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under Contract AT(30-3)-217
with the U. S. Atomic Energy
Commission

MND-P-2483-7
UC-33
TID 4500, 17th edition

SNAP 7 PROGRAM
QUARTERLY PROGRESS REPORT NO. 7
Task 8--Strontium-90 Fueled
Thermoelectric Generator Development

May 1 through July 31, 1962

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Printed in U.S.A. Charge: \$0.50. Available from U. S. Atomic
Energy Commission, Office of Technical Information Extension, P.O.
Box 1001, Oak Ridge, Tennessee.

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FOREWORD

This quarterly report covers the period from May 1 through July 31, 1962. It has been prepared by the Martin Company according to the requirements of Contract AT(30-3)-217, Task 8, with the U. S. Atomic Energy Commission.

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I. INTRODUCTION AND SUMMARY

The efforts of the Martin Company in executing the Task 8 portion of Contract AT(30-3)-217 are detailed in this report. The SNAP 7A and SNAP 7C effort is covered in detail in Chapter II and SNAP 7B and SNAP 7D in Chapter III. The Strontium-90 fuel processing effort formerly reported under this contract is now reported under Contract AT(30-1)-3062.

A. SNAP 7A AND SNAP 7C

The effort in this area has been confined to operating the reliability model. There have been fluctuations in output power that can be attributed to variations in the operating parameters, plus an increase in the internal resistance.

The work on the SNAP 7A, covering the power restoration program, is reported under Contract AT(30-1)-3043.

B. SNAP 7B AND SNAP 7D

The second 60-watt generator has been completed and has undergone the beginning-of-life (maximum input, helium gas) portion of the parametric tests. The performance was nearly identical to that of the first 60-watt generator. The unit will be used with the SNAP 7B system.

The installation concept for the SNAP 7B system has been approved by the U.S. Coast Guard. The generator is to be housed in a finned aluminum container that will provide the required radiator surface. This container will be filled with a water-ethylene glycol mixture that is necessary to transfer the heat from the generator into the container. The battery-converter compartment is an integral part of the container lid.

During the time the entire SNAP 7D system was subjected to shock and vibration tests, no mechanical or functional deficiencies were detected. The required temperature tests followed the mechanical tests. During this period the complete system was operated at maximum intermediate and minimum temperatures. Design objectives were satisfied throughout the test.

The SNAP 7D generator was fueled at Oak Ridge National Laboratory (ORNL) on June 12, 1962, with a total thermal input of 1435 watts. The fueled generator was returned to the Martin Company and integrated with the system. The system was demonstrated and accepted on July 3, 1962.

II. SNAP 7A AND SNAP 7C FIVE-WATT ELECTRIC GENERATION SYSTEM

A. OBJECTIVES

The objectives for the quarter ending July 31, 1962 for Subtasks 8.1 and 8.3 were:

- (1) Continue testing of the SNAP 7A and SNAP 7C reliability model.
- (2) Maintain liaison with the Navy and Coast Guard for exchange of data.

B. ACHIEVEMENTS AND DISCUSSION

The SNAP 7A and SNAP 7C reliability model has been under test for 264 days. Power output variations are noted which are due to changes in the temperatures of the cold and hot junctions and the internal resistance. The hot junction was 888° F with a power output of 2.24 watts for the month of May. The hot junction was raised to 905° F which resulted in power output readings of 2.34 and 2.30 watts in June and July. The readings used are those taken the last working day in a report period. The 0.04-watt difference is attributed to an average cold junction temperature increase from 141° to 154° F that decreased the temperature differential across the thermoelement. The 10-watt reliability model data are plotted on Fig. 1. The increase in internal resistance is the only undesirable result noted. However, the increase, as experienced, is not critical.

Fig. 1. Performance Data SNAP 7A and C 10-Watt Reliability Model
(15 couples made of Martin N and P materials)

III. SNAP 7B AND SNAP 7D 30-WATT ELECTRIC GENERATION SYSTEM

A. OBJECTIVES

The following were the objectives for Subtasks 8.2 and 8.4 during the past quarter:

- (1) Continue reliability model tests.
- (2) Conduct environmental tests on the SNAP 7D components.
- (3) Conduct 30-day cyclic tests on the SNAP 7D system.
- (4) Fuel the SNAP 7D generator.
- (5) Complete design of the SNAP 7B installation.
- (6) Conduct parametric tests on the SNAP 7B generator.

B. ACHIEVEMENTS AND DISCUSSION

1. Reliability Model

The 60-watt reliability model has been under test for 202 days. The present power output is 11.36 watts with the hot junction temperature at 950° F. Figure 2 shows a plot of the 60-watt reliability model data. The Seebeck coefficient, internal resistance and cold junction temperature are nearly constant. The output power follows the input power with the conversion efficiencies falling within the expected range. A gas pressure rise has also been noted in the reliability model, although the rate of increase seems to be less than experienced with the fueled generators.

2. SNAP 7B Environmental Tests

The environmental tests were conducted for shock, vibration and temperature. The following is a description of the individual tests.

The generator was installed in a test container during the shock and vibration tests rather than in a biological shield. The weight of the biological shield made it impractical to include it in the mechanical tests. Also, it is felt that the shield does not affect the dynamic loads in the generator. The generator was electrically heated throughout the tests. A specially designed cooling jacket was used to maintain the cold junction temperatures during the mechanical tests and to physically secure the generator to the test fixtures (see Fig. 3).

Fig. 2. Performance Data SNAP 7B and 7D 60-Watt Reliability Model
(10 couples made of Martin N and 3M P materials)

Fig. 3. 60-Watt Generator Mounted on Vibration Table

The vibration tests utilized an electrodynamic shaker. These tests were performed in each of the three orthogonal axes and consisted of a 5 to 300 to 5 cps sweep over a 15-minute span at a ± 3 g level or 0.060 ± 0.006 inch displacement, whichever was less. No major vibration resonance was noted in the generator, the battery or the relay panel. The two-hour vibration dwell for the generator was conducted in the horizontal plane at 55 cps and those for the relay panel and battery were conducted in the vertical plane at 33 cps.

The primary functions of the equipment were monitored throughout the vibration tests. The generator input power, output power and temperature were recorded. There were no power variations due to the vibration tests; however variations in the cooling water flow caused fluctuations of the cold junction. No deterioration or discontinuity was noted. The primary purpose of the relay panel is to provide emergency switching to a set of reserve batteries in case of generator power failure. The panel was monitored both for resistance to accidental relay tripping and for proper operation under vibration. The results were satisfactory in each case.

The shock tests were conducted on a Barry Medium Impact Shock Machine. The components were subjected to two 6 g shocks having a six-millisecond half-sine wave pulse in each of the three principal orthogonal axes. The primary functions of the components were monitored before and after each shock. No deterioration or discontinuity was noted. The contract requires that shock tests to a minimum of 3 g be conducted. However, it was felt that truck transportation shock might be in excess of this and it was decided to increase the shock load to 6 g to achieve a higher confidence level.

The generator was removed from the test container and assembled with the biological shield prior to conducting the temperature tests. The biological shield was required because of the temperature gradient through the shield and also the increased surface area in contact with the cooling fluid. The generator assembly was then placed in a large tank, and water (with antifreeze) was added until it just covered the fins on the biological shield. The generator and tank were positioned in a large environmental chamber. The battery and converter were placed in an adjacent environmental chamber, and connected to the system using dummy loads to simulate the flashing light and weather station equipment. The equipment was checked at the temperature extremes and at midpoint. The actual stabilized ambient temperatures at sea level pressure were:

	Generator (° F)	Battery and Converter (° F)
Low temperature	28	28
Midpoint	50	53
High temperature	80	80

The system worked well within the range noted and was in accordance with the statement of work. Actually, indications are that the system would perform satisfactorily with temperatures as low as 20° F and as high as 100° F.

3. SNAP 7D 30-Day Cyclic Test

The 30-day cyclic test on the SNAP 7D system was essentially an extension of the temperature tests. After the temperature tests were completed, the environmental chamber doors were opened and the unit was operated at room temperatures for the remainder of the 30 days. The system operation was normal, and the battery remained at full charge.

4. SNAP 7D Fueled Generator

The SNAP 7D generator was fueled at Oak Ridge National Laboratory on June 12, 1962. The total fuel loading was 1435.3 watts. The Strontium-90 content provided 1411.3 watts, with the remaining 24.0 watts provided by Strontium-89. The bulk of the fuel was loaded in 12 capsules with 1386 watts provided by the Sr-90. As this was only six watts above the minimum requirement, it was decided to load three surplus pellets (approximately 25 watts) into a thirteenth capsule. The capsule loadings, leak check and smear count are shown in Table 1.

TABLE 1
Oak Ridge Recorded Data on Date of Fueling
June 12, 1962

<u>Capsule No.</u>	<u>Sr-90 (watts)</u>	<u>Leak Rate (cc/yr)</u>	<u>Smear Count (dpm--entire surface)</u>
1	117.6	3.4	1300
2	116.3	0.75	220
3	113.1	0.38	180
4	114.3	0.75	80

TABLE 1 (continued)

<u>Capsule No.</u>	<u>Sr-90 (watts)</u>	<u>Leak Rate (cc/yr)</u>	<u>Smear Count (dpm--entire surface)</u>
5	115.9	0.75	300
6	115.4	0.75	760
7	115.5	0.23	260
8	118.1	0.26	100
9	113.5	0.81	60
10	115.0	0.75	900
11	116.4	0.75	50
12	115.2	0.75	70
13	<u>25.0</u>	0.44	<u>160</u>
Total	1411.3		4980

Sr-89--24.0 watts

Sr-90--224,000 curies

Total--1435.3 watts

The 12 fully loaded capsules were inserted in the six outer holes in the fuel block. The partially loaded capsule was inserted in the bottom of the center hole in the fuel block. It not only raised the total fuel loading, but it also helped offset the thermal gradient that was present in the fuel block. A fourteenth dummy capsule was inserted in the center hole to act as a spacer.

The radiation from the generator was carefully checked before and after removing the generator from the loading cell. These data are shown in Table 2.

The generator was returned to the Martin Company on June 16, 1962. At this time, it was placed in a tank of water to achieve the desired ambient temperature (80° F), and a fueled generator parametric curve was established. The maximum output with the fuel was 68 watts which corresponded with the predicted power. Following these tests, the SNAP 7D system was demonstrated and accepted on July 3, 1962.

TABLE 2
Radiation Data on Fueled Generator

Assembly Complete	
<u>Contact</u>	<u>(mr)</u>
Top	15
Sides	11
Bottom	20
<u>One Meter</u>	
Top	2
Sides	2
Bottom	2

The system tests indicate that the power requirement of the system is approximately 36 watts rather than the 42 watts initially predicted. The additional allowance had been made because of the unknown charging efficiency of the new batteries used for this application. The energy from the generator is fed directly into the battery. It was found, and substantiated by test, that the generator would stabilize within the desired charging voltage range. This eliminated the converter requirement and thus added to the surplus power from the generator.

The first gas change is recommended at the end of four years when the generator output will be down to 52 watts. It is recommended the gas change be done somewhat early to ensure adequate battery charging voltage without using a converter. The gas is to be changed to pure argon to allow the generator to deliver 49 watts at the end of 10 years. The generator output should be sufficient to meet the system requirement at the end of 15 years; however, a converter might be required to maintain the battery charging voltage after 10 years. The system was tested to verify its operation for 10 years as required by the contract.

On approximately July 18, 1962, it was noticed that the hot junction temperature and power had fallen off on the SNAP 7D generator. A check on the internal pressure revealed that it had changed from

8 to 15.75 in. Hg gage. This is the same problem as encountered on the SNAP 7A generator. A program is being planned to determine the cause of the pressure buildup and the required corrective action.

5. SNAP 7B Installation

The SNAP 7B installation calls for the generator to be installed in a finned aluminum container. A mixture of 30 gallons of ethylene glycol and 55 gallons of water is required to transfer the heat from the generator into the container. The lid of the container is designed with a well to provide a compartment for the battery-converter. The converter is bolted to brackets mounted on the floor of the well. The batteries also rest on the floor of the well and are held in position by dividers attached to the floor. The leads from the generator enter the well through a center tube designed to prevent liquid from the container leaking into the battery-converter compartment. The system will be prewired so the lantern, horn and instrumentation connections are made by merely attaching the wires to standard bulkhead connectors that are located on the exterior of the container.

The finned container provides sufficient heat rejection surface to hold the coolant fluid, and thus the generator cold junction within the upper operational temperature in still air at 110° F (see Fig. 4). The fluid temperature is expected to run approximately 30° F above the ambient air. This temperature differential is used to protect the batteries from the low air temperature of -10° F. This is accomplished by immersing the lower portion of the battery-converter in the coolant fluid. Therefore, the coldest temperature of the batteries will be 20° F, which is the minimum recommended charging temperature. The batteries will, however, operate at lower temperatures.

The SNAP 7B breadboard converter was not adequate to handle the electrical overload produced when the generator external load was removed. It was also marginal over the required temperature range. The unit was redesigned to correct these difficulties. Figure 5 is a schematic of the regulator used to control the converter input, and Fig. 6 is a schematic of the dc-dc converter. The regulator and converter are housed as a single unit. Also combined in the package are the instrumentation terminals and the shunt used to read the generator current.

The SNAP 7B system wiring diagram is shown in Fig. 7. Separate connectors are provided for the lantern and the horn, and the instrumentation leads are brought into a common 20-pin terminal. Instrumentation leads are planned for three hot junction thermocouples, one cold junction thermocouple, one fuel block thermocouple, generator current (read in millivolts across a shunt), and 30- and 12-volt battery pack voltages (same as generator voltage and regulated converter input voltage).

Fig. 4. SNAP 7B Installation

Components		(ohms)	(watts)	Components		(ohms)	(watts)
R ₁ & R ₂	Resistor	562	1/2	R ₁₆ & R ₁₇	Resistor	5	50
R ₃ & R ₇	Resistor	4700	1/2	P ₁	Potenti-ometer	250	1/2
R ₄ & R ₆	Resistor	270	1/2	Q ₁ , Q ₂ & Q ₃	Transistor	Silicon	2N687
R ₅	Resistor	330	1/2	Q ₄	Transistor	Silicon	2N1132
R ₈	Resistor	56	1/2	Q ₅	Transistor	Silicon	2N1647
R ₉ & R ₁₀	Resistor	1000	1/2	Q ₆ & Q ₇	Transistor	Silicon	2N1209
R ₁₁	Resistor	100	1/2	CR ₁ , CR ₂ , CR ₃ & CR ₄	Diode rect		1N538
R ₁₂	Resistor	820	1/2	Z ₁	Zener diode		1N2870
R ₁₃	Resistor	510	1/2	Z ₂	Zener diode		1N429
R ₁₄	Resistor	22	1/2	C ₁ & C ₂	Capacitor		100 μ fd
R ₁₈	Resistor	30	1/2				
R ₁₅	Resistor	10	1/2				

Fig. 5. Regulator

Components

SLT-1	Saturable transformer	SLT-620306
T-1	Power transformer	T-620307
Q ₈ & Q ₉	Transistor	2N1559
Q ₁₀ & Q ₁₁	Transistor	2N1362
R ₁₈ & R ₁₉	Resistor	10 ohms, 1/2 watt
R ₂₀	Resistor	316 ohms, 1/2 watt
C ₃	Capacitor	2000 μ f, 50-v dc

Fig. 6. Converter

6. SNAP 7B Parametric Tests

The beginning-of-life parametric curve was established during this quarter, with the remainder of the parametric testing scheduled for August. The data that have been accumulated are for the generator at maximum input power and filled with helium. These data indicate that the SNAP 7B characteristics and fuel loading will be nearly identical to the SNAP 7D generator.