.

(b) Transfer can opening mechanisms. The transfer can opening mechanisms for Cells Nos. 2 and 5 are being fabricated and will be ready for installation during the next report period.

(c) Capsule calorimeter. The calorimeter for Cell No. 5 has been designed, and is being built. It is designed to handle a capsule of 125 watts (thermal) with an accuracy of ±2%. The capsule is of the flow type using water as the measurable medium. The water will flow at a known rate, and the temperature rise of the water as it flows through the device will be measured. The water is recirculated in a closed system, and will not contact the capsule.

(d) Waste filter. A waste filter design has been completed. The filter has 8 inches of lead shielding, and is able to trap and contain 2 gallons of process waste solids. This capacity has been deemed adequate to handle all the expected solid waste for the entire run of the process. The unit is designed to meet all necessary AEC and ICC regulations.

(e) Control panels. Water control panels have been designed for handling coolant flow to the water-cooled tank and the shipping cask. The panels will be located in the operating area in front of the cells; the connecting piping will pass through the cell wall to the equipment.

The thermocouple readout, vacuum gauge, and electrical control equipment will be on a panel between cells Nos. 1 and 2. This panel has been built, and is ready for shipment.

An interlocking control system has been designed to assure that proper sequence of operations is followed. The controls for the transfer box may be operated at a distance of 30 feet. The general operation and duties remain the same as described in the previous quarterly progress reports.

(f) Overhead transfer box. The overhead transfer box is under construction, and will be delivered to Quehanna in December.

3. Safety

During this period the fuel processing procedure and equipment was reviewed for possible failures that could cause the release of radioactive material from primary containment. Several credible accidents were postulated and a maximum credible accident selected for analysis. The results of the analysis indicated that a release of radioactive strontium-90 would not produce higher radiation levels to the surrounding populated areas than those specified by the AEC in the event of an accident.

The credible accidents postulated included internal pressure accumulation from gas releases and explosion from chemical reactions and fires. In all cases the radioactive materials were contained within the secondary system. A series of additional accidents was then postulated in which the radioactive material was released to the environment by the ventilation system.

In the analysis the strontium was assumed to escape as an aerosol through the building stack, form a radioactive cloud, and then move away from the facility toward populated areas nearby. The distances to populated areas and the possible air contamination at these points are listed in Table V.

Two different atmospheric conditions were considered--lapse and inversion. The lapse condition represents the normal atmospheric case, whereas the inversion condition represents a conceivable extreme case.

The values for atmospheric contamination and activities are listed in Table V. A detailed analysis showing a typical calculation is given in Appendix G. The cloud concentrations for the prevailing atmospheric conditions are below the International Commission on Radiation Protection (ICRP) maximum value of 3.6×10^{-7} microcuries per cubic centimeter except for an area within a radius of 8000 meters from the site during an inversion condition. However, inversion conditions occur during evening hours so that individuals other than facility personnel probably will not be present. In any event the total body burden received by an individual in this area will not exceed the maximum permissible body burden of 2 microcuries.

The detailed report of the postulated accidents and the analysis performed on the maximum credible accident were prepared as an addendum to the report, "Radioactive Materials Laboratory Safety Report" (Ref. 8).

4. Shielding Analysis

An analysis of shielding requirements for the strontium-90 fuel process was completed during the current report period. Detailed dose rates for various locations at the Quehanna Hot Cell facility are given in Appendix H.

TABLE V

Atmospheric Contamination Due to Release of Strontium-90 During Processing

Distance from Facility (meters)	Cloud Concentration (microcuries/cubic centimeter)		Activity Inhaled (microcuries)	
	Stable	Inversion	Stable	Inversion
4,800	7.16×10^{-8}	9.04×10^{-6}	1.2×10^{-2}	1.64
8,000	2.54×10^{-8}	4.66×10^{-6}	4.4×10^{-3}	0.84
16,000	7.52×10^{-9}	1.79×10^{-7}	1.4×10^{-3}	0.32

V. REFERENCES

1. "SNAP Programs Quarterly Progress Report No. 1, Task 8--Sr-90 Fueled Thermoelectric Generator Development, November 1, 1960 through January 31, 1961," USAEC Report MND-P-2483-1, The Martin Company.

2. "SNAP Programs Quarterly Progress Report No. 2, Task 8--Sr-90 Fueled Thermoelectric Generator Development, February 1, 1961 through April 30, 1961," USAEC Report MND-P-2483-2, The Martin Company.

3. "SNAP 7 Program Quarterly Progress Report No. 3, Task 8--Sr-90 Fueled Thermoelectric Generator Development, May 1, 1961 through July 31, 1961," USAEC Report MND-P-2483-3, The Martin Company.

4. "Instruction Manual for the SNAP 7C Generator Systems," MND-P -2640, The Martin Company, October 1, 1961.

5. "Final Safety Analysis for the 10-Watt Sr-90 Fueled Generator, Light Buoy--SNAP 7A," USAEC Report MND-P-2613, The Martin Company.

6. "Final Safety Analysis for the 10-Watt Sr-90 Fueled Generator for an Unattended Meteorological Station--SNAP 7C," USAEC Report MND-P-2614, The Martin Company.

7. "Statement of Work for the SNAP 7 Systems," MND-SW-1013, Revision D, The Martin Company, December 4, 1961.

8. "Addendum, Radioactive Materials Laboratory Safety Report," MND-2410, The Martin Company, The Martin Nuclear Facility, Quehanna Site, November 1961.

APPENDIX A

SNAP 7C SHIPMENT

The SNAP 7C system was shipped from Baltimore, Maryland to Davisville, Rhode Island on October 23, 1961. The items were packed in seven boxes (Ref. No. 398C1080052).

Box	Size	Gross Wt (lb)	Weight Tare (lb)	Net (lb)	Volume (cu ft)
1 of 7	5 ft x 3 ft 8 in. x 4 ft 1 in.	930	390	540	75
2 of 7	4 ft 8 in. x 3 ft 8 in. x 4 ft 1 in.	840	370	470	70
3 of 7	3 ft 8 in. x 3 ft 8 in. x 1 ft 8 in.	320	130	190	24
4 of 7	3 ft 4 in. x 2 ft 6 in. x 1 ft 2 in.	320	40	280	10
5 of 7	5 ft x 4 ft 3 in. x 2 ft 11 in.	2384	505	1879	62
6 of 7	2 ft 9 in. x 2 ft 3 in. x 1 ft 6 in.	160	79	81	9.2
7 of 7	1 ft 8 in. x 1 ft 8 in. x 1 ft 8 in.	40	25	15	4.6
	Total	4994			

Reference No. 398C1080052

Box 1				
398C1080050-19	Welded assy (lower)	ea	1	
Box 2				
398C1080050-79	Welded assy (upper)	ea	1	
398C1080050-69	Insulation	ea	1	
Box 3				
398C1080050-39	Lid Assy	ea	1	
398C1080040-9	Antenna coupling assy	ea	1	
Box 4				
55004-3775-CIKC	Coupling V-retainer	ea	2	6 sections
398C1080050-63	Gasket	ea	4	Incl 2 spares
	2-in. carriage bolt incl washers and nuts	ea	12	Incl 6 spares
398C1080050-49	Welded assy (shelf)	ea	1	
398C1080050-59	Welded assy (shelf)	ea	1	
398C1080051-9	Outrigger	ea	4	
AN12-20A	Bolt	ea	22	Incl 6 spares
AN960-1216	Washer	ea	44	Incl 12 spares
AN363-1216	Nut	ea	22	Incl 6 spares
Box 5				
398-3021050-19	Generator pallet	ea	1	
398C108055-9	Thermoelectric gen	ea	1	
KPB-16 x 14 x 6 -JIC	Tool box	ea	1	
	Contains the following:			
FA-50	Ratchet	ea	1	
F-1220	Socket	ea	1	

Reference No. 398C1080052 (continued)

Box 5	Contains the following:		
F-1224	Socket	ea	1
F-1021	Socket	ea	1
F-1017	Wrench	ea	1
F-1015	Wrench	ea	1
F-1013	Extension	ea	1
F-1001	Rubber mallet	ea	1
200L46-1T	Sling	ea	1
Model JW-1011	Meter 0-1 MA DC	ea	1
Box 6			
398C1080053-9	Battery-converter assy	ea	1
Box 7			
398C1080057-19	Cable	ea	1
398C1080057-29	Cable	ea	1
-1003	Cable (hi-fi)	ea	1
-1005	Cable (lo-fi)	ea	1
-1007	Cable (control)	ea	1
MND-P-2640	Handbook	ea	10

Drawings as follows:

398-3021000, 398-3021042

398C1080050, 398C1080051

398C1080052, 398C1080053

398C1080054, 398C1080055

398C1080056, 398C1080057

APPENDIX B

THERMAL ANALYSIS FOR SNAP 7D AND SNAP 7B

I. THERMAL ANALYSIS FOR SNAP 7D

A. SURFACE TEMPERATURE OF SNAP 7D GENERATOR UNDER OPERATION CONDITIONS

The surface temperature of the 60-watt Sr-90 generator to be employed at sea in unmanned aluminum boats is analyzed to determine its surface temperature under maximum anticipated temperature conditions. If the compartment in which the generator is mounted is filled with water to a level 2 to 3 inches over the generator top, the maximum surface temperature of the generator will be no more than 116° F.

The battery-converter package should be mounted on the inside of the bottom of the boat to take advantage of the proximity of the surrounding water; the water will tend to dampen out daily temperature cycling.

B. ANALYSIS

The determination of the generator surface temperature depends on evaluating the temperature drop between the generator surface and the sea. The sea temperature is assumed to be a maximum of 80° F.

The temperature drop between the sea and boat hull is calculated by means of the usual Nusselt-Grashof-Prandtl number relationship.* The temperature difference between generator surface and boat hull is calculated by means of the special Grashof number.**

Because of the wide variation in temperature of the walls of the compartment, an average temperature is taken (96° F). A safety factor (100%) is added to the temperature drop through the water to ensure conservatism in the calculation.

If the converter-battery package is fastened tightly to the hull of the boat, its temperature should be maintained within a few degrees

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* McAdams, Heat Transmission, Third Edition, p 172.
** Ibid., pp 181 and 182.

of the hull temperature. Since the heat flow from the package to the hull is small, the hull temperature will be nearly the same as the water. Thus, there is no danger of overheating, even in extremely hot climates.

C. RESULTS

The temperature difference between hull and water is 7° F.

The temperature difference between generator surface and compartment walls is 10.4° F x 2 = 21° F.

The generator surface temperature is 116° F.

The generator cold junction temperature is 187° F.

D. CONCLUSIONS

Covering the generator with water will prevent the cold junction of the generator from exceeding 187° F at sea. Fastening the battery-converter package to the hull of the boat below the waterline will prevent overheating in warm climates.

E. RECOMMENDATIONS

The compartment containing the 60-watt Sr-90 generator should be filled to a level of about two to three inches higher than the top of the generator. Care should be taken not to overfill the compartment leaving at least five inches of space between the top of the water and the top surface of the compartment to allow for expansion.

The battery-converter package should be fastened to the hull with substantial brackets to permit heat transfer to the hull with a minimal temperature difference. For arctic operations, insulation of the package cover will prevent damage from the cold.

II. THERMAL ANALYSIS FOR SNAP 7B

A. CONTAINMENT TANK FOR ENVIRONMENTAL CONTROL OF THE LAND-BASED (SNAP 7B) 60-WATT Sr-90 GENERATOR

In order to permit the 60-watt Sr-90 generator (SNAP 7B) to operate in ambient temperatures as high as 125° F, some modification in the heat-transfer characteristics of the generator is required.

Since the design is frozen, modifications must be made in the environment seen by the surface of the generator rather than in the generator itself.

Based on the analysis performed in the report, an aluminum tank 30 inches in diameter and 36 inches high with 100 six-inch long fins is proposed (see Fig. B-1). The generator is to be centered in the tank which is filled with water-ethylene glycol to a height of 32 inches. The tank is then sealed to prevent evaporation.

Sufficient safety factors are incorporated in the analysis to ensure that the temperature of the generator surface positively cannot exceed 175° F, corresponding to a cold junction temperature of 246° F.

B. RESULTS

Temperature Drop Through Liquid*

Properties of the Water-Ethylene Glycol Mixture

Thermal conductivity	0.310 Btu/(hr)(sq ft)(°F)
Specific gravity	62 lb/cu ft
Thermal expansion	0.000138° F^{-1}
Viscosity	3.39 lb/hr-ft
Specific heat	0.89 Btu/lb-°F

h'_c = 30 Btu/(hr)(sq ft) (°F)

$T_1 - T_2$ = 14.4° F x 1.5 = 21.4° F

Number of Aluminum Fins**

h_c = 0.625 (for air)

Thermal conductivity of aluminum = 100 Btu/(hr)(ft)(°F)

$$\text{Profile area} = \frac{0.25 \text{ in.} \times 6 \text{ in.}}{144} = 0.00104 \text{ sq ft}$$

η = 85% (efficiency)

* McAdams, Heat Transmission, Third Edition, pp 181 and 182.
** Schneider, P. J., "Conduction Heat Transfer," Equations 4 to 11, Addison-Wesley, 1955.

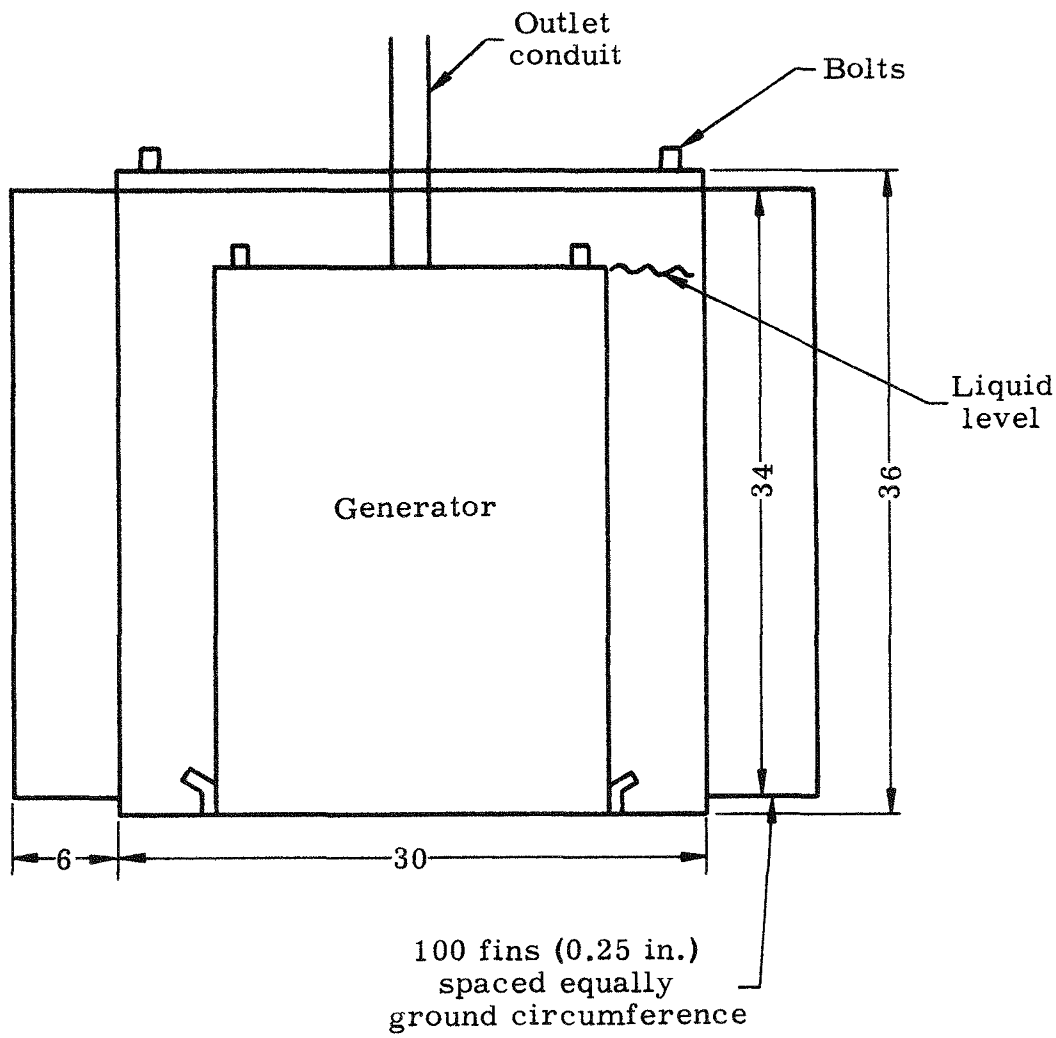

Fig. B-1. Proposed Design of Environmental Control Tank for the SNAP 7B Generator

Radiation heat loss

ϵ = 0.5 (emissivity)

σ = 0.173×10^{-8} Btu/(sq ft)(°R^4)(hr)

$$A = \frac{\pi(42)(34)}{144} = 31 \text{ sq ft}$$

T_2 = 153.7° F (tank wall)

T_3 = 125° F (air)

q_r = 662 Btu/hr (radiation loss)

$$q_u = h_c A_u \Delta T$$

$$q_u = (0.625 \frac{\pi (30)(34)(28.7)}{144} = 399 \text{ Btu/hr (convection from unfinned surface)}$$

A = 276 sq ft (fin area)

$$\text{Number of fins} = \frac{276}{(2)(0.5)\frac{(34)}{12}} = 97.4 \text{ fins}$$

Actual number of fins--98 to 100

C. EVALUATION OF RESULTS

The extreme conditions of ambient temperatures specified are the greatest safety factor taken into account in the results obtained. The absence of wind on the outer surface, which would increase the heat loss, is also ignored. In addition to this, there is an additional safety factor on the temperature difference between the generator and tank wall.

The paucity of actual data or bona fide correlations for the situation prompted the addition of a safety factor of 50 percent to the temperature. Calculation of the film drops from surface to liquid and from liquid to surface in infinite liquid media resulted in temperature differences of 15° and 10° F, respectively. These calculations led to the actual figure taken of 21.4° F.

The generator will operate in the liquid-filled tank under all conditions. Should the mixture freeze under extremely cold conditions there will be no thermal problems created. Freezing might damage the comparatively fragile aluminum tank, although the void space allowed for thermal expansion would probably serve for expansion due to freezing.

D. CONCLUSION

In summary, the 60-watt Sr-90 generator placed in the proposed liquid-filled tank will positively operate with its surface at 175° F or less in environments up to 125° F.

APPENDIX C

SHIELDING ANALYSIS FOR TASKS 8.1, 8.2, 8.3 AND 8.4

The presence of 2.5 millicuries of cerium-144 per curie of strontium-90 in the fueled SNAP 7 generators will not result in dose rates exceeding the specified 10 milliroentgens per hour at one meter. This amount of cerium-144 in the Hanford shipment of strontium-90 would be acceptable for use in the SNAP 7 generators. Table C-1 shows the results of this analysis as applied to each of the generators.

TABLE C-1

Results of Shielding Analysis for SNAP 7 Generators

	SNAPS 7A and 7C	SNAPS 7B and 7D
Power (watts thermal)	256.5	1539
Curies Sr-90 at 6.3 watts/kilocurie	4.07×10^4	2.44×10^5
Curies Ce-144 at 2.5 millicuries/curie Sr-90	102	611
Dose rates at one meter due to Ce-144	1.7 mr/hr	3.5 mr/hr
Dose rates at one meter due to Sr-Y-90	2.5 mr/hr	2.5 mr/hr
Total dose rate at one meter	4.2 mr/hr	6.0 mr/hr

APPENDIX D

SNAP 7A AND SNAP 7C ENGINEERING DRAWINGS

Title	Number
SNAP 7A--5-Watt Electric Generation System Drawings	
Installation--USCG Electric Lighted Buoy	398A1080000
Modifications--USCG Electric Lighted Buoy	398A1080050
Details--Buoy Modification	398A1080051
Batter--Converter Enclosure	398A1080052
Thermoelectric Generator Assembly	398A1080053
Schematic Diagram	398A1080054
Cable Clamp Assembly	398A1080055
SNAP 7C--5-Watt Electric Generation System Drawings	
Installation--USN Weather Station	398C1080052
Container	398C1080050
Outrigger	398C1080051
Battery--Converter Enclosure Assembly	398C1080053
Generator Cover Assembly	398C1080054
Thermoelectric Generator Assembly	398C1080055
Supports--SNAP 7C Container	398C1080056
Interconnection Block Diagram	398C1080057

SNAP 7A-7C Thermoelectric Generator Drawings

Title	Number
Generator--Biological Shield Assembly	398-3021000
Cylinder	398-3021001
End Plate	398-3021002
Fuel Capsule Assembly	398-3021003
Fuel Block	398-3021004
Details--Fuel Block	398-3021005
Shield	398-3021006
Shield Block	398-3021007
Insulation Strip	398-3021008
Insulation Block	398-3021009
Thermoelectric Elements	398-3021010
Shoe--Hot Junction	398-3021011
Details--Cold Junction	398-3021012
Piston	398-3021013
Washer	398-3021014
Frame--Heat Sink	398-3021015
Bars--Heat Sink	398-3021016
Insulation--Corner Strip	398-3021017
Insulation--Spacer	398-3021018
Insulation--Plate	398-3021019
Wire Guide	398-3021020
Plug	398-3021021 *

*Indicates drawings used for both SNAP 7A-7C (10-watt generator) and SNAP 7B-7D (60-watt generator).

SNAP 7A-7C Thermoelectric Generator Drawings (continued)

Title	Number
Electrical Connector	398-3021022
Connector Mount	398-3021023
Connecting Bar	398-3021025
Shipping Pallet	398-3021026*
Nameplate	398-3021027
Cover, Generator Test	398-3021028
Cap Screw	398-3021029*
Fuel Capsule Shipping Cask	398-3021040
Biological Shield Container	398-3021041
Generator Assembly	398-3021042
Generator Cover Assembly	398-3021043
Details and Assembly--Fuel Shipping Cask	398-3021044
Hot Shoe--Element Assembly	398-3021045
Cold Cap Assembly	398-3021046
Thermoelectric Module Assembly	398-3021047
Heat Sink Assembly	398-3021048
Generator Shell Assembly	398-3021049
Generator--Pallet, Shipping Assembly	398-3021050*

*Indicates drawings used for both SNAP 7A-7C (10-watt generator) and SNAP 7B-7D (60-watt generator).

APPENDIX E

SNAP 7B AND SNAP 7D ENGINEERING DRAWINGS

Title	Number
SNAP 7B--30-Watt Electric Generation System Drawings	
Drawings not complete.	
SNAP 7D--30-Watt Electric Generation System Drawings	
Installation Layout--USN Weather Station Buoy	398D1080050
SNAP 7B-7D--60-Watt Thermoelectric Generator Drawings	
Generator--Biological Shield Assembly	398-3021100
Cylinder	398-3021101
End Plates	398-3021102
Fuel Element Assembly	398-3021102
Fuel Block	398-3021103
Plate--Fuel Block	398-3021105
Shield	398-3021106
Shield Block	398-3021107
Insulation Strip	398-3021108
Insulation Block	398-3021109
Thermoelectric Elements	398-3021110
Shoe--Hot Junction	398-3021111
Details--Cold Junction	398-3021112
Piston	398-3021113

SNAP 7B-7D--60-Watt Thermoelectric Generator Drawings (continued)

Title	Number
Washer	398-3021114
Frame--Heat Sink	398-3021115
Module Bar--Heat Sink	398-3021116
Insulation--Corner Strip	398-3021117
Insulation--Plate	398-3021118
Wire Guide	398-3021120
Plug	398-3021121*
Electrical Connector	398-3021122
Connector Mount	398-3021123
Schematic Diagram (Operating Model)	398-3021124
Connecting Bar	398-3021125
Shipping Pallet	398-3021126*
Cap Screw	398-3021129*
Biological Shield Container	398-3021141
Operating Model Assembly	398-3021142
Generator Cover Assembly	398-3021143
Hot Shoe--Element Assembly	398-3021145
Cold Cap Assembly	398-3021146
Thermoelectric Module Assembly	398-3021147
Heat Sink Assembly	398-3021148
Container--Operating Model	398-3021149
Generator--Pallet, Shipping Assembly	398-3021050*

*Indicates drawings used for both SNAP 7A-7C (10-watt) generator and SNAP 7B-7D (60-watt) generator.

APPENDIX F

STRONTIUM-90 FUEL PROCESSING ENGINEERING DRAWINGS

Title	Number
Sr-90 Fuel Processing Installation (Sheet 1)	398-2572000
Sr-90 Fuel Processing Installation (Sheet 2)	398-2572000
Sr-90 Fuel Processing Installation (Sheet 3)	398-2572000
Sr-90 Fuel Processing Installation (Sheet 4)	398-2572000
Sr-90 Fuel Processing Schematic	398-2572001
Welding Fixture Assembly	398-2572002
Torch Assembly Welding Fixture	398-2572003
Electrode Adjuster Welding Fixture	398-2572004
Insulator Bushings Welding Fixture	398-2572005
Chill Block Welding Fixture	398-2572006
Latch Welding Fixture	398-2572007
Housing and Lid Weldments Welding Fixture	398-2572008
Welder Lid Welding Fixture	398-2572009
Welder Housing Welding Fixture	398-2572010
Support Welding Fixture	398-2572011
Torch Details, Welding Fixture	398-2572012
Chill Block Details, Welding Fixture	398-2572013
Stud Welding Fixture	398-2572014
Dry Box, Sr-90	398-2572015
Capsule Holder	398-2572016

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
Flow Diagram Schematic, Sr-90 Fuel Processing	398-2572017
Port Welding Fixture	398-2572018
Cable, Torch Welding Fixture	398-2572019
Flow Diagram Sr-90, Fuel Processing	398-2572020
Spring, Compression Welding Fixture	398-2572021
Ground Contact Welding Fixture	398-2572022
Reflux Condenser, Sr-90 Fuel Processing	398-2572023
Handling Tool, Fuel Capsule	398-2572024
Filter Assembly	398-2572025
Lid, Filter	398-2572026
Filter	398-2572027
Housing, Filter	398-2572028
Shielding, Capsule Storage	398-2572029
Shielding, Filter	398-2572030
Press Assembly, Fuel Pellet	398-2572031
Die Press Assembly	398-2572032
Stud Press Assembly	398-2572033
Transfer Plate Press Assembly	398-2572034
Retainer, Lower Pin Press Assembly	398-2572035
Bushing, Lower Pin Press Assembly	398-2572036
Die Pins Press Assembly	398-2572037
Details Press Assembly	398-2572038

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
Frame Press Assembly	398-2572039
Tray	398-2572040
Exhaust Filter Installation	398-2572041
Base Plates, Transfer Box	398-2572042
Guide and Door Details, Transfer Box	398-2572043
Neoprene Structure Gaskets, Transfer Box	398-2572044
Lifting Mechanism Details, Transfer Box	398-2572045
Latch Details, Transfer Box	398-2572046
Vent Filter Installation	398-2572047
Structures Assembly and Housing, Transfer Box (Sheets 1 and 2)	398-2572048
Lifting Mechanism Assembly, Transfer Box	398-2572049
Details of Yoke, Transfer Box	398-2572050
Upper and Lower Door Assembly, Transfer Box	398-2572051
Gaskets, Transfer Box	398-2572052
Transfer Box Assembly	398-2572053
Transfer Can Assembly, 6-3/4-in. dia	398-2572054
Welded Can Assembly	398-2572055
Lid Assembly, Transfer Can	398-2572056
Gasket, Transfer Can	398-2572057
Lock Spring, Transfer Can	398-2572058
Receptacle, Adapter and Guide Rail 8-in. dia, Transfer Port	398-2572059

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
Receptacle 6-3/4-in. dia, Transfer Mechanism	398-2572060
Gasket 8-in. dia, Transfer Port	398-2572061
Adapter 8-in. dia, Transfer Port	398-2572062
Guide Rail 8-in. dia, Transfer Port	398-2572063
Transfer Box Base Plate Installation	398-2572064
Arm Assembly, 6-3/4-in. Transfer Mechanism	398-2572065
Details, 6-3/4-in. Transfer Mechanism	398-2572066
Cap Seal Assembly, 6-3/4-in. Transfer Mechanism	398-2572067
Screw, Housing and Ratchet Assembly, 6-3/4-in. Transfer Mechanism	398-2572068
Ratchet Wrench Assembly, 6-3/4-in. Transfer Mechanism	398-2572069
6-3/4-in. Transfer Mechanism Assembly	398-2572070
Pellet Transfer Tray	398-2572071
Valve Assembly, Butterfly	398-2572072
Housing Assembly, Filter Precipitate	398-2572073
Lid and Can Assembly Filter, Precipitate	398-2572074
Air Line Hook-up for Transfer Box (Sheets 1 and 2)	398-2572075
Filter Funnel Ball Mill	398-2572076
Filter Housing Ball Mill	398-2572077
Filter Assembly Ball Mill	398-2572078

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
Tray Cover, Pellet Press	398-2572079
Sampler Unit (Sheets 1 through 3)	398-2572080
Glove Box Assembly (Sheets 1 through 4)	398-2572081
Sampling System	398-2572082
Diluent Tank Assembly	398-2572083
**	398-2572084
**	398-2572085
**	398-2572086
**	398-2572087
**	398-2572088
Table, Furnace Loading	398-2572089
Dolly, Hydraulic Power Unit	398-2572090
Panel, Hydraulic Power Unit	398-2572091
Power Supply, Portable Hydraulic	398-2572092
Mounting Strap, Vacuum Tank	398-2572093
**	398-2572094
Layout and Assembly of Control Panel	398-2572095
Electrical Schematic Diagram	398-2572096
**	398-2572097
Cask Cover Glove Box Details and Assembly HAPO II-A (Sheets 1 through 3)	398-2572098

**These numbers not assigned to Task 8.5.

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
Wiring Diagram Control Panel	398-2572099
Filter Assembly Precipitate	398-2572100
Valve and Ducts Inlet Vent	398-2572101
Brackets Inlet Vent	398-2572102
Inlet Filter Installation	398-2572103
**	398-2572104
Blender and Die Charging Assembly	398-2572105
Blender Funnel Holder Assembly	398-2572106
Funnel Assembly (Sheets 1 and 2)	398-2572107
Blender Can Assembly	398-2572108
Blender Canister Lifting Collar Assembly	398-2572109
Blender Funnel Cover Assembly	398-2572110
Electrical Schematic and Wiring Diagram of Transfer Box (Sheets 1 and 2)	398-2572111
Electrical Layout Cell (Nos. 1 and 2)	398-2572112
Wiring Diagram Cell (Nos. 1 and 2)	398-2572113
Control Panel Assemblies	398-2572114
Stand, Vacuum Pumps	398-2572115
Pallet, Shipping Cask	398-2572116
**	398-2572117

**These numbers not assigned to Task 8.5.

Strontium-90 Fuel Processing Engineering Drawings (continued)

Title	Number
**	398-2572118
**	398-2572119
Plumbing Installation (Sheets 1 through 5)	398-2572120
Calorimeter Assembly	398-2572121
Calorimeter, Water Outlet	398-2572122
Calorimeter, Insulator Cover	398-2572123
Calorimeter Base	398-2572124
Transfer Mechanism, Adapter, Counter-balance Assembly and Installation in Cell No. 5	398-2572125
Handling Components for Filter Can Assembly	398-2572126

**These numbers not assigned to Task 8.5.

APPENDIX G

SAFETY ANALYSIS

The following is the method used for determining the activity concentration at various distances from the point of release:

$$X = \frac{2\,Q}{\pi\, C_y C_z \bar{u}\, d^{2-n}} \quad \exp\left[-d^{n-2}\left(\frac{y^2}{C_y^2} + \frac{z^2}{C_z^2}\right)\right] \quad *$$

X = ground level concentration = curie/m^3

Q = rate of activity release = 0.215 curie/sec

C_y = crosswind diffusion coefficient = 0.4 $(\text{meter})^{n/2}$

C_z = vertical diffusion coefficient = 0.4 $(\text{meter})^{n/2}$

$\bar{u}$ = wind speed = 5 meters/sec

d = distance from release = 4800 meters

n = stability parameter = 0.5

y = crosswind distance from centerline of cloud = meters

z = vertical distance from centerline of cloud = 28.1 meters

The individual who may inhale radioactive material is considered to be located at ground level, 28.1 meters below the horizontal centerline of the cloud, and in a position corresponding with an extension of the cloud's vertical centerline.

A typical calculation considering a strontium release during daylight conditions at the boundary of the exclusion area is as follows:

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*Hazards Evaluation Report, Curtiss-Wright Research Reactor, Curtiss-Wright Corp., Quehanna, Penna , April 1959.

$$X = \frac{2 \times 0.215}{3.14 \times 0.4 \times 0.5 \times 5 \times (4800)^{2 - 0.5}}$$

$$\exp \left[- (4800)^{0.25 - 2} \left\{ \frac{0}{(0.4)^2} + \frac{(28.1)^2}{(0.4)^2} \right\} \right]$$

$X = 7.16 \times 10^{-8}$ curies/m^3 (μ c/cm^3)

and

$I = BR \times X \times t$

I = activity inhaled during time t, microcuries

BR = breathing rate of an individual = 232 cm^3/sec

t = time in cloud

$I = 232 \times 7.16 \times 10^{-8} \times 760$

I = 0.012 microcurie

APPENDIX H

SHIELDING ANALYSIS FOR STRONTIUM-90*

A. CELL WALLS

An analysis of the shielding value of the hot cell walls and windows has shown that dose rates will be extremely low for the anticipated amounts of strontium-90. Dose rate calculations were based upon two curie strengths (10,000 and 168,000 curies) and two forms (liquid and titanate). Although it is planned to use cells with three-foot-thick walls for processing, the shielding value of the two-foot-thick walls has been included to show their adequacy if it is required to use these cells at some future date.

Dose rates were calculated at points located in the front of the cell outside the walls and windows, at a point on top of the cells outside the two-foot-thick ordinary concrete roof slabs, at a point in back of the cells outside the cast iron door but inside the isolation room, and at a point in back of the cell outside the isolation room but shielded by the cast iron door only. These points are shown in Parts A and B of Fig. H-1, and the results are given in Table H-1.

TABLE H-1

Strontium-90 Processing--Hot Cell Dose Rates (mr/hr)

Front of Cell	Curies Sr-90	Cells Nos. 1, 2 and 3 Three-Foot Walls	Cells Nos. 4 and 5 Two-Foot Walls
Liquid	10,000	1.1×10^{-6}	0.0023
	168,000	1.8×10^{-5}	0.039
Titanate	10,000	2.9×10^{-6}	0.0059
	168,000	4.9×10^{-5}	0.099
		Three-Foot Windows	Two-Foot Windows
Liquid	10,000	0.0016	0.34
	168,000	0.027	5.7
Titanate	10,000	0.0042	0.89
	168,000	0.070	15.0

*Unless otherwise stated, shielding is designed to limit dose rates to a maximum of 10 mr/hr at one meter.

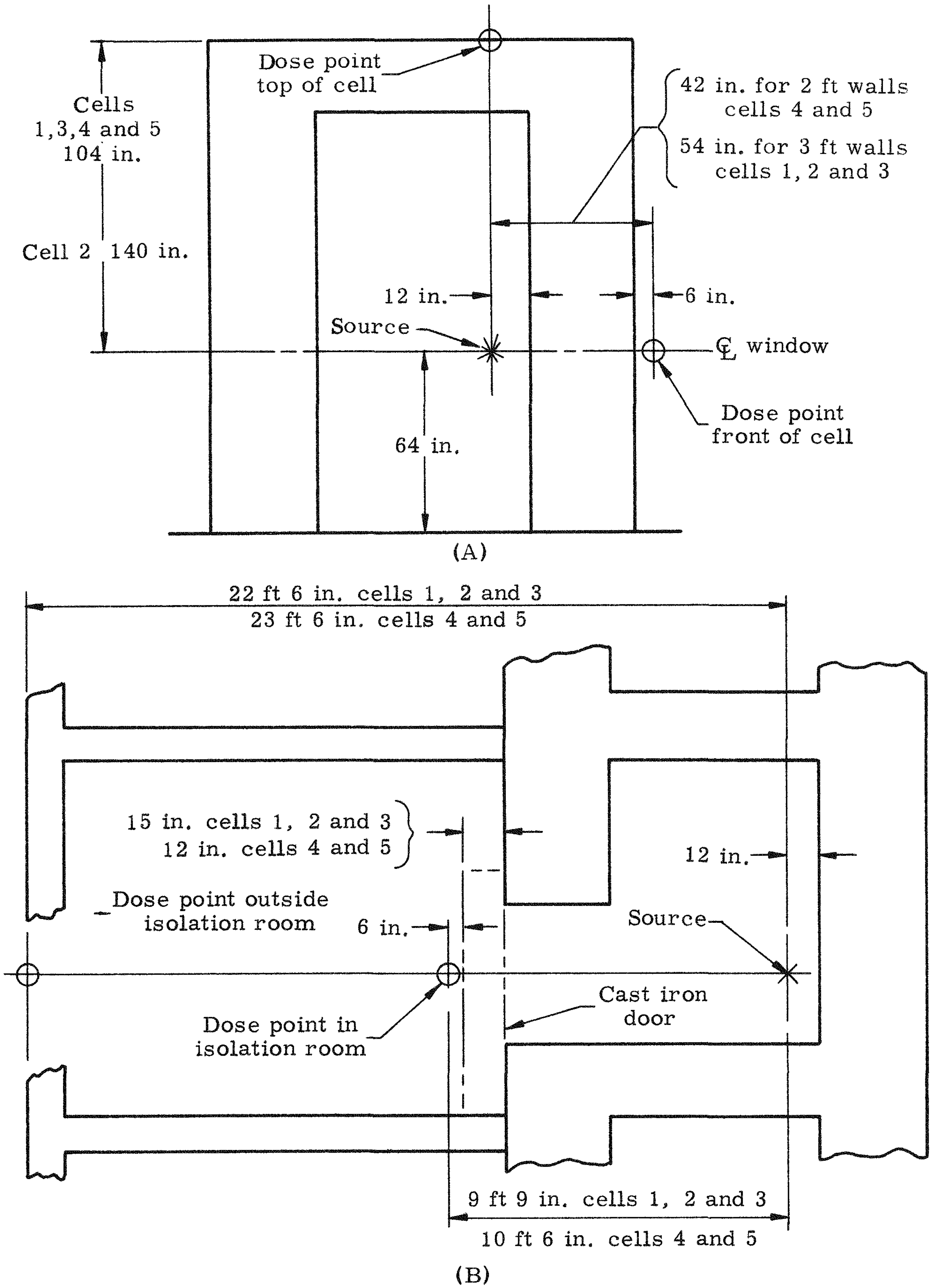

Fig. H-1. Geometry for Shielding Analysis of (A) Front and Top of Hot Cell and (B) Rear of Hot Cell

TABLE H-1 (continued)

Rear of Cell	Curies SR-90	Cells Nos. 1, 2 and 3 Three-Foot Walls	Cells Nos. 4 and 5 Two-Foot Walls
		15-Inch Door	12-Inch Door
		In Isolation Room	
Liquid	10,000	0.0029	0.032
	168,000	0.049	0.54
Titanate	10,000	0.0075	0.083
	168,000	0.13	1.4
		Outside Isolation Room	
Liquid	10,000	0.00054	0.0064
	168,000	0.0091	0.11
Titanate	10,000	0.0014	0.017
	168,000	0.024	0.28
Top of Cell		Two-Foot Ordinary Concrete	
		Cell No. 2	Cells Nos. 1, 3, 4 and 5
Liquid	10,000	0.68	1.2
	168,000	11.5	21
Titanate	10,000	1.8	3.2
	168,000	30	54

The results are conservative since they neglect self-absorption and shielding effect of structural materials and of any localized shielding required for manned entry into the cell.

B. EFFECT OF Ce-144 ON CELL WALL ANALYSIS

The significant bremsstrahlung associated with the decay of cerium-praseodymium-144 arise from the approximately 3-mev beta particle of praseodymium-144. In addition, there are high energy decay gammas associated with praseodymium-144. As a result, the average energy of the gammas for Ce-Pr-144 is higher than those from Sr-Y-90. In terms of shielding, this means that the Ce-Pr-144 gamma rays become more predominant and contribute an increasing amount to the total dose rate as shielding thickness is increased.

It is estimated that the Ce-144 content may be as high as 2 to 3 millicuries per curie of strontium-90. Table H-2 shows the increase in dose rates for selected situations around the hot cells. It should be noted that the shielding of the cells is still adequate with this amount of cerium.

TABLE H-2

Effect of 2.5 Millicuries of Ce-144 per Curie of Strontium-90 on Selected Dose Rates (mr/hr)

	Two-Foot Walls	Two-Foot Windows	Roof	Isolation Room, 12-inch Door
10,000 curies Sr-90	0.0059	0.89	3.2	0.083
25 curies Ce-144	0.008	0.36	0.56	0.018
168,000 curies Sr-90	0.099	15.0	54.0	1.4
420 curies Ce-144	0.14	6.0	9.4	0.31

C. SLURRY TANK

The slurry tank has a capacity of 25 gallons. The maximum loading will be 168,000 curies of Sr-90. Five inches of lead are required to reduce the dose rate at the surface of the lead to 200 mr/hr.

D. DISPOSABLE FILTER FOR SOLID WASTES

The solids in the waste streams will be collected on a disposable filter. The filter will be housed in a lead-lined 55-gallon drum and shipped to a disposal area at the completion of the job. It was assumed that one percent of the total amount of Sr-90 processed will be present in the waste as solids. After processing 600,000 curies, the maximum amount of Sr-90 to be shielded in this drum would be 6000 curies. Analysis of the problems shows that 3-3/4 inches of lead will be required.

E. DISPOSAL OF LOW LEVEL LIQUID WASTES

The processing waste liquids (after removal of solid material) will be disposed in 55-gallon drums lined with three inches of concrete. The remainder of the drum volume is to be filled with an absorbing material such as vermiculite or a mixture of plaster and perlite. An analysis of this situation showed that a maximum of 24 curies of Sr-90 can be contained in the drum.

F. VACUUM PUMP

If some radioactivity is drawn into the vacuum pump, the amount will be small and the pump can be disconnected, taken to the decontamination room, and cleaned.

G. SEALED FILTER UNIT

The filter cake obtained just before the calcination operation may have to be shielded if manned entry into the cell is necessary. It is estimated that the filter cake will contain between 5000 and 10,000 curies of Sr-90. Four and one-quarter inches of lead are required.

H. WASTE HOLD TANK

A 25-gallon stainless-steel vessel is provided in Cell No. 2 for storing liquid wastes from the strontium processing. It is planned to have not more than 40 liters of waste solution in this tank. This is the amount of solution required to process between five and seven 5000-curie batches of Sr-90. Based upon information obtained from ORNL, there will be between 150 and 230 curies in this amount of waste. One and three-quarter inches of lead will be required.

I. CAPSULE STORAGE VESSEL

As the strontium-titanate pellets are made, they will be placed in a Hastelloy-C tube which will serve as the cladding for the finished fuel capsule. The semifinished element will be stored in a shielded water-jacketed copper chill block. The nominal loading of the capsules will be about 17,500 curies. The shield design was based upon 20,000 curies. Four and one-half inches of lead are required.

J. DUST ACCUMULATION

An attempt was made to determine the amount of strontium-90 which could collect in the box and give a dose rate of 500 mr/hr at a distance of six feet. Two geometries were used. One was a point source and the other was an infinite plane source. The point source gave a value of 134 curies, and the plane source a value of 0.0025 curie per square centimeter. The latter curie strength spread over a 6 x 10-foot area becomes a total of 140 curies. By converting these figures to weight, the amount of Sr-90 is about one gram and the corresponding amount of the titanate is about two grams. The 2.5 millicuries per square centimeter appears to be a high value for the whole box, but should not be too high for specific areas. Severe dusting has been experienced at ORNL during weighing and die-loading operations. This accumulation of dust may require partial decontamination of the box between batches to prevent excessive accumulation. It is probable that no method devised to prevent dusting will eliminate the problem.

K. TEMPORARY SHIELDING

A curve was prepared for use in estimating temporary shielding for various amounts of strontium-90. Figure H-2 is a curve of curies versus thickness of lead shielding required to reduce the dose rate to 10 mr/hr at one meter. The values obtained from this figure should give conservative results since the self-absorption of the source and absorption by container materials, and so forth, were not included.

L. LIQUID SAMPLES FOR ANALYSIS

Liquid samples for chemical and radiometric analysis will be drawn into a glove box located in the isolation room of Cell No. 2. The volume of sample drawn is one-tenth of a milliliter. The most active sample that will be drawn will probably be the sample from the slurry tank. In this tank, the maximum concentration will be 168,000 curies in 44 liters of liquid, which gives 3.82 curies per milliliter. The maximum activity in the sample will thus be 0.382 curie. At a distance of one meter, 0.382 curie of Sr-90 in liquid form will give a dose rate of about 2 mr/hr. This sample will be further diluted, possibly to a volume of 100 milliliters, and fractions of this used in analysis. Shielding is, therefore, not required for this phase of the operation.

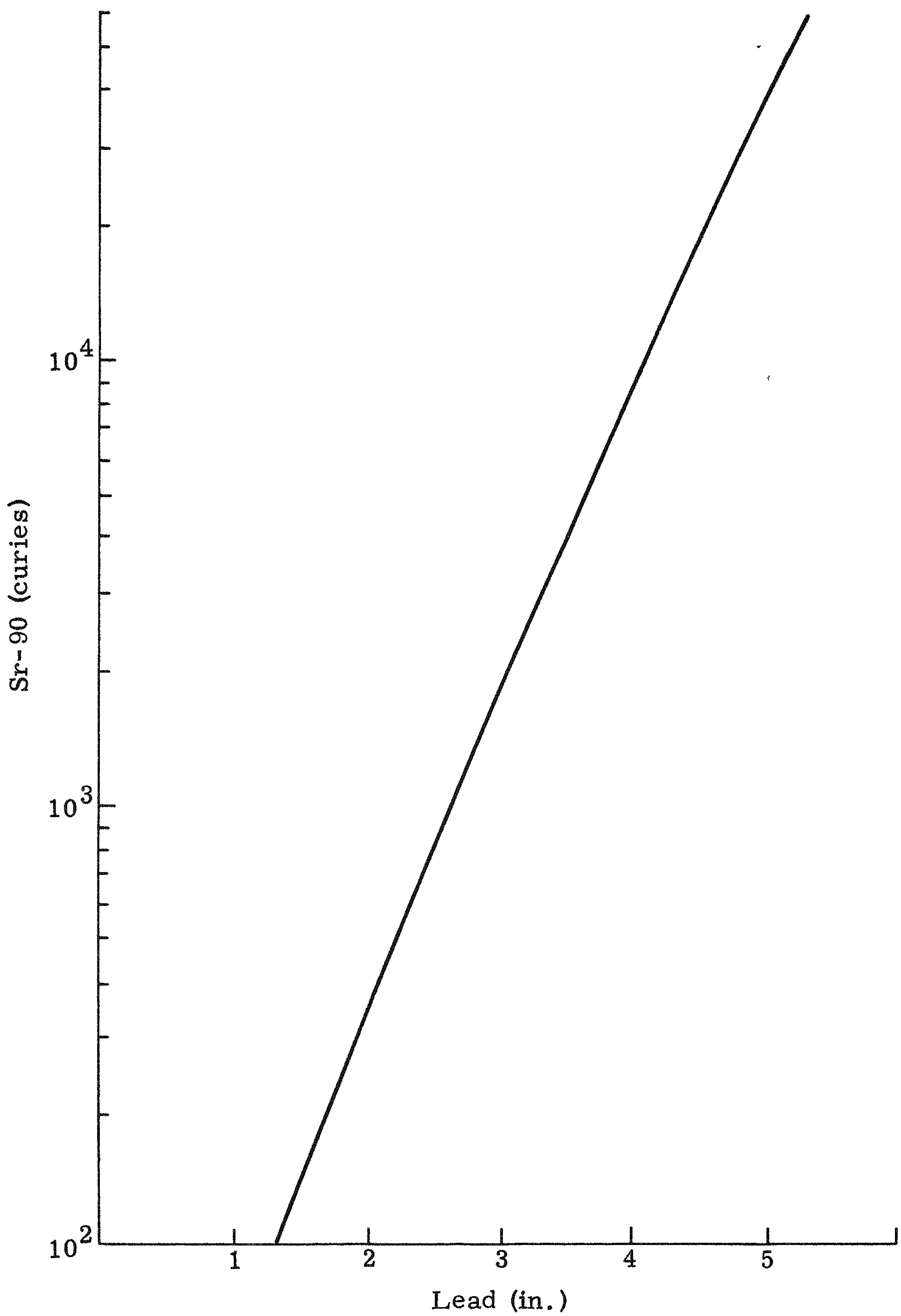

Fig. H-2. Curve Indicating Inches of Lead Necessary for Shielding for Various Amounts of Strontium-90 to Reduce Dose Rate to 10 mr/hr at One Meter

M. TRANSFER CASK

A shielded cask is required to transfer the finished fuel capsule from Cell No. 2 to Cell No. 5. The finished elements will contain less than 20,000 curies of Sr-90 (17,500 curies is the nominal loading). Five inches of lead are required for the 20,000 curies. However, the same cask will be used to transfer the irradiated americium capsule from the storage pool to the process cell; eight inches of lead are required for the transfer. Consequently, the cask will be more than sufficient for transferring the strontium capsule.

N. CAPSULE STORAGE IN CELL NO. 5

The 60-watt SNAP 7B and 7D generators will contain about 244,000 curies of Sr-90 which will be contained in 14 capsules. These capsules are to be stored in a lead pig in Cell No. 5. Six inches of lead will be required for the 14 capsules.

During the operation when the fuel capsules are loaded into the generator fuel block, the dose rate through the two-foot window of Cell No. 5 will be less than 4 mr/hr.