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SNAP-23A PROGRAM POST-TEST ANALYSIS PLAN AND REPORT

VOLUME I
ANALYSIS PLAN

MASTER

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Report No. MMM 3824-0002

AEC RESEARCH AND DEVELOPMENT REPORT**SNAP-23A PROGRAM
POST-TEST ANALYSIS PLAN AND REPORT****VOLUME I
ANALYSIS PLAN****NOVEMBER 1967**

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FOREWORD

The following document reports the plan for and work conducted under the SNAP-23A Program, Task III, SNAP-23 post-test analysis effort. The report consists of two volumes. Volume I contains the post-test analysis plan and Volume II contains the report of the post-test analysis disassembly, observations, results and conclusions drawn from the results.

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1.0 GENERAL INFORMATION

1.1 SCOPE

The SNAP-23 six-couple Module A-2 and 252-couple prototype Converter P-1 will be disassembled for post-test analysis. All components will be inspected and/or analyzed to determine any change in the thermoelectric materials or other components. These two units were selected because:

- Converter P-1 has been held at design temperature throughout its entire test life, whereas, Converter P-2 has been tested at considerably lower temperatures. Any temperature dependent effects should be much more in evidence in Converter P-1 than in Converter P-2.
- Module A-2 has experienced large voltage and resistance changes. The causes of these changes should be more evident in Module A-2 than in Module A-3.

The post-test examination will be conducted in accordance with Section 2.3 of the SNAP-23A Phase I Proposed Program Plan, Volume II, Revision 2, Report No. 3M-39-IPP-42, dated 27 January 1967.

The post-test examination of the converter and module will include the following:

- Catalog and evaluate the pre-test data on the history of the components in the converter and module. This would include all Quality Control data, processing data, and the physical, thermoelectric, and chemical analysis of any residual thermoelectric

legs from the same lot and batch used in the converter and module. The pre-test data will be compared with test data and post-test data so that valid conclusions can be drawn.

- During the disassembly and post-test examination, the majority of the inspections and analyses of the converter and module will be conducted on thermoelectric couples and adjacent components which have the most complete pre-test and test history.
- The pre-test, test, and post-test data will be compiled and correlated. All conclusions and supporting data will be included in a final test report.

1.2 OBJECTIVE

The post-test examination will attempt to establish potential failure or degrading mechanisms within the converter and module.

Several of the problem areas listed in Section 2.3 of Volume No. 1 of the Proposed Program Plan will be examined closely. The principal areas of investigation will be:

- Thermoelectric N- and P-leg performance changes (changes in resistivity and Seebeck coefficient)
- P-type thermoelectric leg-hot junction electrical contact (resistance)
- Metallurgical changes within the P-N thermoelectric couple hardware
- Cold end thermal impedance
- Changes in gas environment
- Chemical and physical changes in the internal thermal insulation.

In addition, several second order problem areas will be investigated. These include:

- Long-term hot junction temperature measurement (determination of iron-constantan thermocouple degradation)
- Electric feedthrus (gas leakage, resistance)
- Follower seizing within the cold frame.

2.0 APPLICABLE DOCUMENTS

This section contains assembly drawings for Converter P-1 and Module A-2, and the titles and numbers of pertinent specifications and publications which will be used to conduct the post-test examination.

2.1 APPLICABLE DRAWINGS

Figure 2-1 shows the assembly drawing of prototype Converter P-1. Figure 2-2 shows the assembly drawing of Module A-2.

2.2 APPLICABLE SPECIFICATIONS

Table 2-1 lists the inspection and operation specifications to be used in the post-test examinations. These specifications are contained in the Appendix.

Table 2-1. Inspection (TPI) and Operation (TPO) Specifications

Specification No.	Title
TPI-1	R vs L - Resistivity Measuring Method
TPI-2	Seebeck Voltage (emf) and Seebeck Coefficient Measuring Method
TPI-11	Mass Spectrometer Leak Detector Operation and Testing
TPO-110	Electrical Continuity Check of a Cold Test Module

Figure 2-1. Assembly - Thermoelectric Converter

Item	BM	Drwg. No.	Req'd.	Mat'l.	Com'l.	Name
0	C	PD-39-2015A				ASSEMBLY - 6-COUPLE MODULE
1	B	PD-39-2012A	6			COLD CAP - "P"
2	B	PD-37-2027A	6			HOT SHOE - STRAP
3	B	PD-37-2028A	1			HEATER BLOCK
4	B	PD-39-2013	6			COLD CAP - "N"
5	A	PD-37-2010A	1			LEG PLUG FITTING
6	A	PD-37-2011A	12			FOLLOWER
7	C	PD-37-2012A	1			COLD JUNCTION PLATE
8	C	PD-37-2013A	1			INSULATION HOUSING
9	C	PD-37-2014A	1			BASE PLATE
10	B	PD-37-2015A	1			CENTER POST
11	C	PD-37-2016A	1			HEAT EXCHANGER
12	A	PD-37-2017A	1			INSULATOR, HEATER BLOCK
13	B	PD-37-2019A	1			HOUSING COVER
14	B	PD-37-1094-1	12			HOT JUNCTION BUTTON
15	A	PD-37-2031A	12			SPRING-FOLLOWER
16	A	PD-37-2021A	1			INSULATION (C)
17	B	PD-37-2022A	1			INSULATION (B)
18	B	PD-37-2023A	1			INSULATION (A)
19	C	PD-37-2024A	1			ELECTRICAL PANEL
20	B	PD-37-2025A	2			SIDE BRACKET
21	B	PD-37-2026A	1			BOTTOM BRACKET
22	B	PD-39-1051A	6			SEGMENTED LEG "P" TYPE
23	B	PD-39-1049A	6			SEGMENTED LEG "N" TYPE
24			1	STL	*	NUT 10-32
25			4	STL	*	CAP SCR. 5/16-18 x 1-1/2 LG.
26			4	STL	*	CAP SCR. 1/4-20 x 1-1/2 LG.
27			1		*	FITTING, TUBE
28			2	STL	*	FLT. HD. MACH. SCR. 5/16-18 x 1/2 LG.
29	C	PD-39-2014A	1			COLD SIDE HEATER BLOCK
30			13		*	BINDING POST-DUAL 269 BB H.H. SMITH COMPANY
31			2		*	HEATER-100W WATCO
32			4		*	SCR. RND HD. 6-32 x 3/8 LG.
33			4		*	NUT, 6-32
34			12	STL	*	TRU-ARC SNAP RING
35	A	PD-37-2029A	12			SPRING INSULATOR
36			12	STL	*	WASHER 0.020 THK. (TO FIT)
37			4	STL	*	WASHER 0.062 THK. x 7/16 DIA.
38			4	STL	*	SCREW, R.H. 6-32 x 1/4 LG.
39			1		*	TOGGLE SWITCH
40	B	PD-37-2020A	1			HOUSING TUBE
41	A	PD-37-2033-A	12			SPRING INSULATOR - SMALL

Figure 2-2. Assembly - Six-Couple Module A-2

2.3 APPLICABLE PUBLICATIONS

Refer to:

- SNAP-23A Phase I, Proposed Program Plan, Volumes I and II, Revision 2, Report No. 3M-39-IPP-42, dated 27 January 1967 (limited distribution).
- SNAP-23 Program, Terrestrial Radioisotope Thermoelectric Power Supply System, Parametric Study Thermoelectric Converter, Report No. MMM-3418-33, dated 20 December 1966.

3.0 DESCRIPTION OF SPECIMEN

This section contains physical descriptions of prototype Converter P-1 and Module A-2, including performance.

3.1 PHYSICAL DESCRIPTION

3.1.1 PROTOTYPE CONVERTER P-1 (Refer to Figures 2-1 and 3-1)

Prototype Converter P-1 consists of 252 couples, connected in series, through 1020 ~~stainless steel~~ steel hot electrode caps and iron-plated copper hot shoes at the hot end, and nickel-plated copper cold caps and jumper wires at the cold end. The thermopile is designed in a cylindrical configuration with the thermoelectric legs positioned between two concentric cylinders. The thermoelectric couples utilize pressure contacts at the hot electrode caps. This pressure contact is provided by a spring and follower arrangement from the cold cap into the aluminum outer cylinder cold frame. The inner cylinder hot frame and converter outer case are constructed of 304 stainless steel. Hot side electrical insulation is boron nitride; internal thermal insulation is powdered Min-K 1301. The followers are aluminum with a hard coat of aluminum oxide. The converter is hermetically sealed and backfilled with xenon gas. The heat required to operate the converter is generated from within a copper accumulator located inside the inner hot frame cylinder. Refer to Figure 2-1.

3.1.2 MODULE A-2 (Refer to Figures 2-2 and 3-2)

The SNAP-23 Module A-2 consists of six thermoelectric couples, connected in series, using the same type of electrode hardware as does the converter. The thermopile is in a parallel plate hot frame-cold frame configuration. The springs, followers, electrical insulation, internal thermal insulation, hot frame, cold frame, and internal atmosphere are of the same material as that used in the converter. Refer to Figure 2-2.

3.2 PERFORMANCE HISTORY

This section contains a discussion of the performance of prototype Converter P-1 and Module A-2. It is necessary to carefully evaluate the performance of the converter and module prior to their disassembly for two reasons:

- 1) Performance data will be correlated with post-test data so that valid conclusions can be drawn.
- 2) Problem areas identified during the converter and module test operations will be examined closely in the post-test examination.

The data for Converter P-1 and Module A-2 are summarized in Figures 3-3, 3-4 and Tables 3-1 and 3-2.

In these tables and graphs, the following nomenclature is used:

- Th - Average hot electrode temperature ($^{\circ}\text{F}$)
- Tc - Average cold electrode temperature ($^{\circ}\text{F}$)
- Ex - Experimental open circuit voltage (volt)
- Ix - Experimental load current (amps)
- Rx - Experimental internal resistance (ohms)
- Px - Experimental power to load (watts)
- Pi - Input power to hot block (watts)

Figure 3-1. Converter P-1

Figure 3-2. Module A-2

3.2.1 PROTOTYPE CONVERTER P-1 (Refer to Table 3-1 and Figure 3-3)

After an initial 1000-hour "settling-in period", the electrical performance of Converter P-1 has been very stable. The output power decreased during the first 1000 hours. The initial power decrease is suspected to be caused by an increase in contact resistance at the hot end of the P legs.

Converter P-1 has required a gradual increase in input power (increased from approximately 1000 watts to 1070 watts) to maintain constant hot electrode temperatures.

3.2.2 MODULE A-2 (Refer to Table 3-2 and Figures 3-4 and 3-5)

The electrical performance of Module A-2 was more unstable than that of Converter P-1. This may be due, in part, to a lower hot electrode contact pressure and a higher hot electrode temperature within Module A-2. (Module A-2 had 150 psi contact pressure compared with 250 psi for Converter P-1.)

Both the P and N legs, with their electrode hardware, have demonstrated performance instability during operation. Based on individual monitoring of two P legs and two N legs, the following comments can be made:

- The increase in power output during the first 3000 hours was due to a decrease in resistance within each of the P legs and their hot and cold electrode hardware. It is suspected that the resistance change occurred mainly at the hot electrode contacts.
- The Seebeck voltages of the P legs have, on the average, decreased approximately 11 millivolts during module operation. The Seebeck voltage change was probably caused by a physical or chemical change within the P legs. It is suspected that the resistivity of the P legs was also decreasing.
- The resistance of the N legs and their hot and cold electrode hardware has increased slowly after the initial 1000 hours of testing. The increase in resistance could be caused by an increase in contact resistance or an increase in N-leg resistivity.

NOMENCLATURE

P = Power Delivered to Load
 E = Open Circuit Voltage
 R = Internal Resistance

T_h Avg = 1070°F
 T_c Avg = 200°F

Figure 3-3. SNAP-23 Prototype Converter Performance (3M-39-P1) - Experimental Data

NOMENCLATURE

P = Power Delivered to Load
 E = Open Circuit Voltage
 R = Internal Resistance

T_h Avg = 1100°F
 T_c Avg = 190°F

Figure 3-4. SNAP-23 Performance Data - Module A-2

Figure 3-5. SNAP-23 Module A-2 N and P Leg Resistance

Table 3-1. SNAP-23 Converter P-1 Performance Data

Date	Hours	Th (°F)	Tc (°F)	Ex (volts)	Ix (amps)	Rx (ohms)	Px (watt)	Pi (watt)
6/22/65	29	1071	199	51.0	2.83	9.01	72.2	945
7/2/65	97	1073	207	50.8	2.78	9.10	70.3	1010
7/9/65	177	1076	205	51.1	2.72	9.37	69.4	----
7/22/65	484	1069	199	51.5	2.63	9.81	67.6	1036
8/2/65	749	1061	199	51.4	2.60	9.88	67.0	1030
8/31/65	1446	1066	200	52.0	2.62	9.92	68.2	1020
10/8/65	2363	1064	205	51.8	2.65	9.77	68.6	1020
11/22/65	3434	1063	203	51.6	2.69	9.59	69.4	1020
2/2/66	4356	1063	205	51.8	2.60	9.96	67.4	1000
2/28/66	5148	1068	206	51.9	2.66	9.76	69.0	1030
3/25/66	5504	----	---	----	----	----	----	----
5/16/66	6749	1071	218	50.8	2.65	9.59	67.3	1010
5/20/66	Converter turned off - moved to Space Center.							
10/28/66	Converter turned on.							
11/10/66	7180	1030 (est)	202	50.0	2.67	9.36	66.8	1080
1/14/67	8670	1040 (est)	209	50.0	2.69	9.30	67.3	1060
2/22/67	9600	1060 (est)	212	51.5	2.70	9.54	69.5	1070

Table 3-2. SNAP-23 Six-Couple Module A-2 Performance Data

Date	Hours	Th (°F)	Tc (°F)	Ex (volts)	Ix (amps)	Rx (ohms)	Px (watt)	Pi (watt)
3/12/65	72	1104	190	1.23	2.32	0.26	1.46	39.2
3/15/65	144	1104	191	1.23	2.37	0.25	1.51	39.0
3/24/65	360	1100	188	1.22	2.46	0.25	1.50	39.2
4/5/65	650	1103 est	190	1.23	2.54	0.24	1.59	39.8
4/16/65	910	1103 est	188	1.23	2.59	0.23	1.68	40.2
5/12/65	1,540	1100 est	189	1.22	2.62	0.22	1.69	41.0
6/3/65	2,040	1100 est	190	1.22	2.66	0.21	1.75	41.0
6/25/65	2,570	1100 est	193	1.22	2.73	0.21	1.73	41.0
7/16/65	3,080	1100 est	195	1.22	2.82	0.22	1.71	41.4
8/25/65	4,050	1100 est	192	1.21	2.54	0.22	1.68	41.0
10/8/65	5,110	1100 est	193	1.21	2.56	0.22	1.63	41.5
11/22/65	6,190	1100 est	193	1.21	2.51	0.23	1.57	41.5
12/30/65	7,090	1100 est	199	1.20	2.46	0.24	1.52	41.6
2/7/66	8,020	1100 est	192	1.19	2.43	0.24	1.49	41.6
3/31/66	9,280	1100 est	193	1.18	2.26	0.25	1.40	----
5/2/66	10,060	1090 est	191	1.17	2.30	0.25	1.39	----
6/17/66	11,160	1100 est	193	1.18	2.34	0.25	1.37	42.0
7/18/66	11,900	1100 est	196	1.18	2.37	0.25	1.39	41.5
8/25/66	12,820	1100 est	197	1.17	2.38	0.25	1.39	41.4
11/17/66	14,840	1100 est	199	1.16	2.31	0.25	1.31	42.0
2/20/67	17,110	1100 est	197	1.15	2.15	0.27	1.23	43.0

4.0 EQUIPMENT AND FACILITIES

4.1 TEST EQUIPMENT

The following test equipment will be used in the post-test examination:

- 1) Resistance versus length measuring apparatus (see TPI-1 included in the Appendix)
- 2) Seebeck measuring apparatus (see TPI-2 in Appendix)
- 3) Microprobe equipment (Material Analysis Corporation, Model #400)
- 4) Milliohm-meter (Keithly Model 503)
- 5) Mass-spectrometer leak detector (Veeco Model MS-9)
- 6) Metallographic equipment
- 7) Mass spectrograph (Consolidated Electrodynamics No. 21-103)

4.2 TEST FACILITIES

The test facilities to be used in the post-test analysis consist of those located in the 3M Isotope Power Project Laboratory and in the 3M Central Research Laboratory.

5.0 PROCEDURES AND DETAILS

During disassembly and post-test analysis, precautions will be taken to assure competent management of the prototype converters and modules. Section 6.2 (included in the Appendix) illustrates the flow of the units and the step-by-step responsibility of the functional groups.

The following is an outline of the procedures to be used for the post-test examination:

5.1 FINAL PERFORMANCE CHECK

Prior to turning off power to the converter and module, final data readings will be obtained.

5.2 GAS ANALYSIS

A gas sample will be taken from the converter and module after each has cooled to room temperature. It is necessary to cool the units to room temperature because of the possibility of accidentally puncturing the hermetic seal during the gas sampling procedure. The gas samples will be analyzed using a mass spectrograph. Gas samples will be taken at the following places:

- Base of Converter P-1
- Top of Module A-2

5.3 LEAK CHECK

(Refer to TPI-11 in Appendix.) After the gas analysis, the converter and module will be leak checked using a mass spectrometer leak detector. Particular emphasis will be placed in detecting leaks in the electrical feedthrus.

5.4 RESISTANCE CHECK

The electrical resistance of the converter and module circuit, and as many couples and legs as possible, will be measured, as follows (refer to TPO-110 in Appendix):

- Before converter and module disassembly
- Before thermal insulation removal
- After thermal insulation removal

Wherever possible, the interface resistances will be measured.

5.5 DISASSEMBLY PROCEDURE

This section describes the disassembly procedures for the P-1 converter and the A-2 module.

5.5.1 PROTOTYPE CONVERTER P-1

During disassembly of Converter P-1, detailed dimensional analyses will be performed. These analyses will be in accordance with procedures described in Section 6.3 of the Appendix.

The P-1 converter will be disassembled as follows:

- Remove outer thermal insulation.
- Remove converter from copper accumulator.
- Remove outer fins.

- Remove a portion of the converter outer case by cutting circumferentially at the points designated "cut #1 and cut #2" in Figure 2-1.
- Remove internal Min-K 1301. Several samples of Min-K 1301 will be saved for possible future analysis.
- Remove the remaining portions of the outer case by cutting circumferentially at points designated "cut #3 and cut #4". Also, make two cuts axially along the side of the converter.
- Mount the converter thermopile in the assembly fixture. The fixture will hold the inner and outer cylinders in a fixed position with respect to each other.
- Remove couples and adjacent electrode hardware from converter. The hot electrode contact pressure will be released from a row of P-N thermoelectric couples by removing the support wire which holds the spring-follower systems within the cold frame.
- Catalog all thermoelectric couples and electrode hardware.
- Seal couples and electrode hardware in plastic bags (backfilled with nitrogen).
- Remove all springs, followers, and support equipment from cold frame.

5.5.2 MODULE A-2

Module A-2 will be disassembled as follows:

- Remove outer case by melting the soft solder seal at the base of the module. (This method worked very successfully in the disassembly of SNAP-17 six-couple modules.)
- Remove internal thermal insulation and insulation housing. Samples of Min-K 1301 will be saved for possible future analysis.
- Remove thermopile from cold side heater block.

- Remove thermoelectric couples and adjacent hardware. Contact pressure at the hot electrode is released by removing the snap ring which holds the spring-follower system within the cold junction plate.
- Catalog all thermoelectric couples and electrode hardware.
- Seal couples and electrode hardware in plastic bags (backfilled with nitrogen).
- Remove all springs, followers, and support equipment from cold junction plate.

5.6 VISUAL INSPECTION

A careful visual inspection will be made of all components internal to the converter and module. Particular emphasis will be made to note the existence of any of the following:

- Physical changes in the thermoelectric legs and electrodes.
- Followers seizing in the cold frame.
- Presence or absence of heat transfer grease in the ball-socket and follower-cold frame interfaces.
- Physical changes in the temperature measuring thermocouples.
- Physical changes in the thermal insulation.
- Presence or absence of any thermal insulation in any interface.

5.7 PHOTOGRAPHS

Photographs, color and black and white, will be taken of the converter and module during various phases of disassembly; close-up photographs will be taken of the individual couples and associated hardware.

5.8 ANALYSIS OF THERMOELECTRIC LEGS

The following operations will be performed on the thermoelectric test specimens. The resulting data will be compared to pre-test standards. Since the hot electrode temperatures varied by approximately 50°F from the top to the bottom of the converter, the majority of the leg samples will be taken from the top and bottom of the converter. The operations will be as follows:

- A. Measure resistance versus length for each thermoelectric leg (Refer to TPI-1 in Appendix).
- B. Measure Seebeck voltage on 20 P legs and 20 N legs of converter and 3 P legs and 3 N legs of module, by the method described in TPI-1. Ten couples will be taken from the top and ten couples from the bottom of converter. The Seebeck voltage will be measured in the radial and axial directions.

If the Seebeck voltage appears to be more altered in one particular direction, this information will be used to determine the origin of the Seebeck change. The legs will be dissected and the Seebeck voltage of each portion determined.

- C. Perform a microprobe analysis of one N leg and one P leg from both the converter and module.
- D. Metallographic examination of one N leg and one P leg from both the converter and module. Photomicrographs will be included.
- E. Dimensional analysis of a representative number of N legs and all P legs. The dimensions of the legs will be compared to pre-test standards.

5.9 COUPLE HARDWARE DISPOSITION

The converter and module will be completely disassembled; all couples and hot electrode hardware will be heat-sealed in individual bags which have been evacuated and backfilled with dry nitrogen.

5.10 ADDITIONAL TESTS

During the post-test examination, additional detailed tests and analysis may be required. Such additional tests will be defined as the requirements become known.

The following table presents a summary of the post-test analysis.

Table 5-1. Post-Test Analysis of Components

Component	Analysis
Thermoelectric Legs	<p>Measure resistivity (each leg)</p> <p>Measure Seebeck (20 N and 20 P for converter and 3 N and 3 P for module)</p> <p>Emission spectrograph (2 N and 2 P for converter and 1 N and 1 P for module)</p> <p>Microprobe (1 N and 1 P for converter and module)</p> <p>Metallographic (1 N and 1 P for converter and module)</p> <p>Dimensional (all N and all P)</p>
Thermal Insulation (Min-K 1301)	Visual examination
Gas	Mass spectrograph
Other Components	<p>Visual examination</p> <p>Chemical analyses of deposits on hot shoe surfaces, if present</p>

6.0 APPENDIX

6.1 THERMOELECTRIC SPECIFICATION SHEETS

TPI-1

TPI-2

TPI-11

TPO-110

6.2 RESPONSIBILITY FLOW CHART

6.3 DETAILED PROCEDURE FOR DIMENSIONAL ANALYSIS

6.1 THERMOELECTRIC SPECIFICATION SHEETS

6.2 RESPONSIBILITY FLOW CHARTS

6.3 DETAILED PROCEDURE FOR DIMENSIONAL ANALYSIS

DIMENSIONAL MAPPING OF THERMOELECTRIC COUPLES AND ASSOCIATED HARDWARE FOR LONGITUDINAL ROW									
RADIAL ROW	A	B	C	D	E	F	G	H	J
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
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32.									
33.									
34.									
35.									

INSTRUCTIONS FOR DIMENSIONING SNAP-23 CONVERTER

- I **PURPOSE**
- The following instructions are presented to provide a methodical means for determining 1) the position of the cold frame relative to the hot frame 2) the longitudinal displacement of legs and their associated hardware and 3) the radial displacement of legs and associated hardware
- II **MAJOR EQUIPMENT REQUIRED**
- Surface Plate S/N _____ Calib _____ Date _____
Cadillac Gage S/N _____ Calib _____ Date _____
Electro limit gage S/N _____ Calib _____ Date _____
Rotab S/N _____ Calib _____ Date _____
- III **GENERAL INSTRUCTIONS**
- Wear gloves or equivalent when handling or touching internal parts or surfaces
- Do not contaminate gloves or equivalent while they are in use
- Do not contaminate piece parts or working surfaces
- Prior to measurement of the followings dry swab them with a dry, lint-free cloth avoiding contamination of adjacent areas
- Take each measurement to four decimal places (0.0000)
- As each dimension is taken record it on the data sheet provided
- Measure at the high point on the circumference of each component being measured
- For each item measured, A thru J, maintain a constant radius R from the center of the converter
- IV **INSTRUCTIONS FOR MEASURING LONGITUDINAL DISPLACEMENT**
- Using a leveling fixture, level the converter on the surface plate by scribing three reference marks 120° apart on the surface of the cold frame and three scribe marks on the hot frame 120° apart and in line with those on the cold frame. Scribe points are to be opposite axial rows 1, 12 and 24. With the converter levelled, scribe an index mark on the cold frame at row #1. Take photographs at this point that best indicate the means whereby level was accomplished

Using the Cadillac and Electro-Limit gages, proceed to measure and record the following dimensions

- Item "A" - cold frame to follower - 36 places
Item "B" - cold frame to cold cap - 36 places
Item "C" - cold frame to hot junction button - 36 places
Item "G" - cold frame to boron nitride strip - 36 places
Item "H" - cold frame to hot frame indexing ring - 6 places 60° apart

INSTRUCTIONS FOR MEASURING RADIAL DISPLACEMENT

Center the converter on the Rotab using extreme caution not to damage the outer case (Protect outer case from Rotab jaws)

Apply only enough pressure to sufficiently hold the converter. Find zero degrees by reference center of cold frame and center of follower #1. Locate the cold frame index hole on zero degrees. At this point, take photographs that best represent converter mounting on Rotab and zero degree alignment

Using the Cadillac and Electro-Limit gages proceed to measure and record the following dimensions

- Item "D" - follower, each 10°
Item "E" - cold cap, each 10°
Item "F" - hot junction button, each 10°
Item "J" - boron nitride strip shoulder each 10°

NOTE Readings taken by Rotab moved in 10° increments and list dimensions observed

INSTRUCTIONS FOR MEASURING POSITION OF COLD FRAME vs HOT FRAME

If necessary, remove the converter from the Rotab and measure the following scribing each point so it may be returned to later for repeat measurements

Determine the O D of the converter at three points, 120° apart and on the same horizontal plane near the bottom of the cold frame (OD 1) Determine the I D of the hot frame at the same points and in the same plane (examples OD=K to M ID=K to M etc)

Determine the dimension from cold frame OD to hot frame ID at six points (example K to K L to L etc)

Repeat these measurements at the same angular displacements, but at some point nearer to the top of the cold frame (OD 2) Note that the Hot frame is tapered inside. These points too, must be returned to with precision later

As each dimension is taken, record it on the data sheet provided

CONVERTER MAY NOW BE REMOVED FOR SUPPORT CONE REMOVAL UPON ITS RETURN

Repeat OD and ID measurements
Level the converter on the surface plate and repeat all measurements outlined in section IV for radial row #14 (Bottom)
Invert converter and repeat measurements for Radial row 1 (Top)
Set converter to Rotab and repeat measurements outlined in section V completely for radial row #1 and as needed for Radial row #14

CONVERTER MAY NOW BE REMOVED FOR OUTER CASE REMOVAL UPON ITS RETURN

as converter is disassembled still further take longitudinal and radial measurements on axial rows 1, 5, 9, 13, 17, 21, 25, 29 and 33, on all 14 radial rows, bagging and identifying couples and hardware. Bag couples separate from hardware except where bonds exist

DIMENSIONS BEFORE CONE REMOVAL

	OD 1	OD 2	OD 3 optional
K to N			
L to P			
M to R			
K' to N'			
L' to P'			
M' to R'			
K to K'			
L to L'			
M to M'			
N to N'			
P to P'			
R to R'			

DIMENSIONS AFTER CONE REMOVAL

	OD 1	OD 2	OD 3
K to N			
L to P			
M to R			
K' to N'			
L' to P'			
M' to R'			
K to K'			
L to L'			
M to M'			
N to N'			
P to P'			
R to R'			

CHANGE INDUCED BY CONE REMOVAL (OD 1)

BEFORE CONE REMOVAL	AFTER CONE REMOVAL	CHANGE
K to N		
L to P		
M to R		
K' to N'		
L' to P'		
M' to R'		
K to K'		
L to L'		
M to M'		
N to N'		
P to P'		
R to R'		

CHANGE INDUCED BY CONE REMOVAL (OD 2)

BEFORE CONE REMOVAL	AFTER CONE REMOVAL	CHANGE
K to K'		
L to L'		
M to M'		
N to N'		
P to P'		
R to R'

SUPPORT CONE END

TOP VIEW - SUPPORT CONE END

APPROVED BY
Handwritten signature
Program Office
James W. Brown
Reliability
Date: 4/15/67
Date: 25 April 1967

SPECIFICATION

IPL 1017B D

THERMOELECTRIC PRODUCTS ISOTOPE POWER LABORATORY		Specification No. TPI-1				
		Code R vs L				
Title P vs L - RESISTIVITY MEASURING METHOD						
<p>Traversing Probe-Resistance vs. Length (R vs L ,</p> <p><u>GENERAL:</u> I. <u>R vs L Method</u></p> <ol style="list-style-type: none"> 1. A-C current (60 cycle) is passed through the thermoelectric element to be measured. 2. As the traversing voltage probe travels along the sample, the A-C voltage is fed into an A-C Hewlett Packard Vacuum tube voltmeter. This is rectified into D-C voltage and is fed into the Leeds and Northrup X-Y Recorder. 3. The Y-axis measures the millivolt rise as the traversing probe travels along the sample. 4. A motor driven screw thread is used to move a probe across the sample. The screw thread in turn drives a voltage divider which sends a signal to the X-axis of the recorder proportional to the distance traveled. 5. Approved equipment: <ol style="list-style-type: none"> (a) Leeds and Northrup X-Y Recorder 3M No.174345 Inst. No. 00235. (b) A-C Hewlett Packard (Portable) 3M No.137279 Inst. No. 00106. (c) A-C Hewlett Packard (Stationary) 3M No.145031 Inst. No. 00133. (d) R vs L Apparatus. (e) A-C Current Source Instr. No. 00130. (f) A-C Current Source Instr. No. 00219. <p><u>Note:</u> Approved Equal Equipment may be substituted for any of the above.</p> <p><u>PROCEDURE:</u> II. <u>R vs L Method</u></p> <ol style="list-style-type: none"> 1. <u>Sample Preparation</u> <ol style="list-style-type: none"> (a) <u>ELEMENT ONLY - DESTRUCTIVE TEST</u> The thermoelectric element should be tinned on both ends with an ample supply of low temperature solder such as "Woods Metal" to give proper current distribution throughout the area of the sample, i.e., uniform flux density. This preparation method is to be used in connection with a statistical sampling plan <u>only</u>. 						
Materials	Design <i>RS</i>	Fabrication <i>RM</i>	Originator	Orig. Dept.	Date	Approval
Welding	Reliability <i>July 5/66</i>	Quality <i>8/11 5/11</i>	Dept. Approval <i>Hen</i>			Issued <i>5-18-66</i>

SPECIFICATION

IPL 1019B D

3M THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No. **TPI-1**

PROCEDURE: II. R vs L Method (continued)

1. Sample Preparation -(continued)
 - (b) Element with single or double electrode -
NON-DESTRUCTIVE: NO PREPARATION REQUIRED.
STATISTICAL sampling or 100% inspections
may be applied to these units.
2. Place unit in current jaws with adequate spring pressure. If element has an electrode, place in jaws such that traversing probe starts on electrode (Ref. 1(b) above). If element only is to be run, place voltage whisker on left end of unit where traversing voltage probe starts; this eliminates the high voltage drop due to contact resistance. Note: See Schematic on Sheet 3.
3. Set A-C current to an appropriate value for a given size element: Example 1/8" dia. use 0.250 amps; 1/4" dia. use 0.5 amps; 3/8" dia. use 1.0 to 2.0 amps; 1/2" dia. use 2.0 amps to 5.0 amps. Desired slope to be approx. 45°.
4. Place traversing probe on sample and record trace of millivolts vs probe travel.
5. The resistivity can then be calculated from this equation:

$$\rho = \frac{E \times A}{I \times L}$$

- (a) E - is the millivolt rise for a given probe travel. For a uniform sample this trace will be a straight line.
- (b) I - is a known A-C current value.
- (c) A - is the area of the sample as calculated from measurement.
- (d) L - is the length of probe travel for a given voltage rise, not necessarily the length of the sample. The X-axis is normally set for 0.10" of probe travel equals 1.0" of chart travel. This can be set to any desired ratio.

Specification No. **TPI-1**

SPECIFICATION

IPL 1017B D

THERMOELECTRIC PRODUCTS ISOTOPE POWER LABORATORY	Specification No. TPI-2
	Code SEEBECK - VOLTAGE, COEFFICIENT

Title SEEBECK VOLTAGE (EMF) AND SEEBECK COEFFICIENT MEASURING METHOD

GENERAL: I. Equipment

1. Seebeck voltage apparatus is electrically connected to the X-Y recorder as per attached sketch. (Sheet 3)
2. The Y-axis measures the Seebeck voltage. (millivolts)
3. The X-axis measures the temperature differential between the hot block and the cold block ($\Delta T^{\circ}F$).
4. The thermocouple from the hot carbon block is electrically but not thermally insulated from the water outlet line of the cold block. The temperature (ΔT) of the cold block is the reference temperature.
5. The thermocouple wire is centered and sealed into the carbon block approximately 0.010" from the contact surface.
6. Water inlet temperature is kept at a constant $75^{\circ}F \pm 2^{\circ}$ through the use of a water mixing valve. A thermometer is inserted in the line for temperature measurement of the inlet water.

II. Pilot Plant Equipment

1. This apparatus is used to measure the Seebeck voltage at fixed temperature differentials (ΔT 's). (Sheet 4)
2. The hot block is electrically heated and kept at a constant temperature by a temperature controller.
3. The water inlet temperature in the cold block is kept at a constant $T_c = 75^{\circ}F \pm 2^{\circ}F$ through the use of a water mixing valve.
4. The temperature controller reads a differential temperature ($\Delta T^{\circ}F$) and may be set to any given fixed ΔT .
5. Seebeck voltage can be read from the Leeds and Northrup millivolt potentiometer.

Equipment:

1. Leeds and Northrup X-Y Recorder 3M No. 174345 Instr. No. 00235.
2. Seebeck Voltage and Coefficient Apparatus.

Pilot Plant

1. Leeds and Northrup Indicating Self-balancing Millivolt Potentiometer. 3M No. 122588 Instr. No. 00067.
2. Capacitrol (WHEELCO Temperature Controller 3M No. 121846 Instr. No. 00061.

Materials	Design <i>WFS</i>	Fabrication <i>K.H.H.</i>	Originator	Orig. Dept.	Date	Approval
Welding	Reliability <i>WFS</i>	Quality <i>WFS</i>	Dept. Approval <i>WFS</i>			Issued 5-18-66

SPECIFICATION

IPL 1017B D

THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No.

TPI-2

GENERAL: II. Pilot Plant

3. Seebeck Voltage (fixed settings) Apparatus.

NOTE: Approved equal equipment may be substituted for any of the above equipment.

PROCEDURE: I. Seebeck Voltage ΔT Using Fixed Setting Pilot Plant Equipment

1. Set temperature controller to desired fixed $\Delta T^{\circ}\text{F}$ setting - allow to stabilize.
2. Plug in voltage leads to indicating millivolt meter.
3. Set water reference temperature to $T_c = 75^{\circ}\text{F} \pm 2\%$.
4. Place cylindrical sample in ΔT apparatus so that the center line of the element is underneath the thermocouple.
5. Bring hot block in contact with element - allow to stabilize - approx. 30 seconds.
6. Read millivolt reading and record if required for the given $\Delta T^{\circ}\text{F}$ when the temperature controller pointer is on the desired setting.

II. Seebeck Voltage and Seebeck Coefficient Using the Equipment

1. Place cylindrical unit in the EMF apparatus so that the centerline of the element coincides as near as possible to the centerline of the carbon block.
2. Push down rod holding carbon block so that the sample is adequately spring loaded.
3. Zero the Y-axis scale.
4. Heat top of carbon block with torch to desired temperature.
5. Remove torch, drop pen and record EMF as ΔT decreases.

CALCULATION:

1. The Seebeck Voltage M.V. at a given $\Delta T^{\circ}\text{F}$ (Ref. $T_c = 75^{\circ}\text{F}$) can be read directly from the chart or from the indicating potentiometer.
2. The Seebeck Voltage Coefficient ($\mu\text{V}/^{\circ}\text{F}$) at a given temperature can be calculated as per typical example. Desire Seebeck Voltage Coefficient ($\mu\text{V}/^{\circ}\text{F}$) at 800°F . Read the Voltage at 850°F and at 750°F (actual temp.) Subtract the 750°F reading from the 850°F and divide by 100°F .

Note: Since this apparatus reads a $\Delta T^{\circ}\text{F}$ temperature (Ref. $T_c = 75^{\circ}\text{F} \pm 2\%$), the chart temperature readings have to be adjusted by 75°F for the actual temperature. Example: A 775°F ΔT reading on the chart is an actual temperature of 850°F .

Specification No.

TPI-2

SPECIFICATION

IPL 1019B D

THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No. **TPI-2**

SCHEMATIC OF LABORATORY SEEBECK VOLTAGE TESTING APPARATUS

Specification No. **TPI-2**

SPECIFICATION

IPL 1019B D

3M THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No. **TPI-2**

SCHEMATIC OF PILOT PLANT SEEBECK VOLTAGE TESTING APPARATUS

Specification No. **TPI-2**

PRELIMINARY SPECIFICATION*

IPL 1017A D

THERMOELECTRIC PRODUCTS ISOTOPE POWER LABORATORY		Specification No. X-TPI-II Code EQUIPMENT OPERATION	
Title MASS SPECTROMETER LEAK DETECTOR OPERATION AND TESTING			
<p>1.0 OBJECTIVE</p> <p>1.1 To define the method for using mass spectrometer type of leak detection equipment for leak checking thermoelectric generators and other miscellaneous vessels.</p> <p>1.2 To describe operating and calibrating procedures for the equipment.</p> <p>2.0 EQUIPMENT REQUIRED</p> <p>2.1 Leak detector (No. 122856).</p> <p>2.2 Mechanical roughing pump.</p> <p>2.3 Vacuum hose "pinch-off" clamp (2 required).</p> <p>2.4 Vacuum hose tee-connector and necessary vinyl hose.</p> <p>2.5 One tank of helium with regulator and hose.</p> <p>2.6 "Standard" leak</p> <p>3.0 OPERATION</p> <p>3.1 Leak Detector Start Up</p> <p>3.1.1 Check the following:</p> <ul style="list-style-type: none"> a. Cold trap bolts are tight. b. Vent valve closed. c. Throttle valve closed. d. Pump shut-off valve open. e. Diffusion pump switch off. f. Regulated-power switch off. <p>3.1.2 Turn on main power forepump switch. (To expedite Step 3.1.3 the following procedures are used).</p>			
Materials	Design D.D.S.	Fabrication McCarran	Originator
Welding	Reliability	Quality McCarran	Dept. Approval
		Orig. Dept.	Approval 4-24-65
		Date	Issued 4-20-65

* PRELIMINARY SPECIFICATION
Developmental specification - revised only by approval of originator

Specification No. **X-TPI-II**

PRELIMINARY SPECIFICATION*

IPL 1019A D

THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No.

X-TPI-II

3.0 Continued

- 3.1.2.1 Connect an external roughing pump to the leak detector inlet and tighten the vacuum line connections.
- 3.1.2.2 Start roughing pump and open throttle valve.
- 3.1.2.3 When the roughing pump quiets down close the throttle valve, and continue with start up procedure.
- 3.1.3 When fore pump quiets down, turn on diffusion pump switch.
- 3.1.4 Allow diffusion pump 20 minutes to warm up.
- 3.1.5 Select "diatron pressure" on left hand selector switch.
- 3.1.6 Turn on regulated power switch.
- 3.1.7 If the diatron-pressure meter pegs full scale (after 30 second delay), turn off regulated-power switch. This condition indicates that the vacuum manifold pressure is above the operating range of the vacuum sensing instrumentation, and prolonged operation of the instrumentation at this pressure will shorten the life of the vacuum sensing elements.
- 3.1.8 Wait 5 minutes and repeat Step 6. Continue vacuum pumping until meter indicates .2 microns. At .2 microns the diatron filament pilot light will start flashing.
- 3.1.9 Fill cold trap with liquid nitrogen. Allow liquid nitrogen level to stabilize - then refill cold trap.
- 3.1.10 Do not allow the cold trap to boil dry during operation as the entrapped contaminants may be released into the manifold, thus increasing manifold pressure.

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Specification No.

X-TPI-II

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THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No.

X-TPI-II

3.0 Continued

Leak Detector Calibration

- 3.2.1 Connect "standard" leak to external manifold.
- 3.2.2 Pump with roughing pump for 5 minutes.
- 3.2.3 Open throttle valve slowly while observing diatron pressure meter. Do not exceed .2 micron pressure while opening valve.
- 3.2.4 When throttle valve is completely open, valve-off external roughing pump.
- 3.2.5 Turn on diatron filament.
- 3.2.6 Rotate leak rate multiplier selector to obtain on-scale reading on leak-rate meter. Record number of divisions on leak-rate meter.
- 3.2.7 Calculate leak detector sensitivity by the following relationship:
$$\text{Sensitivity} = \frac{(\text{Leak rate of "standard" leak}) \times (\text{Temp. correction})}{(\text{leak rate meter divisions}) \times (\text{multiplier})}$$

Record date in Log Book, (If sensitivity is below specified limit, equipment must be serviced before proceeding further.)
- 3.2.8 Close throttle valve.
- 3.2.9 Turn on diatron filament.
- 3.2.10 Leak detector is now ready for use. Remove "standard" leak from manifold and connect test specimen.

3.3 Leak Detector Shut Down

- 3.3.1 Close throttle valve and pump shut-off valve.
- 3.3.2 Turn off regulated-power switch and diffusion pump switch.

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Developmental specification - revised only by approval of originator

Specification No. **X-TPI-II**

PRELIMINARY SPECIFICATION*

IPL 1019A D

3M THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No.

X-TPI-II

3.0 Continued

- 3.3.3 Connect cylinder of nitrogen to vent valve with rubber tubing. Set nitrogen regulator to 5 psig.
- 3.3.4 Loosen cold trap bolts.
- 3.3.5 Vent manifold with hoke valve.
- 3.3.6 Allow 20 minutes for the diffusion pump to cool. Open the pump shut-off valve and purge the diffusion pump with nitrogen.
- 3.3.7 Turn off master power switch.
- 3.3.8 Close vent valve and disconnect nitrogen supply.

4.0 TEST PROCEDURE

- 4.1 Interconnect components of the test set up as shown in the above diagram while complying with the following items:
 - 4.1.1 Keep all vacuum lines as short as possible.
 - 4.1.2 Vinyl vacuum will be used in place of rubber hose.
 - 4.1.3 Securely clamp all vacuum line connections to insure against leaks.
 - 4.1.4 Use a minimum amount of vacuum grease on connections.

* PRELIMINARY SPECIFICATION
Developmental specification - revised only by approval of originator

Specification No. **X-TPI-II**

PRELIMINARY SPECIFICATION*

IPI 101A L

THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

Specification No.

X-TPI-II

4.0 Continued

Note: Vacuum grease and rubber hose absorb helium. During operation the absorbed helium is liberated into the system being tested, thus increasing the background level of the equipment and causing an erroneous leak rate indication.

- 4.2 Open the throttle valve slowly while maintaining the manifold pressure at .2 micron or less.

Note: If the diatron pressure meter reads off-scale turn off regulated-power switch until an on-scale pressure level is established.

- 4.3 After opening the throttle valve, pinch off the rough pump line while maintaining at least .2 micron pressure.

Note: The leak detector manifold must be at a pressure of less than .2 micron when the diatron filament may be energized. In some cases it may be necessary to leave the roughing pump on the system to maintain pressure of less than .2 micron.

- 4.4 Turn on diatron filament. Test specimen may now be subjected to specific leak testing as outlined in paragraphs 4.5 and 4.6.

- 4.5 Helium Probing Test: Under the conditions established above, spray test specimen with helium using the Helium probe. Probe the entire exterior surface of the specimen enclosure while monitoring the leak rate meter. Set the leak rate meter multiplier on $\times 1$. If a deflection is observed during the probing test the test specimen is unacceptable.

- 4.6 Helium "Bag" Test: Place test specimen in a helium filled plastic bag or other enclosure. Soak for 15 minutes and record the leak rate level. The leak rate level must be within the specified limits established for the test specimen.

- 4.7 Removal of test specimen

4.7.1 Pinch off outlet hose from specimen.

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Developmental specification - revised only by approval of originator

Specification No.

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THERMOELECTRIC PRODUCTS
ISOTOPE POWER LABORATORY

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4.0 Continued

4.7.2 Close throttle valve on leak detector.

4.7.3 Remove test specimen.

* PRELIMINARY SPECIFICATION
Developmental specification - revised only by approval of originator

Specification No. **X-TPI-II**

SPECIFICATION

	ELECTRICAL PRODUCTS DIVISION ISOTOPE POWER LABORATORY	Specification No. TPO-110
		Code CONTINUITY CHECK

Title
ELECTRICAL CONTINUITY CHECK OF A COLD TEST MODULE

1. Connect current leads of ohmmeter to output leads of module.
2. The resistance of any portion of the module can be measured with the voltage probes. If the module is sealed, the iron leads of the iron-constantan thermocouples can be connected to the voltage probes.

CAUTION: The voltage probes should not be connected to the module with the incorrect polarity. The plus (+) voltage lead should go to the plus side.

3. The resistance of the following items should be checked (not all possible if module is sealed).
 - a. Resistance between hot junction and T/E leg for each T/E leg.
 - b. Resistance of each T/E leg.
 - c. Resistance between T/E leg and cold electrode.

Specification No. TPO-110

Materials	Design R.R.D	Fabrication	Originator	Orig. Dept.	Date	Approval
Welding	Reliability	Quality C.E.W.	Dept. Approval			Issued 2-17-65

SPECIFICATION

ELECTRICAL PRODUCTS DIVISION ISOTOPE POWER LABORATORY	Specification No. TPO-110
<p>3. continued</p> <p style="margin-left: 40px;">d. Resistance of entire module.</p> <p style="margin-left: 40px;">e. If T/E legs are segmented, measure resistance across segment bond.</p>		

 Specification No. TPO-110