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REPORT NO. RN-S-0121
TO
AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

PRELIMINARY TEST REPORTS
FOR
GROUND TEST REACTOR (GTR) TEST NO. 12A

AUGUST 1964

CONTRACT SNP-1

NERVA PROGRAM

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AZULON, CALIFORNIA

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ABSTRACT

This document contains the preliminary test reports covering strain gages (23/A406), resistance temperature transducers (23/L101) and cables(23/A601) which were irradiated during test number 12A at the Ground Test Reactor, Fort Worth, Texas.

This report is submitted in partial fulfillment of Subtask 1.9, Contract SNP-1, Modification 8.

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Manager, Radiation Effects
Component Development Division

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23/A406 Strain Gages

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GTR-12A DEVELOPMENT STRAIN GAGES 23/A406

Thirty-two (32) Microdot weldable strain gages were installed in a standard Aerojet strain gage test fixture. The gages were mounted in a half-bridge arrangement with the bridge completion network, consisting of two 250 ohm resistors and a 20 ohm null balance pot, mounted on the instrumentation panel in the reactor control room. This arrangement is consistent with that used in previous bonded strain gage tests, (Ref. Test 23/A402).

Because of a mechanical malfunction of the test fixture, water collected and froze in the actuating bellows preventing controlled flexure of the test beams, it was not possible to complete this test. The test assembly remained in the reactor compartment for the full 50-hour test but no strain or insulation resistance was taken. This test will be completed as a part of GTR-13.

Aerojet agrees with the test summary presented in the General Dynamics preliminary report on Irradiation Test, GTR-12A, dated 24 April 1964.

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23/L101 Resistance Temperature Transducers

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I. SUMMARY AND RECOMMENDATIONS

Eleven platinum resistance temperature transducers were irradiated for 50 hours in the GTR at GD/FW while immersed in liquid hydrogen. Resistance measurements were recorded at reactor power levels of 10 KW, 100 KW, 1 MW, and 3 MW during reactor start-up, and once each hour after reactor start for the duration of the test. The resistance measurements were converted to indicated temperatures and compared to reference temperatures that were derived from the dewar pressure measurements.

The results of the experiment showed a gamma-induced error of approximately 0.5°F and an integrated neutron error that became as high as from 2° to 6°F at the end of 50 hours. The integrated error appeared to be inversely proportional to the diameter of the platinum resistance wire used in the transducers.

Recommendations are that further tests be conducted on resistance temperature transducers with some effort expended on optimizing the diameter of the wire used as a resistance element. The trade-off would be between the integrated neutron damage error and gamma induced error.

II. DESCRIPTION OF TEST EQUIPMENT

The test RTT's were mounted in a dewar that had been designed to keep the RTT probes immersed in liquid hydrogen. A shroud surrounded the LH_2 container, through which a continuous gaseous helium purge was maintained. The lower portion of the dewar was covered with a vacuum jacket which was pumped down and sealed off prior to placing the pallet in the test position. A cross-section of the hydrogen dewar is shown in Figure 1. The level of the liquid in the dewar was monitored by means of a liquid-level probe consisting of seven resistors. Level control was manual.

Exclusive of the test items the electrical equipment used in the test consisted of cables, connectors, power supplies, a calibration test set, pressure transducers, and a Dymec data acquisition system. A short length of Physical Sciences Cable and Physical Sciences #PS 08(SP)-10-6S-F1-PB2 Class N Connectors were placed inside the helium shroud. In addition to one connector and cable to each RTT, four lengths of cable were included as "dummy cables."

Three, 37-pin, weldable Physical Science Connectors were used in the top of the dewar as a sealed electrical feed-through into the helium shroud. From the top of the dewar to the calibration test set, located in the control room, 120 feet of Raychem shielded irradiated polyolifin cable was used. One set of Amphenol connectors was placed in the cable for handling convenience.

The calibration test set AGC Part No. 248428-9 provided a means to adjust the RTT current to precisely one milliamp and a means of switching from calibrate to read-out for each RTT. A simplified schematic of the test circuit is shown in Figure 2. The power supply used for the RTT excitation was a Fluke model. Facility supplies were used for 115 vac and 28 vdc. The Dymec data acquisition system consisted of a cross bar scanner, amplifier integrating digital voltmeter, digital clock and paper tape punch coupler with punch. The amplifier provided a gain of 10 and an input impedance of 10 K megohms. The dewar pressure was determined by measuring the dewar gage pressure with a CEC 0-5 psig transducer and recording the

II, Description of Test Equipment (cont.)

atmospheric pressure every hour. The transducer power was provided by a facility supply. A block diagram of the test set-up is shown in Figure 3.

III. TEST RESULTS

Figures 4 through 14 are plots of the temperature deviations vs time throughout the test. The method of calculating the temperature deviations is explained in Appendix A to this test report. Briefly, the deviation is the difference between the temperature indicated by the measured resistance of each RTT probe and a "reference temperature" derived from measurement of the dewar pressure.

During the course of the test, RTT numbers 11, 12, 8, and one dummy cable appeared to have opened. A subsequent post mortem inspection indicated that the open circuits occurred in the cable at the through-bulkhead connector used to enter the helium shroud.

IV. DISCUSSION OF TEST RESULTS

The pre-irradiation analysis in REON Report RN-S-0063 predicted a *gamma*-induced error of approximately $+0.3^{\circ}\text{F}$ and an integrated neutron damage of about $+3.0^{\circ}\text{F}$. An examination of the data shown in Figures 4 through 15 reveals that the experimental results substantially agree with the pre-irradiation analysis.

Figures 4 through 8 show the deviation for the Rosemount 134EB250. Notice that all of these show a *gamma*-induced error of about $+0.4^{\circ}$. The integrated damage deviation varies from $+1.8^{\circ}$ to $+2.5^{\circ}$ at the end of 50 hours for RTT's in the same flux levels. This would indicate that even if one attempted to compensate for the effects of *gamma* error and neutron damage error, the resulting temperature would be accurate to within about 0.7°F .

Figures 9 through 12 show the deviations for the Winsco 2448-5 RTT's. The *gamma* induced deviations for these transducers are about $+0.5^{\circ}\text{F}$ as compared to the 0.3°R predicted by the pre-irradiation analysis. The integrated neutron damage deviations vary from $+4.8$ to $+5.2^{\circ}\text{F}$. The number of test RTT's is small, however, the results indicate that if one corrected for *gamma* error and integrated neutron error, the accuracy would be within about 0.4° .

Figures 13 and 14 show the deviations for the Rosemount 110AA150 RTT's. The plots show that they generally react to the radiation in the same manner as the other RTT's. RTT Circuit No. 12 opened after approximately 43 hours of irradiation as noted previously. Notice in Figure 13 that RTT No. 6 showed a step change in deviation of -1.1°F . One possible explanation for the step change is that instead of a complete open circuit, as occurred in some of the other channels at the same time as the step change, the resistance increased by about 900 ohms.

A post-irradiation test was conducted in June of 1964 in which the RTT's were heated to 100° , 200° , 300° , and 380°F . Calibration data cycles were recorded with the RTT's immersed in liquid hydrogen prior to and after each thermal cycle. The results of this post-irradiation test are not available at this time and will be included in the final test report.

IV, Discussion of Test Results (cont.)

As part of the post-irradiation tests, the dewar was filled with crushed ice and distilled water for an accurate measurement of the ice point resistance on each RTT. The dewar was also filled with LN_2 and LH_2 for an accurate measurement of the resistance of each RTT. The data has not been reduced on this three point post calibration for inclusion in this report, however, will be included in the final test report on GTR 12A.

APPENDIX A

DATA REDUCTION PROCEDURES FOR RADIATION EFFECTS TEST 23/L101

The purpose of this appendix is to describe the data reduction procedure for radiation effects test 23/L101. The 23/L101 is a test of eleven platinum resistance thermometers in liquid hydrogen. The thermometers were inserted into a dewar of liquid hydrogen. The transducer resistances were measured by adjusting the current through each individual transducer to precisely one milliamp, and then measuring the voltage across the transducer resistance element.

The data reduction procedure consists of three basic calculations:

1. The liquid hydrogen temperature, or reference temperature.
2. A calibration constant for each transducer.
3. An indicated temperature.

Some minor additional calculations include conversion of the dewar pressure transducer output into psi, and summing the dewar differential pressure with the current atmospheric pressure.

Reference Temperature

The reference temperature is the temperature of the liquid hydrogen surrounding the test transducers. If the assumptions are made that the hydrogen is at the boiling point and that there are no thermal gradients in the hydrogen, the reference temperature can be determined from measurements of the dewar pressure.

Allen Schmidt at the National Bureau of Standards recommended a paper, The Vapour Pressure of 20°K Equilibrium Hydrogen, by L. A. Weber, D. E. Diller, H. M. Roder, and R. D. Goodwin, Cryogenics, June 1962, as the best vapor pressure vs temperature data available for hydrogen at pressures near atmospheric. Since the absolute pressure in our dewar is about 18 psi, the following data was extracted from the paper to be used in the reference temperature calculation:

Temperature	21°K	37.8°R
Pressure	1.2334 atm.	18.126 psi
1st Derivative	0.3435 atm/degK	2.804 $\frac{\text{psi}}{\text{degR}}$
2nd Derivative	0.0690 atm/deg ² _R	.31297 $\frac{\text{psi}}{\text{degR}}^2$

The equation to be used in the reference temperature calculation is:

$$T_R = 37.8 + 0.3566 (P - 18.126) \quad (1)$$

T_R is in degrees Rankine

P is in psia.

This straight line curve is adequate for pressures from 17 to 19 psia.

Calibration Constant

Within a narrow range of temperatures, the resistance vs temperature characteristics of the platinum resistance transducers can be represented by a straight line equation of the form:

$$T = C_1 + R \frac{dT}{dR} \quad (2)$$

The constant C_1 can be considered a "calibration constant" since each transducer requires a different constant to give an indicated temperature that is the same at the reference temperature. The slope, $\frac{dT}{dR}$, can be approximated by $\frac{\Delta T}{\Delta R}$ if the increments are small enough. The resistance vs temperature data published by Rosemount is in one degree F increments. In the range of from -421°F to -422°F, the Rosemount 134EB Specifications show a change in resistance of 0.656 ohms. The standard slope for the Rosemount 134EB's, and Winsco 2448's is then 1.5244 °R/ohms.

The constant C_1 can now be determined by use of the reference temperature (from Equation 1) and the measured resistance, R_1 . C_1 is then:

$$C_1 = T_R - 1.5244R \quad (3)$$

(Or, substituting Eq. 1 into Eq. 3)

$$C_1 = 37.8 + 0.3566 (P - 18.126) - 1.5244R \quad (4)$$

The dewar pressure, P , is calculated from:

$$P = P_a + vC_t \quad (5)$$

where

P_a is the atmospheric pressure in psi.

C_t is the differential pressure transducer constant 0.50 psi/mv (0.54 for the post radiation rest)

v is the pressure transducer output in millivolts.

Substituting Eq. (5) into Eq. (4) results in the final equation for the calibration constant C_1 .

$$C_1 = 37.8 + 0.3566 (P_a + 0.84v - 18.126) - 1.5244R \quad (6)$$

This equation should be solved for each pre-radiation run for each applicable RTT channel and the results averaged.

The resulting averaged constant for each RTT will then be used to calculate the indicated temperature for the rest of the radiation test. Similar manipulations result in the equation for C_2 , the calibration constant for the Rosemount 110AA RTT's.

$$C_2 = 37.8 + 0.3566 (P_a + 0.50v - 18.126) - 5.235R \quad (7)$$

Indicated Temperature

The indicated temperature should be calculated for each data point throughout the radiation test. The equation to be used for the calculation is Eq. (3), with the appropriate calibration constant and slope. The equation for the Rosemount 134EB's and the Winsco 2448's would be:

$$T_i = C_{RTT} + 1.5244R \quad (8)$$

for the Rosemount 110AA's it would be:

$$T_i = C_{RTT} + 5.235R \quad (9)$$

Error or Temperature Deviation

The reference temperature should be calculated along with the indicated temperature at each data point. The error, or deviation, is then the difference between the two temperatures.

FIGURE 1
HYDROGEN DEWAR

RTT LOCATION CHART	
ITEM	LOCATIONS
22	RTT5, RTT6, RTT7,
23	RTT8, RTT9, RTT10
24	RTT1, RTT2, RTT3, RTT4
25	RTT11, RTT12, RTT13, RTT14, RTT15

SECTION A-A

FIGURE 2
SIMPLIFIED TEST CIRCUIT

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

FIGURE 9

FIGURE 10

FIGURE 11

FIGURE 12

FIGURE 13

FIGURE 14

23/A601 Cables

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GTR-12A Cables 23/A601

Four 10 foot sections of Rockbestos, four conductor, shielded cable were mounted near the GTR. Measurements of insulation resistance and cable temperatures were recorded throughout the test. The results of the test were published in General Dynamics Preliminary Report on Irradiation Test, GTR-12A, dated 24 April 1964.

Figures 1 through 7 from the referenced report show the data. There was apparently no degradation in insulation resistance caused by radiation effects after the initial 3 Mw data.

FIGURE 1
CABLE TEST CIRCUIT

Cable Test

Data Run Correlation

<u>Data Run</u>	<u>Megawatt-Minutes</u>
4	260
5	690
6	1410
7	2130
8	2850
9	3520
10	4290
11	5010
12	5730
13	6450
14	7120
15	7890
16	8610

FIGURE 2

CTR-12A Cable Test (23/A601)

Insulation Resistances - Megohms

Data		Switch Position								
Run		1	2	3	4	5	6	7	8	9
Lab		62500	62500	62500	62500	71500	50000	62500	62500	62500
Pre	Irr	227	625	625	312	500	625	166	500	556
1	10 kW	143	715	500	128	286	455	123	357	417
2	100 kW	151	46.5	357	109	217	385	117.5	263	250
3	1 Mw	50	147	45.5	16.7	27.8	807	20	41.7	55.5
4	3 Mw	15.6	135	33.3	18.5	25	9.62	27.8	62.5	7.35
5	3 Mw	100	1670	1670	1250	2170	3330	2940	4170	2940
6	3 Mw	10000	5000	1000	2500	6250	100000	41700	167000	50000
7	3 Mw	6250	12500	6250	6250	5000	33300	20000	20800	16700
8	3 Mw	5000	5000	16700	25000	12500	14300	12500	12500	12500
9	3 Mw	4170	4170	31200	50000	50000	33300	25000	7820	2500
10	3 Mw	1190	1190	1670	22270	2500	1670	1670	1250	1520
11	3 Mw	1670	2000	3330	12500	1670	2780	2500	2500	2500
12	3 Mw	5000	5000	12500	1670	2000	2000	1920	1920	1790
13	3 Mw	5000	4170	10000	10000	5000	2780	5000	4160	5000
14	3 Mw	4170	2780	5000	50000	10000	50000	2780	2500	6250
15	3 Mw	2170	2370	4550	12500	6250	19200	2000	1850	2780
16	3 Mw	3570	4170	11100	2000	1670	1430	1320	1670	2500
Post	1	1430	1790	2500	2500	4550	1780	100	2500	500
Post	2	4170	3520	4170	4550	5000	6250	5550	5550	1250
Post	3	1670	3520	4550	5000	5000	1110	1110	1670	2080
Post	4	5000	5000	10000	3330	8350	1250	10000	10000	12500

FIGURE 3

FIGURE 4
CABLE NO. 1 TEMPERATURES

FIGURE 5
CABLE NO. 2 TEMPERATURES

FIGURE 6
CABLE NO. 3 TEMPERATURES

CABLE NO. 4 TEMPERATURES

FIGURE 7