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Gulf General Atomic
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AEC RESEARCH AND
DEVELOPMENT REPORT

GA-9763
UC-33 Propulsion
Systems and Energy
Conversion

SNAP-15A THERMOELECTRIC GENERATOR

SUMMARY REPORT

July 1, 1968 through June 30, 1969

Prepared under
Contract AT(04-3)-167
Project Agreement No. 21
for the
San Francisco Operations Office
U.S. Atomic Energy Commission

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for Federal Scientific and Technical Information National Bureau of
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Price: Printed Copy \$3.00; Microfiche \$0.65.

Gulf General Atomic Incorporated

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1. ABSTRACT

This report summarizes the activities of the SNAP-15A testing program for the period July 1968 through June 1969. During this period twenty five generators were continued on life testing and the data analyzed for performance summary. Also one of the generators with more than 5 years life time was removed from test and examined for compatibility evaluation.

Examination of the interior components of the generator shows that they were in excellent condition even though they had operated in air for over 4 years. The changes in performance of all the generators due to causes other than fuel depletion has been less than 1% per 10,000 hours.

The program is being continued at Gulf General Atomic expense through Fiscal Year 1970 as a life testing program for the remaining twenty-four generators. Several electrically heated generators will have exceeded 5 year lifetime at the end of FY 70.

2. INTRODUCTION

This report summarizes the past year's progress on a program to develop the SNAP-15A generator, a Pu-238, fueled, metal thermocouple generator capable of producing about 1 milliwatt of output power at greater than 4.5 volts at high reliability under extreme environmental conditions. The specified environmental conditions include an ambient temperature operating range of + 165°F to - 65°F, with thermal cycling through this range. The dynamic environment included vibration at 10 g from 10 cps to 2000 cps, constant acceleration at 60 g for 5 minutes and mechanical shock of 100 g for 11 millisecc for all 3 orthogonal axes.

During the first several years of the program, 32 generators were fabricated, and over 1,100,000 total test hours have now been accumulated. During the development phase it was discovered that a more reliable hermetic seal was needed for containment, and that the method of fabrication of thermocouple junctions needed upgrading for reliability. A development program was then conducted which resulted in 1) an all welded and brazed stainless steel hermetically sealed container; 2) two reliable methods of fabrication of thermocouple junctions by dip brazing or electrolytic nickel plating; and 3) a fabrication method for winding of wire thermocouple bundles to achieve complete parallel redundancy of all 1300 thermocouple junctions. During a subsequent phase, 12 generators were fabricated with the upgraded cannister design. Several of these generators developed leaks in a solder joint between the electrical output connector and the containment. A method of sealing these leaks and strengthening this joint was developed and proven by mechanical testing. The environmental performance and life testing of these generators was then initiated and is still in progress. The evaluation of long life generators has been initiated. All of the electrically heated prototype generators have operated continuously for more than 5 years. During FY 70 many nuclear heated generators will pass the 5 year lifetime goal.

3. TESTING

3.1 SUMMARY

A total of 24 generators remained on room ambient life testing during the entire report period of July 1, 1968 through June 30, 1969. Of these generators, 19 were fueled with Pu-238 and five were electrically heated. No generators have failed during the report period. A summary of accumulated test hours for all generators is given in Table I. There was no dynamic testing conducted during the report period. All generators were monitored regularly and the performance data was recorded and reported monthly.

3.1.1 Experimental Generators

Three electrically heated experimental generators remained on room ambient life test. Each of these generators has passed five and one-half years operation in air without failure. Accumulated hours for these generators are listed in Table II.

3.1.2 Demonstration Generators

Three prototype demonstration generators were maintained on room ambient life test and monitored regularly. An electrical heater failed in generator number 7 in February. A new heater was installed in the generator and testing was continued on this unit. The heater consists of a 2,000 Ω , 2-watt resistor which operates at $\sim 400^{\circ}\text{F}$. This was the first failure of an electrical heater. In July, generator number 8 was removed from test and delivered to the materials evaluation group for disassembly according to an approved plan. At the time of termination, this generator had accumulated 48,833 hours without failure. The two remaining demonstration generators, number 6 and 7 will remain on test and will continue to be reported periodically. The accumulated test times on these generators are presented in Table II.

TABLE I GENERATOR LIFE TEST SUMMARY

Accumulated Life Test Hours

7/25/69

TYPE	TESTS TERMINATED (HOURS)	TESTS CONTINUING (HOURS)	TOTALS FOR ALL TESTS
Experimental	5,088	153,240	158,328
Demonstration	48,833	97,459	146,292
Prototype Fueled and Electrical	<u>214,223</u>	<u>602,575</u>	<u>816,798</u>
TOTALS	268, 144	853,274	1,121,418

PROTOTYPE GENERATOR LIFE TEST SUMMARY

AMBIENT TEMPERATURE °F	ELECTRICALLY HEATED		PLUTONIUM HEATED	
	ACCUMULATED TEST HOURS	MAXIMUM TEST HOURS (SINGLE GENERATOR)	ACCUMULATED TEST HOURS	MAXIMUM TEST HOURS (SINGLE GENERATOR)
-65	2,564	2,459	46,487	8,694
Room	17,700	4,108	488,343	45,003
165	4,078	3,627	26,348	13,599
Cycling	—		<u>17,055</u>	13,599
TOTALS	24,342		578,233	

TABLE II LIFE TEST TIMES ON EXPERIMENTAL AND
DEMONSTRATION GENERATORS

7/25/69

Electrically Heated Experimental Generators

<u>Serial No.</u>	<u>Test Times (Hours)</u>
3	51,376
4	51,067
5	50,797
TOTAL	153,240

Electrically Heated Demonstration Generators

<u>Serial No.</u>	<u>Test Times (Hours)</u>
6	49,766
7	47,693
TOTAL	97,459

3.1.3 Pu-238 Fueled Generators

For the period July 1, 1968 through June 30, 1969, 21 Plutonium fueled generators remained at Gulf General Atomic, Incorporated. Of these, 19 were on room ambient life testing over the entire period. Generators 103 and 104, which were reported in the last annual summary to have failed during vibration testing, remained fueled, but were removed from testing and reporting. The accumulated life test hours of the generators currently on test are listed in Table III, their life performance test plots are presented in Figures 1 through 19.

3.2 EVALUATION OF DATA

The total hours (fueled and electrically heated) and the hours on test under each ambient condition for the generators under test are given in Table IV. The data on those generators removed from test are presented in Table V. Table VI summarizes the hours on test under each ambient condition for all generators which have been electrically heated at least once during the test program.

For evaluation of this data, the generators are separated into two groups for better comparison of performance and for more effective interpretation of changes in operating levels. One group, generators 14, 15, 22, 26, 101 and 111, are known to be operating with air in the body cavity, the Argon having diffused through large leaks in the cannister seal. These generators are listed in Table VII and their life performance data plots are presented referenced to start of life performance with air backfill. The remaining 13 generators are operating with Argon remaining in the cannister but with known leaks. The latest leak rate data on these generators are presented in Table VIII. Life performance data are tabulated in Table IX. The life performance data plots reflect a comparison to initial operation with Argon backfill. Thus, one is able to assess performance changes related to fuel depletion, Argon displacement with time, leak rate, and changes in resistance. Of the factors affecting power output, the displacement of the Argon is the most significant. Complete displacement results in a power loss of approximately 25%. The effect of fuel depletion is a continuing one, but only on the order of approximately 0.6% per 10,000 hours of operation.

TABLE III GENERATOR PERFORMANCE SUMMARY

7/25/69

Gen. No.	Test (1) Hours	R _i (2) KΩ Fab.	R _i (3) KΩ Initial	R _i (4) Now	% R _i (5) Change	V _o (3) Volts Initial	V _o (4) Volts Now	% V _o (5) Ch Change	V _L (3) Volts Initial	V _L (4) Volts Now	% V _L (5) Change	P _o (3) MW Initial	P _o (4) MW Now	% P _o (5) Change	(6) Remarks
14	40806	9.15	8.96	9.19	3	6.89	6.79	- 1	4.93	4.82	- 2	1.08	1.03	- 4	Ref. air data
15	45003	8.50	8.70	8.66	0	6.59	6.37	- 3	4.76	4.60	- 3	1.00	0.94	- 6	Ref. air data
19	41124	8.47	8.74	8.65	- 1	7.62	7.20	- 5	5.49	5.20	- 5	1.34	1.20	-10	Ref. argon data
20	41235	8.55	8.74	8.65	- 1	7.97	7.38	- 7	5.74	5.33	- 7	1.46	1.26	-14	Ref. argon data
22	41131	8.65	8.84	8.74	0	6.84	6.72	- 2	4.92	4.84	- 1	1.08	1.04	- 3	Ref. air data
26	41239	8.72	8.93	8.87	- 1	7.19	6.93	- 4	5.15	4.97	- 5	1.18	1.10	- 6	Ref. air data
29	41071	9.14	9.53	9.30	- 2	7.87	7.35	- 6	5.53	5.20	- 6	1.36	1.20	-11	Ref. argon data
30	40765	8.57	8.84	8.74	- 1	8.00	7.58	- 5	5.75	5.46	- 5	1.47	1.33	- 9	Ref. argon data
31	41093	8.61	8.77	8.79	0	8.06	7.65	- 5	5.80	5.50	- 5	1.49	1.34	-10	Ref. argon data
32	41067	8.44	8.62	8.57	- 1	7.95	7.54	- 5	5.75	5.46	- 5	1.46	1.33	- 9	Ref. argon data
101	22746	8.48	8.72	8.35	- 4	6.80	6.50	- 4	4.90	4.74	- 3	1.07	0.99	- 6	Ref. air data
105	18548	8.64	8.87	8.34	- 6	7.32	6.77	- 7	5.25	4.94	- 6	1.22	1.08	-11	Ref. argon data
106	18515	8.61	8.83	8.33	- 6	7.84	6.96	-11	5.63	5.08	-10	1.40	1.15	-18	Ref. argon data
107	18491	8.54	8.76	8.66	- 1	6.96	6.87	- 1	5.01	4.96	- 1	1.11	1.09	- 2	Ref. argon data
108	18395	8.65	8.86	8.83	0	7.29	7.24	0	5.23	5.20	0	1.21	1.20	0	Ref. argon data
109	17760	8.54	8.73	8.69	0	7.01	6.82	- 2	5.05	4.92	- 2	1.13	1.08	- 5	Ref. argon data
110	17736	8.60	8.79	8.86	1	7.51	7.40	- 1	5.40	5.31	- 1	1.29	1.25	- 3	Ref. argon data
111	13820	8.64	8.86	8.76	- 1	6.30	6.13	- 3	4.52	4.41	- 2	0.91	0.86	- 5	Ref. air data
112	17688	8.59	8.81	8.79	0	6.86	6.73	- 2	4.93	4.84	- 2	1.08	1.04	- 3	Ref. argon data

- Notes: (1) Total accumulated operational hours with PU-238 source.
 (2) Internal resistance in ohms of the generator immediately after fabrication. Measured at room temperature
 (3) Internal resistance, open circuit voltage, load voltage, and power output determined at steady-state gradient operation following fueling with PU.
 (4) Internal resistance, open circuit voltage, load voltage, and power output determined at the end of the current report period.
 (5) Internal resistance, open circuit voltage, load voltage, and power output change from start to fueled life test.
 (6) Notes on present status of the generators.

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with air

Fig. 1 SNAP-15A Generator No. 14

NOTE: 1. Ambient temperature 76°F
2. Generator backfilled with air

Fig. 2 SNAP-15A Generator No. 15

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 3 SNAP-15A Generator No. 19

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 4 SNAP-15A Generator No. 20

NOTE: 1. Ambient temperature 76°F
2. Generator backfilled with air

Fig. 5 SNAP-15A Generator No. 22

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with air

Fig. 6 SNAP-15A Generator No. 26

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 7 SNAP-15A Generator No. 29

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 8 SNAP-15A Generator No. 30

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 9 SNAP-15A Generator No. 31

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 10 SNAP-15A Generator No. 32

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with air

Fig. 11 SNAP-15A Generator No. 101

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 12 SNAP-15A Generator No. 105

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 13 SNAP-15A Generator No. 106

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 14 SNAP-15A Generator No. 107

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 15 SNAP-15A Generator No. 108

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 16 SNAP-15A Generator No. 109

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 17 SNAP-15A Generator No. 110

- NOTE: 1. Ambient temperature 76°C
 2. Generator backfilled with air

Fig. 18 SNAP-15A Generator No. 111

NOTE: 1. Ambient temperature 76°F
 2. Generator backfilled with argon

Fig. 19 SNAP-15A Generator No. 112

TABLE IV TIME AND TEMPERATURE DISTRIBUTION ON SNAP-15A
FUELED GENERATORS ON TEST

7/25/69

Generator Number	-65°F	Room Temp.	165°F	Thermal Cycling	Total Fueled Test Time Hours	Total Elect. Test Hours	Cumulative Total	
14	8694	32100	12		40806	4815	45621	
15	5420	39571	12		45003	1195	46198	
19	8694	32418	12		41124	4132	45256	
20	23	27613	13599		41235	4059	45294	
22	8694	32425	12		41131	3787	44918	
26	0	27640	0	13,599	41239	2853	44092	
29	12	32053	9006		41071	1222	42293	
30	8694	32059	12		40765	1470	42235	
31	1869	39212	12		41093	339	41432	
32	1869	39186	12		41067	470	41537	
101	12	22722	12		22746	0	22746	
105	16	17996	8	528	18548	0	18548	
106	16	17963	8	528	18515	0	18515	
107	16	16790	1205	480	18491	0	18491	
108	16	16694	1205	480	18395	0	18395	
109	16	16059	1205	480	17760	0	17760	
110	1213	16035	8	480	17736	0	17736	
111	0	13820	0	0	13820	0	13820	
112	1213	15987	8	480	17688	0	17688	
Total	19	46,487	488,343	26,348	17,055	578,233	24,342	602,575

TABLE V TIME AND TEMPERATURE DISTRIBUTION OF SNAP-15A
FUELED GENERATORS REMOVED FROM TEST

<u>Generator Number</u>	<u>-65°F</u>	<u>Room Temp.</u>	<u>165°F</u>	<u>Thermal Cycling</u>	<u>Total Fueled Test Time Hours</u>	<u>Electrically Heated Test Hours</u>	<u>Cumulative Total Test Time</u>
9	6076	12206	9006		27,288	1992	29,280
11	0	27996	0		27,996	1443	29,439
13	5739	21216	12		26,967	2085	29,052
16	12	7210	9006		16,228	27,862*	44,090
17	21	1011	4970		6,002	211	6,213
18	396	18054	9006		27,456	44	27,500
23	0	220	570		790	3,610	4,400
24	0	261	570		831	3,610	4,441
25	0	261	570		831	3,611	4,442
27	0	3554	0	13,599	17,153	2,179	19,332
28	0	261	570		831	2,546	3,377
102	12	53	12		77	0	77
103	16	6254	8	48	6,326	0	6,326
104	16	6182	8	48	6,254	0	6,254
TOTALS	12,288	104,739	34308	13,695	165,030	49,193	214,223

* Electrically heated generator No. 16 is currently operating at the Gulf General Atomic office in Washington, D.C..

TABLE VI TIME AND TEMPERATURE DISTRIBUTION OF ELECTRICALLY
HEATED SNAP-15A GENERATORS

<u>Generator Number</u>	<u>-65°F</u>	<u>Room Temperature</u>	<u>+165°F</u>	<u>Total Hours</u>
8	4	48825	4	48833
9	936	1047	9	1992
11	432	987	24	1433
13	648	1347	88	2085
16	17	27766	79	27862
17	32	163	16	211
18	16	20	8	44
23	16	132	3462	3610
24	16	167	3427	3610
25	16	245	3350	3610
27	16	2156	7	2179
28	16	5	2525	2546
	<u>2,165</u>	<u>82,862</u>	<u>12,999</u>	<u>98,026</u>

Generators Currently on Fueled Life Test

14	18	1170	3627	4815
15	16	1089	90	1195
19	16	4108	8	4132
20	17	4034	8	4059
22	17	3762	8	3787
26	2459	269	125	2853
29	7	1199	16	1222
30	5	1297	168	1470
31	4	331	4	339
32	5	441	24	470
	<u>2,564</u>	<u>17,700</u>	<u>4,078</u>	<u>24,342</u>

Total Electrical Life Test Hours

122,368

TABLE VII FUELED GENERATORS REFERENCED TO
INITIAL AIR OPERATION

Generator Number	Test Hours	Observed Power Output Changes (%)			Non-Fuel Causes per 10,000 hrs. %
		Due to Fuel Depletion %	Other Causes %	Total Power Output Change %	
14	40806	- 2.6	- 1.8	- 4.4	- 0.45
15	45003	- 2.8	- 3.8	- 6.6	- 0.86
22	41131	- 2.6	- 0.6	- 3.2	- .15
26	41239	- 2.6	- 3.3	- 5.9	- .80
101	22746	- 1.4	- 5.0	- 6.4	-2.20
111	13820	- 0.8	- 4.0	- 4.8	-2.86

TABLE VIII MEASURED LEAK RATES ON FUELED GENERATORS
REFERENCED TO ARGON

<u>Generator Number</u>	<u>Leak Rate Std. cc/sec. Argon</u>	<u>Test Time</u>	<u>Remarks</u>
19	$< 1 \times 10^{-9}$	41124	Argon depletion not completed
20	$< 1 \times 10^{-9}$	41235	Argon depletion not completed
29	$< 1 \times 10^{-9}$	41071	Argon depletion not completed
30	$< 1 \times 10^{-9}$	40765	Argon depletion not completed
31	$< 1 \times 10^{-9}$	41093	Argon depletion not completed
32	3×10^{-9}	41067	Argon depletion not completed
105	$< 1 \times 10^{-9}$	18548	Argon depletion not completed
106	3×10^{-9}	18515	Argon depletion not completed
107	$< 1 \times 10^{-9}$	18491	Argon depletion not completed
108	3×10^{-9}	18395	Argon depletion not completed
109	$< 1 \times 10^{-9}$	17760	Argon depletion not completed
110	7×10^{-7}	17736	Argon depletion not completed
112	$< 1 \times 10^{-7}$	17688	Argon depletion not completed

TABLE IX FUELED GENERATORS REFERENCED TO INITIAL ARGON OPERATION

<u>Generator Number</u>	<u>Test Hours</u>	<u>Observed Power Output Changes (%)</u>			<u>Non-Fuel Causes per 10,000 hrs. %</u>	<u>Remarks</u>
		<u>Due to Fuel Depletion %</u>	<u>Other Causes %</u>	<u>Total Change %</u>		
19	41124	- 2.6	- 7.7	-10.3	- 1.9	Leaking - 1% Resistance Decrease
20	41235	- 2.6	-11.2	-13.8	- 2.8	Leaking - 1% Resistance Decrease
29	41071	- 2.6	- 8.9	-11.5	- 2.2	Leaking - 2% Resistance Decrease
30	40765	- 2.6	- 6.9	- 9.4	- 1.7	Leaking - 1% Resistance Decrease
31	41093	- 2.6	- 7.5	-10.1	- 1.8	Leaking - 1% Resistance Decrease
32	41067	- 2.6	- 7.2	- 9.8	- 1.8	Leaking - 1% Resistance Decrease
105	18548	- 1.2	-10.3	-11.5	- 5.0	Leaking - 6% Resistance Decrease Thermopile shorts
106	18515	- 1.2	-17.3	-18.5	- 8.5	Leaking - 6% Resistance Decrease Thermopile shorts
107	18491	- 1.2	- 0.7	- 1.9	0.3	Leaking - No Resistance Change
108	18395	- 1.2	+ 0.1	- 1.1	.05	Leaking - No Resistance Change
109	17760	- 1.1	- 3.9	- 5.0	- 1.9	Leaking - No Resistance Change
110	17736	- 1.1	- 2.2	- 3.3	- 1.1	Leaking - No Resistance Change
112	17688	- 1.1	- 2.5	- 3.6	- 1.2	Leaking - No Resistance Change

For those generators with air backfill, changes in power output as a result of causes other than fuel depletion is less than 1% per 10,000 hours. Generator 101 shows a slightly higher rate of degradation, but shows a greater change in resistance indicating that there are possibly electrical problems within the thermopile. Although generator 111 does not show a significant change in internal resistance, the change in power output is about the same as for generator 101. This can be explained since the circuitry is series-parallel where combinations of opens and shorts can produce no net change in internal resistance.

Generators 105 and 106 have experienced the greatest change in power output due to possible thermopile damage during vibration testing conducted during the previous report period.⁽¹⁾ The Argon backfilled generators all show a considerably higher total change in power output as a result of gradual air diffusion into the cannister.

4. GENERATOR EVALUATION

4.1 SUMMARY

A SNAP-15A thermoelectric generator which had operated satisfactorily for a period of six years was examined for signs of deterioration and no signs of adverse behavior were observed. This particular generator used an internal electrical heater, powered by an external source, for maintaining the hot junction at 390°F. This generator contained 26 thermobundles with 25 thermocouples in series in each thermobundle, resulting in 650 thermocouples in series. There are two series circuits of thermocouples connected in parallel at each thermobundle junction for a total of 1300 thermocouples in a thermopile.

The examination of the unit consisted of removing the outer aluminum can and the thermal insulation thereby exposing the thermopile for closer examination. After removing several thermobundles, the thermopile was mounted and sectioned at discreet places for microscopic examination. In particular, the following features were examined.

4.1.1 Individual Thermobundles

The condition of the RTV insulation on the removed thermobundles was visually examined and voltage breakdown tests were conducted of the wires through the ML varnish and RTV insulation.

4.1.2 Individual Wires

A sample of RTV was removed from a thermobundle and the thermocouple wires were examined to observe any surface discoloration of the ML varnish insulation. Voltage breakdown tests of the individual wires and the ML varnish were performed.

4.1.3 Cross Sections of Thermopile

The cross sections of the thermopile were examined microscopically for evidence of microcracks or spalling of the RTV insulation and possible

reactions between the braze and the RTV in the hot junction area.

4.2 METHODS AND PROCEDURES

A jewelers saw was used to cut open the outer aluminum can and expose the thermal insulation (Fig. 20). The electrical heater was bonded to the hot junction of the thermopile and couldn't be removed at this initial stage. The insulation between the heater wires and the top of the outer can was removed carefully to avoid damaging the hot junctions. After removing the thermal insulation, the thermopile was exposed for examination (Fig. 21).

Six thermobundles from the thermopile were removed for observations and voltage breakdown studies. Using the technique shown in Fig. 22, the voltage breakdown of the thermobundle through the ML and RTV insulation was determined. Individual thermocouple wires were removed from the thermobundle for visual observations and the voltage breakdown through the ML insulation was determined.

For microscopic examination, the rest of the thermopile was mounted and sectioned at three locations. The sections are near the hot junction, in the center of the thermopile and near the cold junction (Fig. 23). A jewelers saw was used for initial cuts through the mounted thermopile, but it was necessary to remount these individual sections prior to a final polishing due to the elasticity of the RTV insulation.

4.3 RESULTS

4.3.1 Thermobundles

The RTV insulation around each thermobundle that was checked showed no detectable signs of having degraded elastically. These checks consisted of probing the material with a pair of fine tweezers and comparing it to new material. Table X shows the results of the voltage breakdown of the wires through the ML varnish of the wires and the RTV insulation of the thermobundle. The value for the voltage breakdown is an average for approximately six times. Sometimes the first or first few breakdowns were higher in value than the successive ones, and this value is given together with the steady state value.

Fig. 20 SNAP-15A generator after removal of
container from thermopile - insulation
assembly

Fig. 21 SNAP-15A generator components after disassembly (operating time > 48,000 hours)

Fig. 22 Method for determining voltage breakdown of thermobundle or individual thermocouple wire

Fig. 23 Sections of thermopile examined

TABLE X VOLTAGE BREAKDOWN OF WIRES THROUGH
ML VARNISH AND RTV OF THERMOBUNDLE

SAMPLE	V BREAKDOWN (kv)
1	4.0
2	2.3
3	3.0 - 2.6
4	2.5
5	4.0 - 3.5
6	3.5

NOTE: When two (2) values are given, first no. represents initial value, second no. represents steady state average for approximately six (6) voltage breakdown cycles.

4.3.2 Individual Wires

Examination of the individual wires revealed little, if any at all, change in the color of the ML varnish. Table XI shows the results of the voltage breakdown obtained from five wire specimens. As with the previous results in Table X, if the first or first few values for breakdown were higher than the steady state value, both values are given. As seen from Table XI, several wires had rather high initial breakdown values.

4.3.3 Cross Sections of Thermopile

The thermopile was mounted and polished and examined metallographically. In all cases, the braze between the wire showed no degradation nor did it exhibit any attack beyond the initial braze on the cupron or tophel special wires. Figures 24 and 25 show typical hot junction braze joints in the thermopile. The RTV-60 surrounding each couple also showed no degradation and Fig. 25 shows several of these couples in the RTV-60 matrix.

TABLE XI VOLTAGE BREAKDOWN OF INDIVIDUAL WIRES WITH ML VARNISH

SAMPLE	V BREAKDOWN (kv)
1	1.1
2	1.1
3	0.75
4	4.0 - 0.4
5	2.0 - 0.6

NOTE: When two (2) values are given, first no. represents initial value, second no. represents steady state average for approximately six (6) voltage breakdown cycles.

Fig. 24 Brazed hot junctions of SNAP 15A generator after operation > 48,000 hours

Fig. 25 Several brazed hot junctions of SNAP 15A generator separated by RTV-60 after operation > 48,000 hours

REFERENCES

1. SNAP-15A Thermoelectric Generator Summary Report July 1, 1967 through June 30, 1968, U. S. Atomic Energy Commission Report GA-8821, Gulf General Atomic (Sept. 3, 1968).