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AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

FAST AND THERMAL NEUTRON AND PROTON EFFECTS ON
PLATINUM RESISTANCE TRANSDUCERS AT
LIQUID HYDROGEN TEMPERATURE

NERVA PROGRAM

JUNE 1967

CONTRACT SNP-1

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NUCLEAR PRODUCTS AND SERVICES GROUP

AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

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FAST AND THERMAL NEUTRON AND PROTON EFFECTS ON
PLATINUM RESISTANCE TRANSDUCERS AT
LIQUID HYDROGEN TEMPERATURE

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ABSTRACT

Twenty platinum resistance temperature transducers (RTT) were irradiated in the 200-hour GTR-18 test to assess radiation damage at liquid hydrogen temperatures. The test included 11 units that were used to determine the mechanism of damage to the probes, three development transducers for evaluation, and six units that had been irradiated in previous GTR tests to determine effects of extended exposures and to observe evidence of radiation hardening.

The units used in the mechanism of damage study were Rosemount 134EB186 transducers, and a current of 4.5 milliamps was used for each unit. Shielding was provided for protons, thermal neutrons, and epithermal neutrons. The following data summarize the test conditions and the results. The temperature deviations are for fast neutron exposures of 5×10^{16} n/cm² (E >1.0 Mev).

RADIATION DAMAGE TO ROSEMOUNT 134EB186 PLATINUM SENSORS IN LH₂ (36.5°R)

<u>Material</u>	<u>Type</u>	<u>Attenuation</u>	<u>Units Tested</u>	<u>Fast Neutron Temperature Degradation, °R</u>
Unmodified	None	None	2	2.48
Stainless Steel	Proton	Black	2	2.28
Cadmium and Stainless Steel	Thermal Neutron Proton	1.8×10^{-4} Black	2	2.20
Hafnium and Stainless Steel	Epithermal Neutron Proton	2.9×10^{-3} Black	2	2.48
Hafnium Cadmium Stainless Steel	Epithermal Neutron Thermal Neutron Proton	5.3×10^{-2} 1.3×10^{-2} Black	3	2.32

Radiation Environment:

Neutron exposures: $E > 1.0 \text{ Mev} = 5 \times 10^{16} \text{ n/cm}^2$
 $E < 0.48 \text{ ev} = 5.1 \times 10^{16} \text{ n/cm}^2$
Proton exposure: $3 \times 10^{16} \text{ protons/cm}^3$

It was concluded that the observed radiation damage to platinum RTT's was caused by fast neutrons, as significant contributions to the damage by thermal neutrons and protons could not be detected within the accuracy of this test.

A least-squares expression for temperature deviation as a function of fast neutron exposures up to 5×10^{16} nvt at liquid hydrogen temperature based on eleven units was developed for Rosemount 134EB sensors. The expression is as follows:

$$\Delta T = 0.036 + 0.498 (\phi t / 10^{16}) - 0.00846 (\phi t / 10^{16})^2$$

for $5 \times 10^{14} < \phi < 5 \times 10^{16} \text{ n/cm}^2$

where:

ΔT = temperature deviation, degrees Rankine

ϕt = fast neutron dose ($E > 1.0 \text{ Mev}$)

ϕ = fast neutron flux, $\text{n/cm}^2\text{-sec}$

t = exposure period, seconds

and $\Delta T = 0$, $\phi < 5 \times 10^{14}$

Three development transducers were irradiated. Their identification and performance for fast neutron exposures of $5 \times 10^{16} \text{ n/cm}^2$ ($E > 1.0 \text{ Mev}$) were as follows:

	<u>No. of units</u>	<u>T, °R</u>
Rosemount 134CJ	2	2.74
Temtech 1881-2	1	3.02

Six units that had been irradiated in previous GTR tests were recalibrated and reirradiated in GTR-18. They performed well; however, the higher damage rates that occurred in GTR-18 than in previous tests could have been

the result of interpolations necessary for the circular arrangement of previous tests. It was not possible to make conclusions relative to the effects of extended dosages which required comparisons with previous tests. One Rosemount 134EB was reirradiated. Its temperature deviation for a fast neutron exposure of $5 \times 10^{16} \text{ n/cm}^2$ ($E > 1.0 \text{ Mev}$) was 2.56°R .

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I. INTRODUCTION

Twenty platinum resistance temperature transducers (RTT) were irradiated in GTR-18 on the east reactor face for 200 hours to assess radiation damage at liquid hydrogen temperatures. The test included eleven units that were used to determine mechanism of damage to the probes; three development transducers for evaluation; and six units that have been irradiated in previous GTR tests to determine the effects of extended dosages and to observe the effects of radiation hardening.

During 1965, the radiation effects group of Aerojet-General proposed the hypothesis that protons, which are formed as the result of neutron and hydrogen atom collisions in liquid hydrogen, caused more radiation damage to platinum than did fast neutrons (References 1 and 2). Protons are relatively easy to shield and the implication was that improvements might be made in platinum resistance temperature transducers to reduce temperature inaccuracies when these instruments are used in the NERVA radiation environment. A test was conducted as part of GTR-18 to determine the magnitude of damage caused by the fast, thermal and epithermal neutrons and protons. This report describes the resistance temperature transducer test of GTR-18.

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II. EXPERIMENTAL ARRANGEMENT

The experimental arrangement of GTR-18 was reported by General Dynamics Corporation (Reference 3); therefore description is minimized in this report and is given only when necessary to clarify test results.

The RTT's were submerged in liquid hydrogen and were irradiated on the east face of the reactor. Figure 1 shows a diagram of the location of the RTT's in the Dewar. The numbers show channel identification used in the data acquisition system. The channel relationship to the RTT serial numbers is given in Table 1.

An Aerojet calibration panel and a 150-volt John Fluke power supply provided the excitation of the RTT's. The calibration panel has 24 independent circuits that contain plug-in dropping and plug-in precision resistors for regulating the current flow through the RTT's. The unit also contains variable rheostats that can be used to make fine adjustments in the RTT excitation current. The nominal current in each RTT, is tabulated in Table 1. The calibration circuit is shown in Figure 2. When the calibrator panel is set on calibration, the voltage output across the known precision resistance can be measured, and the precise current through each RTT can be determined.

The measured voltage drop across each RTT and each precision resistor comprised the data acquired during the irradiation test. A known current passing through each unit enabled the resistances of the RTT's to be obtained. The resistance versus temperature relationships for each RTT provided the indicated Dewar temperature measured by each unit.

The data were obtained with a Dymec (2010-D) digital voltmeter, and the RTT and calibration outputs were recorded on punched paper tape. Four channels (6, 12, 18, and 24) recorded the voltage output of a differential pressure transducer that monitored Dewar vapor pressure.

Liquid hydrogen calibrations for the RTT's were taken in the Dewar prior to reactor startup. The Dewar temperature was 36.45°R. Eleven values of resistance were taken for each transducer.

Figure 1 - RTT Mounting Panel Locations Viewed from Reactor

TABLE 1

RESISTANCE TEMPERATURE TRANSDUCERS IN GTR-18

<u>Channel Number</u>	<u>Type*</u>	<u>Serial No.</u>	<u>Shielding Material</u>	<u>Nominal Current, ma</u>	<u>Nominal Ice Point Resistance, ohms</u>	<u>Nominal LH2 Resistance, ohms</u>
1	134EB186	8927	Cadmium	4.5	1380	6.6
2	134EB186	12333	Cadmium	4.5	1380	6.6
3	134EB186	6317	Hafnium-Cadmium	4.5	1380	6.6
4	134EB186	12330	Hafnium-Cadmium	4.5	1380	6.6
5	134EB186	4092	Hafnium	4.5	1380	6.6
7	134EB186	12340	Hafnium	4.5	1380	6.6
8	134EB186	4094	None	4.5	1380	6.6
9	134EB186	4096	Stainless Steel	4.5	1380	6.6
10	134EB186	4104	None	4.5	1380	6.6
11	134EB186	6319	Stainless Steel	4.5	1380	6.6
13	134EB186	7365	Hafnium-Cadmium	4.5	1380	6.6
14	134EB1X	9372**	None	1	635	3.2
15	134EB2X	9371**	None	1	131	0.6
16	134EB2X	9370**	None	1	131	0.6
17	137CJ	1667***	None	10	50	0.2
19	137CJ	1666	None	10	50	0.2
20	1881-2	6149	None	1	200	1.0
21	134EB250	4107**	None	1	1380	6.6
22	110AA	211**	None	1	400	3.0
23	134EB1X	9373**	None	1	635	3.2

*All are Rosemount models except 1881-2, which is a Temtech unit.

**Irradiated in previous GTR tests.

***Transducers on Channels 17, 19, and 20 were provided by C. R. Tallman, LASL.
The remaining transducers were provided by Aerojet.

Figure 2 - RTT Calibration Circuit

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III. DATA ACQUISITION

The GTR operated at 3 megawatts during the 200-hour irradiation. Data runs were made hourly throughout the test. With a few exceptions each run was immediately preceded by a calibration run to establish the current. Each data run consisted of three complete data cycles for each of the 24 channels.

After the reactor was brought to power, it was observed that heat dissipation from the shielded units was poor. Therefore, readings were made periodically during the test with the reactor retracted so that the readings could be made with no gamma heating within the units. Thirty-five data runs were made while the reactor was retracted and 196 3-megawatt runs were taken.

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IV. DATA REDUCTION

Prior to each data run the calibrator panel was set on calibration and the Dymec recorded the voltage output through each precision resistor, R_c , for each channel. The switches were then placed on read, and three separate readings of output were taken in quick succession across all 24 channels.

The current through each RTT was obtained from the output of the calibration run and the expression:

$$I_x = \frac{(E)_c}{R_c}$$

where I_x is the excitation current, E_c is the voltage output across the precision resistor (R_c) of each channel.

The measured voltage across each RTT determined the element resistance by substitution into the expression:

$$R_x = \frac{E_o}{I_x} = \frac{E_o R_c}{E_c}$$

where E_o is the voltage drop across the RTT.

The indicated temperature read by each RTT during the test was determined by generating a resistance versus temperature table for each unit. This procedure was taken from Corruccini (Reference 4). A detailed description is given in Appendix A, and the calibrations for the units are given in Appendix B. The temperature versus resistance tables for the low temperature ranges of each channel are given in Appendix C.

Dewar gage pressure was measured with a differential pressure transducer, CEC 4-312-0002, with a range of ± 5 psid with one port referenced to atmosphere. Full-scale output was 10.995 millivolts. The voltage output of the pressure transducer was programmed on four channels of the Dymec (6, 12, 18, and 24). Barometric pressure was measured in inches of mercury for each data run and was converted to psia (0.4912 psi/(in. of Hg)).

True Dewar hydrogen temperature was related to absolute pressure by evaluating the polynomial:

$$T_r = A_0 + A_1 P + A_2 P^2 + A_3 P^3 + A_4 P^4 \quad (\text{Reference 5})$$

where T_r is the true Dewar temperature and P is the hydrogen vapor pressure. The coefficients in the polynomial are:

$$\begin{aligned} A_0 &= + 0.6428989 \times 10^2 \\ A_1 &= - 0.4059046 \times 10 \\ A_2 &= + 0.1159437 \\ A_3 &= + 0.4859399 \times 10^{-2} \\ A_4 &= - 0.1847997 \times 10^{-3} \end{aligned}$$

The polynomial was based on a least-squares to fit three vapor pressure-temperature combinations for liquid hydrogen (Reference 6), which are:

<u>T, °R</u>	<u>P, psia</u>
36.4824	14.696
37.8000	18.126
39.6000	23.7000

GTR-18 data consisted of more than 20,000 voltage output values that had to be converted to temperatures and pressures. Consequently, a computer program was written to reduce the data. This program consisted of obtaining true Dewar

hydrogen temperatures and indicated temperatures of the RTT's; determining the difference between true and indicated temperatures; and, for the three megawatt values, determining the cumulative neutron damage by subtracting the gamma heating. The zero-power level (O-PL) readings did not have gamma heating, consequently the temperature deviations (ΔT_1) for these runs indicated directly the radiation degradation, where ΔT_1 is the difference between the indicated temperature and the Dewar hydrogen temperature.

The indicated temperature for each RTT was taken as the average of three data cycle values for each run. Tables for resistance versus temperature for each RTT were programmed and linear interpolation was used between half-degree intervals.

Dewar gage pressure was obtained from the average of the 12 readings (four channels, three cycles) for each run.

Radiation-induced degradation for the three-megawatt runs was determined for two different gamma corrections: one based on gamma heating the first time the reactor was brought to power and the other based on the gamma heating determined after each reactor retraction. The latter correction did not include the radiation degradation between the high power value immediately following a reactor retraction.

The radiation temperature degradation, ΔT_2 , corrected for gamma heating of the initial 3-megawatt correction was computed from

$$\Delta T_2 = \Delta T_1 \text{ (current run, PL = 3 mw)} - \Delta T_1 \text{ (initial run, PL = 3 mw)}$$

where

$$\begin{aligned} \Delta T_2 &= \text{temperature decrement caused by radiation degradation} \\ \Delta T_1 &= \text{indicated temperature} - \text{true Dewar hydrogen temperature} \end{aligned}$$

The radiation temperature degradation corrected for gamma heating based on the most recent reactor retraction was computed from

$$\Delta T_3 = \Delta T_1 \text{ (current run, PL = 3) } - [a - b]$$

where

$$\begin{aligned}\Delta T_3 &= \text{temperature decrement caused by radiation degradation} \\ a &= \Delta T_1 \text{ (most recent run 0 PL + 1, PL = 3)} \\ b &= \Delta T_1 \text{ (most recent run, PL = 0)}\end{aligned}$$

Both methods should give the same values if test conditions are consistent. Data showed that gamma heating values varied with reactor retractions and generally decreased as the test progressed. Therefore, the values corrected by the initial power run, or ΔT_2 , gave incorrect values.

For the zero power level measurements the values of ΔT_1 give directly the nuclear degradation of platinum.

V. RADIATION EXPOSURES

Radiation exposures, except for protons, were furnished by General Dynamics (Reference 3). Fast neutron dosages ($E > 2.9$ Mev) and thermal neutron dosages ($E < 0.48$ ev) were measured inside the Dewar during the GTR-18 test. The fast neutron dosages with $E > 1$ Mev were obtained by applying a factor of 2.8 to the $E > 2.9$ Mev dosages. Gamma dosages were determined by using the neutron-to-gamma ratio established in previous experiments and by the neutron flux measurements made in GTR-18. The RTT exposures, which were reported by General Dynamics, are shown in Table 2. Estimated uncertainty of the values for both types of radiation was given as $\pm 15\%$.

The proton density in the LH_2 Dewar was estimated analytically by integrating the hydrogen-neutron reaction.

$$N' = \frac{N_H \int_{th}^{10 \text{ Mev}} \sigma(E) \phi(E) dE}{\int_{th}^{10 \text{ Mev}} E dE}$$

where:

- N' = Proton density, per cc
- N = Hydrogen atoms per cc
- $\sigma(E)$ = Neutron-proton collision cross section
- $\phi(E)$ = Neutron flux in the dewar

The neutron spectrum was taken from Reference 7, and the neutron-proton collision cross section versus neutron energy relationship was taken from Reference 8. The neutron densities were decreased by a factor of 3.5 to account for the change of Dewar location from the north to the east reactor face.

TABLE 2

RTT RADIATION EXPOSURE

Channel No.	S/N	Integrated Fast Neutron Flux, (n/cm ²)		Integrated Thermal Neutron Flux, n/cm ²	Gamma Dose, ergs/gm(C)
		E>1 Mev	E>2.9 Mev	E<0.48	
1	8927	5.26(16)	1.88(16)	5.31(16)	2.3(11)
2	12333	5.24(16)	1.87(16)	5.29(16)	2.3(11)
3	6317	4.34(16)	1.55(16)	4.38(16)	1.9(11)
4	12330	4.84(16)	1.73(16)	4.89(16)	2.1(11)
5	4092	4.34(16)	1.55(16)	4.38(16)	1.9(11)
7	12340	4.20(16)	1.50(16)	4.24(16)	1.8(11)
8	4094	5.07(16)	1.81(16)	5.11(16)	2.2(11)
9	4096	5.21(16)	1.86(16)	5.25(16)	2.3(11)
10	4104	4.98(16)	1.78(16)	5.04(16)	2.2(11)
11	6319	5.12(16)	1.83(16)	5.18(16)	2.2(11)
13	7365	5.38(16)	1.92(16)	5.43(16)	2.3(11)
14	9372	5.04(16)	1.80(16)	5.09(16)	2.2(11)
15	9371	4.96(16)	1.77(16)	5.00(16)	2.2(11)
16	9370	4.48(16)	1.60(16)	4.52(16)	1.9(11)
17	1667	5.01(16)	1.79(16)	5.06(16)	2.2(11)
19	1666	4.73(16)	1.69(16)	4.16(16)	2.1(11)
20	6149	4.68(16)	1.67(16)	4.10(16)	2.0(11)
21	4107	5.18(16)	1.85(16)	5.23(16)	2.3(11)
22	211	4.93(16)	1.76(16)	4.34(16)	2.1(11)
23	9373	4.90(16)	1.75(16)	4.31(16)	2.1(11)

The calculated value of proton density was $n_p = 5 \times 10^{10}$ protons/cm³-sec with average energy $E = 0.5$ Mev, which is the same value calculated except for the factor 3.5 in Reference 1. The change in Dewar design was not included in computing the proton density. Proton measurements were not made during the test.

The total reactor time at 3 megawatts was 200 hours.

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VI. TECHNICAL DISCUSSION

Data were acquired for three groups of transducers: those that measured the radiation effects of various particles, three development transducers, and previously irradiated RTT's.

A. DAMAGE MECHANISM STUDY

Nine Rosemount 134EB RTT sensors were modified to include shielding to measure relative damage caused by fast, thermal, and epithermal neutrons and protons. Two unmodified units were included as standards. An unmodified Rosemount 134EB probe is shown in Figure 3. The units were modified by removing the perforated cover, inserting neutron shields, and replacing the perforated cover with solid stainless steel jackets and end plates. A typical modified unit is shown in Figure 3.

A summary of the types of modifications that were made is given in Table 3. The attenuation of incident particles is also shown.

1. Proton Shields

Protons, being charged particles, have definable ranges in materials because they ionize the atoms of the materials they transverse and thereby lose most of their energy. A shield thicker than the range of protons in that material captures the incident protons.

Experimentally, the range of protons in the air can be expressed by

$$R_p \text{ (cm)} = 1.007 R_\alpha \text{ (at 3.971E)} - 0.20$$

Figure 3 - Rosemount 134EB Probes

TABLE 3

PHYSICAL DESCRIPTION OF MECHANISM OF DAMAGE STUDY
ROSEMOUNT 134EB187 PROBES

<u>Group</u>	<u>Serial Number</u>	<u>Shielding Material</u>	<u>Type of Shield</u>	<u>Shield Thickness, in.</u>	<u>Attenuation</u>
I	4096 & 6319	Stainless Steel	Proton	0.020	Black
II	8927 & 12333	[Cadmium Stainless Steel]	Thermal neutron and Proton	0.030 0.020	1.8×10^{-4} Black
III	4092 & 12340	[Hafnium Stainless Steel]	Epithermal neutron and Proton	0.030 0.020	2.9×10^{-3} Black
IV	6317 12330 7365	[Hafnium Cadmium Stainless Steel]	Epithermal neutron, Thermal neutron, and Proton	0.015 0.015 0.020	5.3×10^{-2} 1.3×10^{-2} Black

Two transmitters, (serial numbers 4094 and 4104), were unmodified and were used as control units.

where E is the proton energy in Mev and R_{α} the range of α particles in the air at 3.971 E (Reference 9). The range of α particles in the air at standard conditions is given to within 10% by

$$R_{\alpha} \text{ (cm)} = 0.56 E \text{ (Mev)} \text{ for } 0 < E < 4 \text{ Mev}$$

In substances other than air, the range of protons and α particles, expressed as areal densities, is given by

$$\bar{R} \text{ (E) mg/cm}^2 = 0.56 A^{1/3} R \text{ (E) air cm}$$

where A is the mass number of the stopping material.

Considering 0.5 Mev protons (the average energy of protons in the Dewar) the areal range in stainless steel (A = 56) is 1.97 mg/cm^2 . The linear range is $2.5 \times 10^{-4} \text{ cm}$ or $6 \times 10^{-4} \text{ inches}$. The 0.020-inch stainless steel jacket that was used around the sensing element is black to protons for energies that greatly exceed those present in the Dewar.

2. Thermal and Epithermal Neutron Shields

In contrast to charged particles, which have a definable range, neutrons and gamma rays are stopped approximately exponentially. The number of particles that are transmitted through an incident target is given by

$$n = n_0 \exp (- \sigma N X)$$

where σ is the cross section of the material, N is the density of target atoms, and X is the target thickness.

The thermal neutron cross section of cadmium is 2450 barns. The resonance integral of hafnium is 2000 barns (Reference 10).

The neutron shields for the resistance probes were 0.030-inch for two probes each of cadmium and hafnium and 0.015-inch each for two probes that contained a combination of cadmium and hafnium. The attenuation of the neutrons is as follows:

<u>Material</u>	<u>Neutron Energy</u>	<u>Thickness, in.</u>	<u>n/n_o</u>
Cadmium	Thermal	0.030	1.76×10^{-4}
		0.015	1.32×10^{-2}
Hafnium	Epithermal	0.030	2.86×10^{-3}
		0.015	5.35×10^{-2}

The symbol n_o is the incident neutron flux at the probe. The last column shows the factor of reduction of incident neutron flux at the resistance element, and the degradation, which is contributed by thermal and epithermal neutrons, is reduced by a corresponding amount in the shielded units.

3. Fast Neutrons

The most likely cause of nuclear degradation and resistivity increase at cryogenic temperature in platinum is the effect of fast neutrons, which primarily cause lattice dislocations in a metal. If, in an elastic collision, the lattice atom receives an energy (E_p) in excess of the displacement energy (E_d), it is displaced from its normal lattice site. The interaction between the incident energetic particle and the lattice atom is the primary collision. The primary "knock-on" is also of considerable importance to the damage process. The energy of the primary may be greater than E_d , which is approximately 25 ev. When this is true, the primary assumes the role of projectile and causes further atomic displacements by secondaries, and they, in turn, produce tertiaries, until the energy of each particle has been degraded so that E_d cannot be transferred in subsequent collisions. The displacement cascades account for most of the defects produced during bombardment with fast neutrons. Neutrons with energy as low as 1181 ev can produce platinum lattice

defects. The number of displacements that result from a single primary event is a function of the primary energy and is denoted by $\gamma(E_p)$.

The neutrons above 0.1 Mev are essentially a fission spectrum in GTR (Reference 5), and their average energy is 2.3 Mev. The value of $\gamma(E_p)$ is approximately 500 defects per struck atom in platinum. The fast neutron cross-section of platinum is approximately 5 barns.

With a few exceptions, the number of defects indicated by experiment are smaller than theoretical values by a factor of three to ten. This discrepancy is most pronounced for neutron bombardment. It appears that simple theory overestimates the number of displacements to be expected. However, in order to compare experimental and theoretical data, it is necessary to reduce the observed physical property to concentrations of Frenkel defects. In the case of resistivity changes in metals, this reduction requires the use of calculated relationships that cannot be readily verified by experiments (Reference 11).

A relationship of the number of defects produced that caused the platinum resistivity increase was not attempted in view of the uncertainty involved. The results are presented as a function of the neutron exposure that each sensor received.

The unmodified units received the cumulative dose from all damage mechanisms. The respective shields reduced contributory effects from the respective projectiles by the factors shown in Table 3.

B. DEVELOPMENT TRANSDUCERS

Three development transmitters provided by C. Tallman, Los Alamos, were included in the test. Two of the units were Rosemount Models 137CJ, and the other was a Temtech Model 1881-2. All transducers primarily were

developed to have low gamma-ray heating errors. All units had platinum sensing elements. The liquid hydrogen resistances were 0.25 ohm and 1 ohm for the two models, respectively. The ice-point resistances were 50 ohms for Model 137CJ and 200 ohms for Model 1881-2. In order to improve the signal, the Rosemount units were excited with 10 ma currents.

C. REIRRADIATED TRANSDUCERS

The reirradiated transducers were previously irradiated in GTR-12A and GTR-15 tests. The units exposed were Rosemount platinum resistance transducers: two 134EB1X, two 134EB2X, one 134EB, and one 110AA. Model 134EB1X was an experimental unit that contained 1.0 mil wire in the sensing elements with ice-point resistance of 635 ohms. Experimental Model 134EB2X contained 2.0 mil wire in the sensing elements with ice-point resistance of 131 ohms. Model 134EB was the standard unit with 0.7 mil wire, with ice-point resistance of 1380 ohms. Model 110AA contained 0.3 mil wire with 400 ohm ice-point resistance. Detailed descriptions of these units are given in Reference (1).

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VII. RESULTS

A. TEMPERATURE DEVIATIONS

The graphical results of the RTT irradiations are shown in Figures 4 through 25. Figures 4 through 10 show the mechanism-of-damage study temperature deviations, Figures 11 through 15 show temperature deviation of the development transducers, and Figures 15 through 25 show the reirradiated unit temperature deviations.

The graphs are plots of temperature deviation as functions of fast neutron exposure ($E > 1.0$ Mev). The zero power levels did not have gamma corrections; the 3 megawatt power values were corrected for gamma heating. Discontinuities in the data do not appear at the same abscissas because radiation doses were not equal; therefore, run numbers indicate corresponding events.

Annealing occurred when the hydrogen supply was depleted 64 hours into the test (Run 48). The RTT temperatures increased to room temperature during that period. The reactor was shut down for 29.8 hours. A lesser anneal occurred at run 189, which corresponds to the time that a LH_2 trailer change caused the Dewar liquid level to drop below the RTT's for a period of one minute.

Although no other incidents were reported by General Dynamics, other discontinuities are present on the curves. The zero power level curves show an additional break at run 161, and the 3-megawatt curves had additional breaks at runs 25 and 208.

The neutron-induced temperature deviation values of ΔT_2 , based on initial gamma heating corrections, are plotted in Figures 5, 6, 12, and 19. The plots show that there were variations in reactor placement after retractions. The variations of gamma heating with reactor retractions are tabulated in Appendix D. Although the trend was downward for gamma heating during the

Figure 4 - Temperature Deviation of Unmodified Rosemount 134EB
 RTT, Zero Power Level Values

Figure 5 - Temperature Deviation of Unmodified Rosemount 134EB
RTT, Three Megawatt Power Level Values, Channel 8,
Serial No. 4094

Figure 6 - Temperature Deviation of Unmodified Rosemount 134EB RTT, Three Megawatt Power Level Values, Channel 10, Serial No. 4104

Figure 7 - Temperature Deviation of Stainless Steel Shielded
Rosemount 134EB RTT, Zero Power Level Values

Figure 8 - Temperature Deviation of Cadmium Shielded Rosemount 134EB RTT, Zero Power Level Values

Figure 9 - Temperature Deviation of Hafnium Shielded Rosemount
 134EB RTT, Zero Power Level Values

Figure 10 - Temperature Deviation of Hafnium and Cadmium Shielded Rosemount 134EB RTT, Zero Power Level Values

Figure 11 - Temperature Deviation of Rosemount 137CJ RTT, Zero Power Level Values

Figure 12 - Temperature Deviation of Unmodified Rosemount 134EB
RTT, Three Megawatt Power Level Values, Channel 17,
Serial No. 1667

Figure 13 - Temperature Deviation of Rosemount 137CJ RTT, Three Megawatt Power Level Values, Channel 19, Serial No. 1666

Figure 14 - Temperature Deviation of Temtech 1881-2 RTT, Three Megawatt Power Levels, Channel 20, Serial No. 6149

Figure 15 - Temperature Deviation of Temtech 1881-2 RTT, Zero Power Level Values, Channel 20, Serial No. 6149

Figure 16 - Temperature Deviation of Reirradiated Rosemount 134EB
RTT, Zero Power Level Values, Channel 21, Serial No. 4107

Figure 17 - Temperature Deviation of Reirradiated Rosemount
134EB RTT, Three Megawatt Level Values, Channel 21,
Serial No. 4107

Figure 18 - Temperature Deviation of Reirradiated Rosemount 134EB1X
 RTI, Zero Power Level Values

Figure 19 - Temperature Deviation of Reirradiated Rosemount
134EB1X RTT, Three Megawatt Power Levels, Channel 14,
Serial No. 9372

Figure 20 - Temperature Deviation of Reirradiated Rosemount 134EB1X
RTT, Three Megawatt Power Level Values, Channel 23,
Serial No. 9373

Figure 21 - Temperature Deviation of Reirradiated Rosemount 134EB2X
RTT, Zero Power Level Values

Figure 22 - Temperature Deviation of Reirradiated Rosemount 134EB2X RTT, Three Megawatt Power Level Values, Channel 15, Serial No. 9371

Figure 23 - Temperature Deviation of Reirradiated Rosemount 134EB2X
RTT, Three Megawatt Power Level Values, Channel 16,
Serial No. 9370

Figure 24 - Temperature Deviation of Reirradiated Rosemount 110AA
RTT, Zero Power Level Values, Channel 22, Serial No. 211

Figure 25 - Temperature Deviation of Reirradiated Rosemount 110AA RTT,
Three Megawatt Power Level Values, Channel 22, Serial No.
211

test, all transducers did not move together for any particular run. Initial gamma heating was not typical for the total test, therefore ΔT_2 's were not used to determine final temperature deviations.

The gamma heating values are for stagnant hydrogen in an average field of 1.1×10^9 ergs/gm(C)hr (0.03 watts/gm). The average heating for Rosemount 134EB unmodified units was 0.25° , for the two Rosemount 137CJ units it was 0.33° , and for the Temtech 1881-2 unit it was 0.17° . The separate average gamma heating values are given in Table 4. The 3-megawatt values for ΔT_3 , based on gamma heating adjusted for reactor retractions, were plotted for all unmodified units and are shown in the figures. The shielded units had large gamma deviations, and subtracting the gamma heating produced erratic results, so they were omitted.

Temperature deviations for the entire test were determined by fitting the data by least squares to several straight line segments. The zero power level fits were made to four segments that fell in the ranges of runs 3-47, 70-161, 165-189, and 193-245. The 3-megawatt values were fit in five segments for the ranges of runs 1-25, 27-48, 64-188, 190-208, and 210-244. The slopes of the segments varied and possibly were the result of reactor placement variations. The temperature deviations were totaled to determine final results.

The 3-megawatt values corrected by the current gamma heating gave final values that were within the uncertainty limits of the zero power level values. The values were redundant; therefore, they were not repeated. A tabulation of the total deviations based on values taken when the reactor was retracted is given in Table 4.

The range between the minimum and maximum temperature deviations in the mechanism of damage study is 0.47° , which is smaller than twice the uncertainty ($\pm 0.35^\circ$) of the individual measurements. Differences between the transducer temperature deviations cannot be detected within the accuracy of this test.

TABLE 4

RADIATION-INDUCED TEMPERATURE ERROR LIQUID HYDROGEN IRRADIATION

Channel No.	Shielding	Serial No.	Measured		Normalized			Average Gamma Heating Rate, watts/gm	Average Gamma Heating, °F
			Integrated Neutron Flux n/cm ² x 10 ¹⁶ E >1.0 Mev	Temperature Deviation Neutron Contribution, °F	Integrated Neutron Flux n/cm ² x 10 ¹⁶ E >1.0 Mev	Temperature Deviation Neutron Contribution °F	ΔT °F		
			MECHANISM OF DAMAGE STUDY - ROSEMOUNT 134EB186						
8	None	4094	5.07	2.50	5.0	2.46 + 0.37		0.030	0.26
10	None	4104	4.98	2.49	5.0	2.50 + 0.37	2.48	0.030	0.23
9	Stainless	4096	5.20	2.33	5.0	2.24 + 0.34		0.030	- -
11	Steel	6319	5.12	2.38	5.0	2.32 + 0.35	2.28	0.030	- -
1	Cadmium	8927	5.26	2.21	5.0	2.10 + 0.32		0.032	- -
2	Cadmium	12333	5.24	2.41	5.0	2.30 + 0.34	2.20	0.032	- -
5	Hafnium	4092	4.24	2.06	5.0	2.38 + 0.36		0.026	- -
7	Hafnium	12340	4.20	2.16	5.0	2.57 + 0.39	2.48	0.026	- -
3	Hafnium	6317	4.34	2.05	5.0	2.36 + 0.35		0.026	- -
4	and	12330	4.84	2.31	5.0	2.38 + 0.36		0.026	- -
13	Cadmium	7365	5.38	2.39	5.0	2.22 + 0.33	2.32	0.026	- -
DEVELOPMENT TRANSDUCERS							ΔT =	2.35 + .03°R	
	Model								
17	Rosemount	1667	5.01	2.72	5.0	2.72 + 0.41		0.030	0.34
19	137CJ	1666	4.73	2.61	5.0	2.76 + 0.41	2.74	0.029	0.32
20	Temtech 1881-2	6149	4.68	2.83	5.0	3.02 + 0.45	3.02	0.028	0.17
ROSEMOUNT REIRRADIATED TRANSDUCERS									
14	134EB1X	9372	5.14	2.54	5.0	2.47 + 0.37		0.030	0.33
23	134EB1X	9373	4.90	2.39	5.0	2.44 + 0.37	2.46	0.029	0.36
15	134EB2X	9371	4.96	2.30	5.0	2.32 + 0.35		0.030	0.37
16	134EB2X	9370	4.48	2.51	5.0	2.78 + 0.42	2.55	0.026	0.36
21	134EB250	4107	5.18	2.65	5.0	2.56 + 0.38	2.56	0.032	0.33
22	110AA	211	4.94	4.74	5.0	4.80 + 0.72	4.80	0.029	0.10

The average degradation of the eleven 134EB's in the mechanism of damage study was 2.35°R. The standard deviation, σ , of the set of measurements is 0.13 degrees. The probable error of the mean, $[0.6745\sigma/(n-1)^{1/2}]$ is 0.03°. The average degradation is therefore:

$$\Delta\bar{T} = 2.35^{\circ}\text{R} \pm 0.03^{\circ}\text{R}$$

Channel 21 (Serial No. 4107) is a previously irradiated Rosemount 134EB. Its temperature deviation in the test indicated damage within the uncertainty limits of the new Rosemount 134EB's. The sensing elements in Models 134EB250 and 134EB186 are identical. The last three numbers refer to the probe lengths, which are 2.50- and 1.86-in., respectively.

After it was determined that the radiation damage was caused by fast neutrons, a composite graph of the zero power level values of the eleven 134EB's was prepared. The anneals during the runs were added to the succeeding data, thereby shifting the data upward so that the neutron damage results are continuous with dose. The curve is shown in Figure 26. Also shown are straight line and second order polynomial least square fits. The polynomial equation is:

$$\Delta T = a + b [\phi t / 10^{16}] + c [\phi t / 10^{16}]^2$$

for $5 \times 10^{14} < \phi t < 5 \times 10^{16} \text{ n/cm}^2$.

For $\phi t < 5 \times 10^{14} \text{ n/cm}^2$, $\Delta T = 0$.

where: ΔT = temperature deviation at liquid hydrogen
temperature caused by fast neutrons

ϕt = neutron exposure ($E > 1.0 \text{ Mev}$)

ϕ = flux $\text{n/cm}^2\text{-sec}$

t = time, sec

a, b, c = coefficients determined by least squares fit.
The values are as follow:

Figure 26 - Temperature Degradation of Rosemount 134EB RTT by Fast Neutrons at Liquid Hydrogen Temperature, Composite of 11 Units in GTR-18, Zero Power Level Values

<u>Least Squares Fit</u>	<u>a</u>	<u>b</u>	<u>c</u>
Straight line	0.062	0.462	0
Polynomial	0.036	0.498	-0.00846

The polynomial formula is recommended.

Flux limitations were placed on the foregoing expression because it represents a least-squares fit that does not vanish at zero exposure. The offset at the lower region was possibly the effect of higher fluxes during the first part of the run, as was indicated by higher gamma heating. However, dosimetry was obtained for the whole test and it was impossible to account for the differences when the data were reduced. For doses less than 5×10^{14} neutrons/cm² the effect is negligible.

The data from this test were independently reduced by personnel at General Dynamics, Fort Worth, and the results of their report (Reference 3) are not consistent with those of this report. The General Dynamics values were necessarily limited because manual calculations were required; therefore, some of the minor anneals were not apparent. The major difference was caused by the method of obtaining the value of $\Delta T/\Delta R$. The values used at General Dynamics were obtained by a straight-line relationship between liquid hydrogen and liquid neon points. The Aerojet values were based on Rosemount data fit by polynomials and evaluated at half-degree intervals. The original data of the runs, which determine the shape of Figures 4 through 25, are given in Appendix E, Table 1. The precision resistor values are tabulated in Table 2 of Appendix E, and the digital printout temperatures for the corresponding runs are given in Table 3 of Appendix E.

The resistance versus temperature relationships for each transducer, which are given in Appendix C, and the tabulations of Appendix E provide documentation of the source of values obtained in this report.

B. RESISTIVITY CHANGES

Resistivity changes as a function of neutron doses are functions of irradiation temperature and neutron spectrum. In addition, such factors as impurities, specimen preparation, and metal annealing history may produce differences.

Based on an ice-point resistance of 10.04 ohms per foot length of 0.7 mil diameter wire (furnished by Rosemount), the change of resistivity of the eleven Rosemount 134EB transducers was calculated as a function of exposure.

The ice-point resistivity was taken as 9.825×10^{-6} ohm-cm. The liquid hydrogen temperature (36.45°R) resistivity was based on the calibrations that were performed at that temperature.

The average change of resistivity of the units was found to be

$$\Delta\rho = 2.1 \times 10^{-25} \text{ (ohm-cm)/(n/cm}^2\text{)}$$

based on the results of a total dose of 5×10^{16} n/cm² ($E > 1.0$ Mev).

The standard deviation is $.1 \times 10^{-25}$.

The published work of Blewitt (Reference 11) showed the change in platinum resistivity as

$$\Delta\rho \approx .25 \times 10^{-25} \text{ (ohm-cm)/(n/cm}^2\text{)}$$

which was irradiated at LH_2 temperature in the reactor at Oak Ridge. However, calculations based on unpublished work, which Blewitt performed at Argonne National Laboratory* in tests of platinum in a well-defined neutron spectrum at liquid helium temperature, gave a value of

*Private communication with J. E. Stadig, Aerojet-General, 14 September 1966.

$$\Delta \rho \sim 4.5 \times 10^{-25} \text{ (ohm - cm)/ (n/cm}^2\text{)} \quad (E > 1.0 \text{ Mev})$$

The comparison of the latter value and the GTR-18 data is reasonable, considering that more damage is expected at the lower temperature of Blewit's irradiation.

The percentage change of resistivity ($100 \Delta R/R_{LH_2}$) was found for each transducer, and is independent of the (L/A) ratio for that transducer, where L is wire length and A is the cross-sectional wire area of the sensitive element. If the percentage change remains constant for various sizes, it may be assumed that the changes are independent of wire diameter as well as other unknown effects. The percentage changes in resistivity for transducers in GTR-18 are shown in Table 5. The results, except for the single .3 mil diameter transducer, show a spread which indicates that the radiation damage is independent of wire diameter.

C. ANNEALING EFFECTS

Temperature of irradiation has an effect on damage incurred in various metals. Coltman, et al (Reference 12) investigated isochronal annealing (3-minute annealing periods) of platinum that had been irradiated at liquid helium temperature (8°R). The results showed a step annealing peak at 36°R, which is in the region of the current irradiation. The modified units were subject to several degrees of gamma heating during irradiation that could have caused smaller damage coefficients. Table 6 shows a comparison of the average gamma heating of the GTR-18 transducers and their resultant temperature degradation arranged in descending order of element temperature during irradiation.

The data in Table 6 show that the higher irradiation temperature did not produce systematically lower temperature deviations. It is concluded that the gamma heating did not shift the defect formation-extinction equilibria to the extent that it could be detected in this test.

TABLE 5

RESISTIVITY PERCENTAGE CHANGE AS A
FUNCTION OF ELEMENT WIRE DIAMETER
 $5 \times 10^{16} \text{ n/cm}^2$, $E > 1.0 \text{ Mev}$

<u>Model</u>	<u>No. of Units</u>	<u>Average Resistivity Percentage Change</u>	<u>Range Percentage Change</u>	<u>Wire Diameter, mils</u>
Rosemount 110AA	1	50.2	- - - - -	0.3
Temtech 1881-2	1	26.5	- - - - -	0.5
Rosemount 134EB186	11	22.3	20.7 - 24.4	0.7
Rosemount 134EB250	1	21.2	- - - - -	0.7
Rosemount 134EB1X	2	23.2	22.3 - 24.2	1.0
Rosemount 137CJ	2	29.6	29.4 - 29.7	1.5
Rosemount 134EB2X	2	25.9	22.1 - 29.8	2.0

TABLE 6

EFFECT OF RADIATION TEMPERATURE ON ROSEMOUNT 134EB186 TRANSDUCERS
(LIQUID HYDROGEN TEMPERATURE $\sim 36.5^{\circ}\text{R}$)

<u>Probe No.</u>	<u>Modification</u>	<u>Average Gamma Heating, $^{\circ}\text{R}$</u>	<u>Fast Neutron Degradation, $^{\circ}\text{R}$</u>
4096	SS	13.28	2.24
12333	Cd	11.46	2.30
12340	Hf	8.28	2.57
7365	Hf-Cd	4.67	2.22
6319	SS	4.28	2.32
12330	Hf-Cd	3.84	2.38
4092	Hf	3.49	2.38
6317	Hf-Cd	2.46	2.36
8927	Cd	1.94	2.10
4094	UN	.26	2.46
4104	UN	.23	2.50

VIII. MEASUREMENT UNCERTAINTY

Measurement uncertainty was determined by the law of propagation of errors and probable errors. Errors were contributed by the system, the Dewar pressure transducer, and the dosimetry.

A. SYSTEM UNCERTAINTY

Dymec uncertainty was based on catalog information, and system uncertainty was based on the three-cycle values for individual runs. The Dymec overall basic dc accuracy for DY-2010 systems (specifications hold for $\pm 10\%$ line voltage change) is: $\pm 0.01\%$ reading, $\pm 0.005\%$ of full-scale, ± 1 digit (0 to full-scale); $\pm 0.025\%$ reading, ± 1 digit (at 3X full-scale). This basic accuracy applies to all ranges for 6 months operation and assumes daily calibration against internal standard operation at 25°C (Reference 13).

Channel accuracy was found for appropriate full-scale readings. The value of $\Delta^{\circ}\text{R}/\text{mv}$ was determined for each RTT and was multiplied by the Dymec root-sum-square (RSS) accuracy in millivolts to obtain uncertainty introduced by the Dymec.

System uncertainty was taken as the RSS spread in the cycle values of ΔT_1 for all of the zero power level runs. When these values were larger than the Dymec uncertainty they were assumed to include the Dymec accuracy. Both values are given in the tabulation of Table 7.

B. DEWAR PRESSURE TRANSDUCER

The tolerance of the Dewar pressure transducer (Model CEC) was given by General Dynamics as $\pm 1\%$ of full-scale. The range is ± 5 psig, which gives maximum error of 0.05 psi. The temperature-pressure slope of the

TABLE 7

UNCERTAINTY OF NEUTRON-INDUCED TEMPERATURE DEVIATION

Channel No.	Type	Serial No.	$\pm \Delta T, ^\circ F$				RSS Combined
			Dymec	System	Pressure Transducer	Dosimetry	
8	Rosemount	4094	0.002	0.02	0.02	0.37	0.37
10	134EB186	4104	↑	↑	↑	0.37	0.37
9		4096				0.34	0.34
11		6319				0.35	0.35
1		8927				0.32	0.32
2		12333				0.34	0.34
5		4092				0.36	0.36
7		12340				0.39	0.39
3	Rosemount	6317	↓	↓	↓	0.35	0.35
4	134EB186	12330				0.36	0.36
13		7365	0.002	0.02	0.02	0.33	0.33
17	Rosemount	1667	0.022	0.01	0.02	0.41	0.41
19	137CJ	1666	0.022	0.01	0.02	0.41	0.41
20	Temtech 1881-2	6148	0.008	0.01	0.02	0.45	0.45
14	Rosemount	9372	0.003*	0.01	0.02	0.37	0.37
23	134EB1X	9373	0.013*	0.01	↑	0.37	0.37
15	Rosemount	9371	0.007	0.02		0.35	0.35
16	134EB2X	9370	0.006	0.02		0.42	0.42
21	Rosemount	4107	0.002	0.01		0.38	0.38
	134EB250				↓		
22	Rosemount	211	0.009	0.01	0.02	0.72	0.72
	110AA						

*Difference was caused by channel 14 being read on 0.01 Dymec scale, and channel 23 being read on 0.1 Dymec scale.

hydrogen Dewar pressure is 0.384°F/psi. The temperature uncertainty caused by the pressure transducer is

$$\Delta T = \pm 0.02^{\circ}\text{F}$$

C. DOSIMETRY

General Dynamics gave the estimated uncertainty of both neutron and gamma radiation at $\pm 15\%$. The contribution to temperature deviation uncertainty is directly proportional to dosimetry uncertainty.

A tabulation of the uncertainties contributed by each component is given in Table 7. The RSS combination is the uncertainty in each RTT. The last column in Table 7 corresponds to the uncertainties placed on ΔT 's in Table 4.

The major contribution in temperature uncertainty is caused by dosimetry values. The data obtained by the 11 Rosemount 134EB transducers, with one exception, are within $\pm 10\%$ of the mean. The average normalized ΔT caused by degradation is 2.35° at exposures of $5 \times 10^{16} \text{ n/cm}^2$.

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IX. COMPENDIUM OF REIRRADIATED UNITS

Six sensors that were irradiated in GTR-12A and GTR-15 tests were reirradiated in GTR-18. Five Rosemount 134EB transmitters were irradiated in GTR-12A, of which one was reirradiated in GTR-18. The results obtained with the Rosemount 134EB's, as well as the reirradiated units, are repeated in Table 8 for comparison with GTR-18 data. The values reported in this table were not corrected for gamma heating. The Rosemount 134EB probes used in GTR-12A were identical with the GTR-18 134EB probes, except for their length.

Comparison with the present test results requires that the temperature deviations correspond to the same dosages. Temperature deviations for neutron dosages of 5×10^{16} n/cm² were obtained from the GTR-12A and GTR-15 plots of data presented by Aerojet and GD/FW (References 1, 14, 15). The deviations were corrected for gamma heating. The best estimates of the values are tabulated in Table 9. A comparison of those data with the GTR-18 data shows that the correlation between tests is poor for the reirradiated units.

The results obtained with the 143EB RTT's that were in GTR-12A include the range of the values of the 134EB results from GTR-18. The 134EB RTT's in GTR-12A had a 1 milliamper excitation, which resulted in less resolution than the values of GTR-18, which had 4.5 milliamper excitation. The uncertainty, including the $\pm 15\%$ dosimetry values that were given for GTR-18, does not account for the spread in the GTR-12A values. The RTT's in GTR-12A and GTR-15 were irradiated on the radii of a circular Dewar. The dosimeters were placed on the outside of the Dewar and the data were extrapolated to give dosages at the RTT's. The data as a function of ϕ , the angle from the reactor face, were published in References 14 and 15. When the data are plotted as a function of ϕ , it is apparent that the extrapolated values were made over a factor of 10 dose levels between the front face ($\phi = 0^\circ$) and the back of the Dewar ($\phi = 180^\circ$). According to General Dynamics* part of the spread in GTR-12A 134EB values

*Telephone communication with J. W. Guinn, General Dynamics and G. Fluke, Aerojet-General, 12 January 1967.

TABLE 8*

MAXIMUM TEMPERATURE DEVIATIONS IN PRIOR GTR TESTS

Rosemount Model	Serial No.	GTR-12A 50 Hour Test			GTR-15 100 Hour Test		
		Integrated			Integrated		
		Neutron Flux** n/cm ² x 10 ¹⁶ E>1.0 Mev	Max*** Temp, °F	Gamma Heating, °F	Neutron Flux** n/cm ² x 10 ¹⁶ E>1.0 Mev	Max Temp, °F	Gamma Heating, °F
134EB250	4081	3.7	2.2	0.5	- -		
134EB250	4079	3.4	2.4	0.56	- -		
134EB250	4080	3.7	2.7	0.56	- -		
134EB250	4087	7.1	2.9	0.56	- -		
134EB250	4107	6.8	2.9	0.69	11	2.9	0.5
134EB1X	9372	--	--	--	15	3.1	0.65
134EB1X	9373	--	--	--	18	4.0	0.62
134EB2X	9370	--	--	--	11	3.0	0.58
134EB2X	9371	--	--	--	15	3.5	0.73
110AA150	211	3.1	6.2	0.44	15	9.0	--

(Cable Opened)

*Reference 1.

**The neutron exposure of E>1.0 Mev was obtained by multiplying the dosage of E>2.1 Mev by the factor of 2.8. (Reference 3)

***Includes gamma heating.

TABLE 9

NORMALIZED TEMPERATURE DEVIATION*
 NEUTRON DOSE ($E > 1.0 \text{ Mev} = 5 \times 10^{16}$)

Rosemount Model	Serial No.	Temperature Degradation, °R		
		GTR-12A North Face	GTR-15 North Face	GTR-18 East Face
134EB250	4081	1.83	- -	- -
134EB250	4079	2.54	- -	- -
134EB250	4080	2.76	- -	- -
134EB250	4087	1.75	- -	- -
134EB250	4107	1.83	1.20	2.56
	Avg	2.14**		
	($\sigma = .44^\circ\text{R}$, Probable Error = $.15^\circ$)			
134EB1X	9372	- -	1.2	2.47
134EB1X	9373	- -	1.4	2.44
134EB2X	9370	- -	1.5	2.78
134EB2X	9371	- -	1.7	2.32
110AA150	211	Cable Opened	3.8	4.8

*Temperature deviations for neutron degradation - gamma heating subtracted

**Average ΔT of 11 134EB's in GTR-18 = 2.35°

could have been contributed by the extrapolation. The RTT's in GTR-18 were irradiated in a redesigned Dewar in a plane parallel to the reactor face. The radiation exposures were more uniform, and the measurements were considered to be more reliable.

A comparison was made of the ratio of neutron dose to gamma dose for each test and of the gamma heating rates in the three tests. This comparison (Table 10) shows that the gamma heating, which is proportional to the gamma field, is consistent between the tests for the 134EB units but not for the 134EB1X and 134EB2X units. The neutron/gamma ratios are not consistent for the three tests. The ratio of the average (n/γ) ratios for GTR-18 to GTR-15 is equal to 1.78 (4.10/2.30). The ratio of the average neutron-induced temperature deviations of GTR-15 to GTR-18 is 1.73. It is possible that inherent inaccuracies in the Dewar design and dosimetry locations of GTR-12A and GTR-15 contributed to the lack of correlation. The test fixture used in GTR-18 was designed to reduce dosimetry uncertainties.

The preceding consideration of the neutron dosages between the tests precludes any conclusions about the differences in temperature deviation being caused by subjecting the RTT units to extended radiation fields separated by long annealing periods.

TABLE 10

COMPARISON OF NEUTRON/ γ RATIO AND GAMMA HEATING
ROSEMOUNT RTT'SGTR-12A (50 Hour Test)

<u>Model</u>	<u>Serial Number</u>	Neutron Exposure E>1.0 Mev n/cm ²	Gamma Dose Ergs/gm(C)	n/ γ ratio*	Gamma Rate, w/gm	Gamma Heating ΔT , °F	Neutron Degradation ΔT E>1.0 Mev n = 5 x 10 ¹⁶ , °F
134EB250	4081	3.7(16)	1.4(11)	2.6(5)	0.073	0.5	1.83
	4079	3.4(16)	1.6(11)	2.1(5)	0.083	0.56	2.54
	4080	3.7(16)	1.4(11)	2.6(5)	0.073	0.56	2.76
	4087	7.1(16)	1.6(11)	4.4(5)	0.083	0.56	1.75
134EB250	4107	6.8(16)	1.7(11)	4.0(5)	0.089	0.60	1.83

GTR-15 (100 Hour Test)

134EB250	4107	11.0(16)	2.80(11)	3.9(5)	0.078	0.5	1.2
134EB1X	9372	15.0(16)	3.70(11)	4.0(5)	0.10	0.65	1.2
134EB1X	9373	18.0(16)	3.78(11)	4.8(5)	0.10	0.62	1.4
134EB2X	9370	11.0(16)	2.80(11)	3.9(5)	0.078	0.58	1.5
134EB2X	9371	15.0(16)	3.70(11)	4.0(5)	0.10	0.73	1.7
110AA	211	15.0(16)	3.70(11)	4.0(5)	0.10	- -	3.8

GTR-18 (200 Hour Test)

134EB250	4107	5.18(16)	2.3(11)	2.3(5)	0.032	0.33	2.6
134EB1X	9372	5.04(16)	2.2(11)	2.3(5)	0.030	0.34	2.5
134EB1X	9373	4.90(16)	2.1(11)	2.3(5)	0.029	0.36	2.4
134EB2X	9370	4.48(16)	1.9(11)	2.4(5)	0.026	0.36	2.8
134EB2X	9371	4.96(16)	2.1(11)	2.3(5)	0.030	0.37	2.3
110AA	211	4.93(16)	2.1(11)	2.3(5)	0.029	0.10	4.8
134EB186	4094	5.07(16)	2.2(11)	2.3(5)	0.030	0.26	2.5
134EB186	4104	4.98(16)	2.2(11)	2.3(5)	0.030	0.23	2.5

*The gamma dosages in GTR-18 were obtained by taking a common ratio of the neutron dosage.

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X. CONCLUSIONS

A. MECHANISM OF DAMAGE STUDY

The shields for protons and thermal and epithermal neutrons attenuated the incident flux on the sensing elements of nine Rosemount 134EB sensors by the factors shown in Table 3. Their effect on the sensing elements was reduced effectively to zero, and their contribution to the temperature deviation was determined by comparing them with the unshielded values. The temperature deviations of the shielded units were as great as the unshielded units within the uncertainty limits of the test. Therefore, it is concluded that the radiation damage of platinum resistance temperature transducers at cryogenic temperatures is caused by fast neutrons for the reactor spectrum tested. Transmutation by thermal and epithermal neutrons and defects caused by protons caused negligible temperature deviations within the accuracy of this experiment.

The nine shielded units and the two unmodified Rosemount 134EB transducers that were used to study the mechanism of damage study experienced an average temperature deviation of $2.35^{\circ}\text{F} \pm 0.03^{\circ}\text{F}$ for fast neutron exposures of $5 \times 10^{16} \text{ n/cm}^2$ ($E > 1.0 \text{ Mev}$).

B. DEVELOPMENT TRANSDUCERS

The temperature deviations of the development transducers are given in Table 4. The two identical Rosemount 134CJ units agreed with each other within 0.04°F . The temperature deviation was 2.74°F in fast neutron exposure of $5 \times 10^{16} \text{ n/cm}^2$ ($E > 1.0 \text{ Mev}$). The average gamma heating for the two Rosemount units was 0.33°F .

The temperature degradation of the Temtech 1881-2 unit was 3.02°F for a $5 \times 10^{16} \text{ n/cm}^2$ ($E > 1.0 \text{ Mev}$) exposure. The average gamma heating was 0.17°F .

All of the units showed greater temperature deviation than the Rosemount 134EB's. Their gamma heating was comparable to the unmodified 134EB's ($\Delta T_Y = 0.24^\circ$).

C. REIRRADIATED TRANSDUCERS

The temperature deviations of the reirradiated units correlated well among themselves for the GTR-18 test. That is, the two pairs of Rosemount 134EB1X and Rosemount 134EB2X were well within the allowable uncertainty of the deviations, and as previously noted, the reirradiated 134EB temperature deviation agreed with the new units.

Comparison of data with those from previous GTR test showed poor correlation, which is possibly attributable to the apparent anomaly of reported neutron exposures. On the basis of the values it must be concluded that the reirradiated units produced higher temperature deviations during the second irradiation. It is difficult to attribute this condition to physical causes because a majority of the original defects was annealed out, and a new resistance versus temperature function was generated for the RTT's, which accounted for the residual defects when the reirradiation began.

XI. REFERENCE LIST

1. W. A. Greenhow, et al., Summary Report, Resistance Temperature Transducer Irradiation Program, Aerojet-General Corporation, RN-S-0251, December 1965.
2. W. A. Greenhow, et al., Cryogenic Irradiation of Resistance Temperature Transducers for NERVA, Aerojet-General Corporation, Presented at American Nuclear Society Meeting, Washington, D. C., November 1965.
3. J. W. Guinn and L. W. Nelms, NERVA Irradiation Program, Vol. I GTR Test 18 - Components Test, General Dynamics, Fort Worth Division, FZK-310-1, 31 August 1966.
4. R. J. Corruccini, Cryogenic Temperature Measurement with Platinum Resistance Thermometers - Is Fixed-Point Calibration Adequate? NBS, Boulder Laboratories, Technical Note No. 147, 30 April 1962.
5. Final Test Report, RTT Test 23/L101 (12A), Aerojet-General Corporation, RN-S-0157, December 1964.
6. L. A. Weber, et al., "The Vapor Pressure of 20°K Equilibrium Hydrogen," Cryogenics, Vol. 2, No. 4, June 1962, pp. 236-238.
7. Pre-Irradiation Analysis of Test 23/L101, Resistance Temperature Transducers, GTR-12, Aerojet-General Corporation, RN-S-0063, March 1964.
8. Harold Etherington, Nuclear Engineering Handbook, McGraw-Hill Books Inc., 1958, pp. 5-43.
9. H. Soodak, Reactor Handbook, Vol. III, Part A, Physics, p. 30, Interscience Publishers, 1962.
10. I. Itken, Analysis of the Neutron Cross Section and Resonance Integral of Hafnium, Westinghouse, Bettles, WAPD-TM-324, Contract AT (11-1)-Gen-14.
11. D. S. Billington and J. H. Crawford, Radiation Damage in Solids, Princeton University Press, 1961, p. 114.
12. R. R. Coltman, et al., Reactor Damage in Pure Metals. Journal of Applied Physics. Vol. 33, No. 12, pp. 3509-3522, December 1962.
13. Hewlett Packard Electronic Test Instruments, Catalog No. 25, 4-16, p. 84.
14. R. L. Burtnett, et al., NERVA Components Irradiation Program, Vol. 2: GTR Tests 12 and 12A, General Dynamics/Fort Worth, FZK-184-2, 24 July 1964.
15. R. L. Burtnett, et al., NERVA Components Irradiation Program, Vol. 6, GTR Test 15, General Dynamics/Fort Worth, FZK-184-6, 19 March 1965.

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APPENDIX A

PROCEDURE FOR RESISTANCE VERSUS TEMPERATURE RELATIONSHIPS WITH THREE CALIBRATION POINTS

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Appendix A

The resistance-temperature relationships for each probe in the GTR-18 test were generated by the procedure taken from Corruccini (Reference 4). Three calibration points and two resistance versus temperature curves of standard units were required. The standard curves were taken as the 134EB relationships (R_A) and the standard platinum wire curve (R_B), both furnished by Rosemount Engineering Company.

Equation (6) is the relation by which the individual functions are generated. Tabulation of reference Curves A and B are given in Tables 1 and 2. The coefficients (equations (7) and (8)) for the transducers are given in Table 3. Three calibration points were taken at LH_2 , LNe , and LN_2 temperatures to generate the curves. The calibration points that were used are shown in Appendix B. Tables of function of resistance versus temperature for the transducers are given in Appendix C.

The value of the resistance of the probe at any temperature is given by:

$$R_X'' = R_X' - \left(\frac{R'_{3X} - R_{3X}}{R'_{3B} - R_{3B}} \right) (R'_B - R_B) \quad \text{where} \quad (1)$$

$$R'_X = R_{1X} + \left(\frac{R_{2X} - R_{1X}}{R_{2A} - R_{1A}} \right) (R_A - R_{1A}) = R_{1X} + (R_{2X} - R_{1X}) Z_A \quad (2)$$

Subscript A denotes the unit from whose calibration the reference function Z was derived. T_1 and T_2 are two calibration temperatures with resistances R_1 and R_2 . Subscript B denotes the second reference curve. Subscript 3 refers to the third calibration temperature, T_3 and R_3 .

Appendix A

$$R'_{3X} = R_{1X} + (R_{2X} - R_{1X}) / (R_{2A} - R_{1A}) [R_{3A} - R_{1A}] \quad (3)$$

$$R'_{3B} = R_{1B} + (R_{2B} - R_{1B}) / (R_{2A} - R_{1A}) [R_{3A} - R_{1A}] \quad (4)$$

$$R'_B = R_{1B} + (R_{2B} - R_{1B}) / (R_{2A} - R_{1A}) [R_A - R_{1A}] \quad (5)$$

By substitution

$$R'_X = C + (Z - XY) R_A + YR_B \quad (6)$$

where

$$C = [R_{1X} - ZR_{1A} - YR_{1B} + XYR_{1A}] ; \quad X = \frac{R_{2B} - R_{1B}}{R_{2A} - R_{1A}}; \quad Y = \frac{R'_{3X} - R_{3X}}{R'_{3B} - R_{3B}}; \quad (7)$$

$$Z = (R_{2X} - R_{1X}) / (R_{2A} - R_{1A}). \quad (8)$$

APPENDIX A - TABLE 1
RESISTANCE TEMPERATURE TRANSMITTER
ROSEMOUNT MODELS 134EB AND 134JA
REFERENCE CURVE A

T ₀ , °R	RESISTANCE - OHMS		T ₀ , °R	RESISTANCE - OHMS	
	R(T ₀)	R(T ₀ + 0.5)		R(T ₀)	R(T ₀ + 0.5)
35.00000	5.75065	6.01557	124.00000	210.00000	211.62100
36.00000	6.20114	6.57710	125.00000	212.00000	213.25016
37.00000	6.67402	7.18149	126.00000	214.00000	214.92721
38.00000	7.15002	7.82048	127.00000	216.00000	216.64255
39.00000	7.62941	8.49256	128.00000	218.00000	218.39638
40.00000	8.11254	9.20007	129.00000	220.00000	220.18802
41.00000	8.60000	9.94492	130.00000	222.00000	222.01797
42.00000	9.09250	10.72888	131.00000	224.00000	223.88577
43.00000	9.59000	11.55255	132.00000	226.00000	225.79085
44.00000	10.09250	12.41652	133.00000	228.00000	227.73277
45.00000	10.60000	13.32050	134.00000	230.00000	229.71100
46.00000	11.11250	14.26500	135.00000	232.00000	231.72597
47.00000	11.63000	15.25050	136.00000	234.00000	233.77700
48.00000	12.15250	16.27750	137.00000	236.00000	235.86450
49.00000	12.68000	17.34650	138.00000	238.00000	237.98800
50.00000	13.21250	18.45800	139.00000	240.00000	240.14700
51.00000	13.75000	19.61250	140.00000	242.00000	242.34100
52.00000	14.29250	20.81000	141.00000	244.00000	244.57000
53.00000	14.84000	22.05000	142.00000	246.00000	246.83400
54.00000	15.39250	23.33250	143.00000	248.00000	249.13250
55.00000	15.95000	24.65800	144.00000	250.00000	251.46600
56.00000	16.51250	26.02750	145.00000	252.00000	253.83450
57.00000	17.08000	27.44100	146.00000	254.00000	256.23800
58.00000	17.65250	28.90000	147.00000	256.00000	258.67650
59.00000	18.23000	30.40450	148.00000	258.00000	261.15000
60.00000	18.81250	31.95500	149.00000	260.00000	263.65800
61.00000	19.40000	33.55250	150.00000	262.00000	266.20100
62.00000	20.00000	35.19750	151.00000	264.00000	268.77900
63.00000	20.60000	36.89000	152.00000	266.00000	271.39200
64.00000	21.21250	38.63000	153.00000	268.00000	274.04000
65.00000	21.83000	40.41750	154.00000	270.00000	276.72300
66.00000	22.45250	42.25250	155.00000	272.00000	279.44100
67.00000	23.08000	44.13500	156.00000	274.00000	282.19400
68.00000	23.71250	46.06500	157.00000	276.00000	284.98200
69.00000	24.35000	48.04250	158.00000	278.00000	287.80500
70.00000	25.00000	50.06750	159.00000	280.00000	290.66300
71.00000	25.65250	52.14000	160.00000	282.00000	293.55600
72.00000	26.31000	54.26000	161.00000	284.00000	296.48400
73.00000	26.97250	56.42750	162.00000	286.00000	299.44700
74.00000	27.64000	58.64250	163.00000	288.00000	302.44500
75.00000	28.31250	60.90500	164.00000	290.00000	305.47800
76.00000	28.99000	63.21500	165.00000	292.00000	308.54600
77.00000	29.67250	65.57250			
78.00000	30.36000	67.97750			
79.00000	31.05250	70.43000			
80.00000	31.75000	72.93000			
81.00000	32.45250	75.47750			
82.00000	33.16000	78.07250			
83.00000	33.87250	80.71500			
84.00000	34.59000	83.40500			
85.00000	35.31250	86.14250			
86.00000	36.04000	88.92750			
87.00000	36.77250	91.76000			
88.00000	37.51000	94.64000			
89.00000	38.25250	97.56750			
90.00000	39.00000	100.54250			
91.00000	39.75250	103.56500			
92.00000	40.51000	106.63500			
93.00000	41.27250	109.75250			
94.00000	42.04000	112.91750			
95.00000	42.81250	116.13000			
96.00000	43.59000	119.39000			
97.00000	44.37250	122.69750			
98.00000	45.16000	126.05250			
99.00000	45.95250	129.45500			
100.00000	46.75000	132.90500			
101.00000	47.55250	136.40250			
102.00000	48.36000	140.94750			
103.00000	49.17250	145.54000			
104.00000	49.99000	150.18000			
105.00000	50.81250	154.86750			
106.00000	51.64000	159.60250			
107.00000	52.47250	164.38500			
108.00000	53.31000	169.21500			
109.00000	54.15250	174.09250			
110.00000	55.00000	179.01750			
111.00000	55.85250	183.99000			
112.00000	56.71000	189.01000			
113.00000	57.57250	194.07750			
114.00000	58.44000	199.19250			
115.00000	59.31250	204.35500			
116.00000	60.19000	209.56500			
117.00000	61.07250	214.82250			
118.00000	61.96000	220.12750			
119.00000	62.85250	225.48000			
120.00000	63.75000	230.88000			
121.00000	64.65250	236.32750			
122.00000	65.56000	241.82250			
123.00000	66.47250	247.36500			
124.00000	67.39000	252.95500			

ICE POINT REGION

APPENDIX A - TABLE 2
RESISTANCE TEMPERATURE FUNCTIONS
ROSEMOUNT PLATINUM WIRE
REFERENCE CURVE B

T ₀ , °R	RESISTANCE - OHMS		T ₀ , °R	RESISTANCE - OHMS	
	R(T ₀)	R(T ₀ + 0.5)		R(T ₀)	R(T ₀ + 0.5)
35.00000	5.62782	5.80128	12.00000	22.60100	21.12126
36.00000	6.16510	6.40066	125.00000	217.04665	212.58872
37.00000	6.74455	7.06052	126.00000	216.21607	212.95207
38.00000	7.36754	7.89517	127.00000	215.48026	222.12000
39.00000	8.03531	8.38636	128.00000	214.76806	222.60000
40.00000	8.74902	9.12342	129.00000	214.07004	222.60000
41.00000	9.50970	9.80725	130.00000	213.38500	222.60000
42.00000	10.21828	10.74081	131.00000	212.71240	222.60000
43.00000	11.07562	11.62280	132.00000	212.05130	222.60000
44.00000	12.09244	12.55460	133.00000	211.40106	222.60000
45.00000	13.27026	13.53679	134.00000	210.76131	222.60000
46.00000	14.61692	14.56893	135.00000	210.13150	222.60000
47.00000	16.13556	15.65117	136.00000	209.51058	222.60000
48.00000	17.83561	16.70000	137.00000	208.89722	222.60000
49.00000	19.72732	17.87761	138.00000	208.29121	222.60000
50.00000	21.81170	19.21710	139.00000	207.69122	222.60000
51.00000	24.09562	20.50851	140.00000	207.09622	222.60000
52.00000	26.57368	21.85191	141.00000	206.50622	222.60000
53.00000	29.25288	23.24680	142.00000	205.92122	222.60000
54.00000	32.13920	24.69329	143.00000	205.34122	222.60000
55.00000	35.23664	26.18916	144.00000	204.76622	222.60000
56.00000	38.54831	27.73201	145.00000	204.19622	222.60000
57.00000	42.07727	29.32002	146.00000	203.63122	222.60000
58.00000	45.82644	30.95811	147.00000	203.07122	222.60000
59.00000	49.79844	32.64729	148.00000	202.51622	222.60000
60.00000	53.99520	34.38767	149.00000	201.96622	222.60000
61.00000	58.42918	36.18020	150.00000	201.42122	222.60000
62.00000	63.10472	38.02551	151.00000	200.88122	222.60000
63.00000	68.02916	39.92542	152.00000	200.34622	222.60000
64.00000	73.20854	41.88002	153.00000	199.81622	222.60000
65.00000	78.64700	43.89002	154.00000	199.29122	222.60000
66.00000	84.34878	45.95501	155.00000	198.77122	222.60000
67.00000	90.31764	48.07571	156.00000	198.25622	222.60000
68.00000	96.55826	50.25152	157.00000	197.74622	222.60000
69.00000	103.07512	52.48205	158.00000	197.24122	222.60000
70.00000	109.87390	54.76758	159.00000	196.74122	222.60000
71.00000	116.95855	57.10871	160.00000	196.24622	222.60000
72.00000	124.33322	59.50571	161.00000	195.75622	222.60000
73.00000	131.99260	61.95889	162.00000	195.27122	222.60000
74.00000	139.93973	64.46816	163.00000	194.79122	222.60000
75.00000	148.17722	67.03364	164.00000	194.31622	222.60000
76.00000	156.70810	69.65541	165.00000	193.84622	222.60000
77.00000	165.53531	72.33364			
78.00000	174.66220	75.06801			
79.00000	184.09220	77.85801			
80.00000	193.82820	80.70301			
81.00000	203.87320	83.60301			
82.00000	214.22820	86.55801			
83.00000	224.89320	89.56801			
84.00000	235.86820	92.63301			
85.00000	247.15320	95.75301			
86.00000	258.74820	98.92801			
87.00000	270.65320	102.15801			
88.00000	282.86820	105.44301			
89.00000	295.39320	108.78301			
90.00000	308.22820	112.17801			
91.00000	321.37320	115.62801			
92.00000	334.82820	119.13301			
93.00000	348.59320	122.69301			
94.00000	362.66820	126.30801			
95.00000	377.05320	130.07801			
96.00000	391.74820	133.90301			
97.00000	406.75320	137.78301			
98.00000	422.06820	141.71801			
99.00000	437.69320	145.70801			
100.00000	453.62820	149.75301			
101.00000	469.87320	153.85301			
102.00000	486.42820	158.00801			
103.00000	503.29320	162.21801			
104.00000	520.46820	166.48301			
105.00000	537.95320	170.80301			
106.00000	555.74820	175.17801			
107.00000	573.85320	179.60801			
108.00000	592.26820	184.09301			
109.00000	610.99320	188.63301			
110.00000	629.92820	193.22801			
111.00000	649.07320	197.87801			
112.00000	668.42820	202.58301			
113.00000	687.99320	207.34301			
114.00000	707.76820	212.15801			
115.00000	727.75320	217.02801			
116.00000	747.94820	221.95301			
117.00000	768.35320	226.93301			
118.00000	788.96820	231.96801			
119.00000	809.79320	237.05801			
120.00000	830.82820	242.20301			
121.00000	852.07320	247.40301			
122.00000	873.52820	252.65801			
123.00000	895.19320	257.96801			

ICE POINT REGION

Appendix A Table 3

COEFFICIENTS OF CORRUCINI EQUATION

$$R_x'' = C + R_A [Z - XY] + R_B Y$$

Channel No.	Probe No.	<u>C</u>	<u>X</u>	<u>Y</u>	<u>Z</u>	<u>Z-XY</u>
1	8927	-0.349305	0.994342	-2.63621	1.01172	3.63302
2	12333	0.184201	1.05131	-0.300299	0.983775	1.29948
3	6317	-0.104816	0.994318	-1.03277	1.00261	2.02950
4	12330	0.384062	0.994356	1.80098	0.990853	-0.799958
5	4092	0.158767	0.994318	1.12614	0.993945	-0.125796
7	12340	0.537332	0.994286	3.14314	0.984919	-2.14026
8	4094	0.413911	0.994305	1.62315	0.990944	-0.622966
9	4096	0.366009	0.994355	1.48948	0.992227	-0.488849
10	4104	0.984894	0.994361	-0.271809	1.00046	1.27074
11	6319	0.135857	0.994361	0.249942	0.997504	0.748971
13	7365	0.153265	0.994361	1.90040	0.991587	-0.898093
14	9372	0.271352	0.994410	0.0360561	0.464626	0.428772
15	9371	-0.0223311	0.994410	-0.411834	0.0953262	0.504858
16	9370	-0.152940	0.994397	-1.09894	0.101616	1.19440
17	1667	-0.0174782	0.996174	0.0268866	0.0361416	0.0093579
19	1666	-0.0127946	0.996174	0.0594564	0.0360404	-0.0231886
20	6148	0.11843	0.998982	-0.151874	0.145455	0.297174
21	4107	1.43475	0.994386	1.95500	0.988495	-0.955533
22	* 211					
23	9373	-0.560255	0.994397	-5.57517	0.480511	6.02444

*A factor of 2.046 was used throughout for 110A-211.

Values based on calibration at:

	<u>T, °R</u>
LH ₂	36.45
LN ₂	~49.00
LN ₂	~139.3

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APPENDIX B

CALIBRATION OF GTR-18 PROBES

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Appendix B

The RTT's submitted by Aerojet were calibrated in the Measurements Standard Laboratory at Sacramento. Each RTT was calibrated in baths of ice water, LN_2 , and LNe , and the element resistance was measured with a Leeds and Northrup bridge. LNe points were not obtained for modified units procured immediately to GTR-18 startup. Calibrations were also supplied by the original manufacturers. Values used for generating the RTT curves were obtained from combinations where applicable.

The previously irradiated units were calibrated after GTR-15, and the calibrations are given in Reference 1. During January 1966, the reirradiated units were heated at 203°F for three periods with a total heating period of 187 hours, and the ice points were recorded. The annealing effect was small. In February 1966, the units were recalibrated before they were sent to General Dynamics, Fort Worth, for GTR-18. These calibrations are given in the following table.

The hydrogen calibration was taken at Fort Worth in the Dewar prior to reactor startup; 11 values were taken for each RTT. Dewar temperature was determined by the vapor-pressure relationship. The average output of the differential pressure transducer was 0.400 millivolt, sensitivity was 2.199 mv/psi, and the barometric pressure was 28.99-in. of mercury, or $(28.99)(0.4912 \text{ psi/in Hg}) = 14.240 \text{ psi}$. The total Dewar vapor pressure was 14.422 psia; the corresponding temperature was 36.45°R . Table 1 summarizes the calibration data.

Appendix B Table 1
CALIBRATION OF GTR-18 PROBES

Model & Ser. No.	Bath	Original Manufacturer			AGC			Value Used In R vs T Evaluation		
		Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms
Rosemount 134EB186 8927	LH ₂ LNe LN ₂ Ice	-320.81 32.0	138.86 491.67	258.84 1380.4	-410.867 -320.200 32.00	48.80 139.47 491.61	17.420 260.750 1380.400	-410.867 -320.505	36.45 48.80 139.120	6.5116* 17.420 259.80
Rosemount 134EB186 12333	LH ₂ LNe LN ₂ Ice	-411.34 -320.63 32.00	48.33 139.04 491.67	16.8292 259.4634 1380.238	-320.520 32.00	139.15 491.67	260.17 1380.10	-411.34 -320.58	36.45 48.33 139.09	6.7640* 16.829 259.82
Rosemount 134EB186 6317	LH ₂ LNe LN ₂ Ice				-410.910 -320.200 32.00	48.76 139.47 491.67	17.315 260.400 1379.200	-410.91 -320.20	36.45 48.76 139.46	6.5515* 17.315 260.400
Rosemount 134EB186 12330	LH ₂ LNe LN ₂ Ice	-411.31 -320.63 32.00	48.36 139.04 491.67	16.8912 259.4412 1380.135	-320.529 32.00	139.14 491.67	260.01 1380.65	-411.31 -320.57	36.45 48.37 139.10	6.7090* 16.892 259.72
Rosemount 134EB186 4092	LH ₂ LNe LN ₂ Ice	-320.251 32.00	491.67	260.484 1380.002	-410.908 -320.200 32.00	48.76 139.47 491.67	17.395 260.640 1380.090	-410.908 -320.226	36.45 48.76 139.45	6.5653* 17.235 260.740
Rosemount 134EB186 12340	LH ₂ LNe LN ₂ Ice	-410.97 -320.61 32.0	48.70 139.06 491.67	17.2192 259.522 1380.335	-320.512 32.00	139.16 491.67	260.16 1380.45	-410.97 -320.56	36.45 48.71 139.10	6.7043* 17.219 259.84

* Based on average of 11 values obtained at GTR prior to startup

Appendix B Table 1
CALIBRATION OF GTR-18 PROBES (cont.)

Model & Ser. No.	Bath	Original Manufacturer			AGC			Value Used In R vs T Evaluation		
		Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms
Rosemount 134EB186 4094	LH ₂ LNe LN ₂ Ice	-320.332 32.00	139.34 491.67	260.2634 1379.518	-410.917 -320.200 32.00	48.75 139.47 491.67	17.370 260.760 1379.920	-423.22 -410.917 -320.26	36.45 48.74 139.41	6.7555* 17.370 260.63
Rosemount 134EB186 4096	LH ₂ LNe LN ₂ Ice	-320.271 32.00	139.40 491.67	260.6021 1380.503	-410.863 -320.200 32.00	48.81 139.47 491.67	17.450 260.800 1380.500	-423.22 -410.863 -320.24	36.45 48.82 139.43	6.7276* 17.450 260.80
Rosemount 134EB186 4104	LH ₂ LNe LN ₂ Ice	-320.339 32.00	139.33 491.67	260.4041 1380.7166	-410.831 -320.200 32.00	48.84 139.47 491.67	17.495 260.900 1380.500	-423.22 -410.831 -320.27	36.45 48.83 139.39	6.6732* 17.495 260.65
Rosemount 134EB186 6319	LH ₂ LNe LN ₂ Ice	-320.15 32.00	139.52 491.67	260.91 1379.9	-410.835 -320.200 32.00	48.83 139.47 491.67	17.434 260.660 1380.300	-423.22 -410.835 -320.18	36.45 48.83 139.48	6.6441* 17.434 260.78
Rosemount 134EB186 7365	LH ₂ LNe LN ₂ Ice				-410.820 -410.832 -320.340 -320.519 -320.49 32.00 32.00	48.85 48.84 139.33 139.15 139.18 491.67 491.67	17.215 17.194 260.385 260.14 259.92 1380.94 1381.17	-423.22 -410.83 -320.45	36.45 48.83 139.21	6.4738* 17.20 260.15

* Based on average of 11 values obtained at GTR prior to startup

Appendix B Table 1
CALIBRATION OF GTR-18 PROBES (cont.)

Model & Ser. No.	Bath	Original Manufacturer			AGC			Value Used In R vs T Evaluation		
		Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms
Rosemount 134EB1X 9372	LH ₂	Not Applicable						-423.22	36.45	3.3099*
	LNe	Reirradiated			-410.761	48.91	8.380	-410.761	48.91	8.380
	LN ₂				-320.150	139.52	121.650	-320.150	139.52	121.65
	Ice				32.00	491.67	642.00			
Rosemount 134EB2X 9371	LH ₂	Not Applicable						-423.22	36.45	0.6394*
	LNe	Reirradiated			-410.765	48.91	1.6792	-410.765	48.91	1.6792
	LN ₂				-320.150	139.52	24.430	-320.150	139.52	24.430
	Ice				32.00	491.67	129.150			
Rosemount 134EB2X 9370	LH ₂	Not Applicable						-423.22	36.45	0.6116*
	LNe	Reirradiated			-410.805	48.87	1.710	-410.78	48.89	1.718
					-410.765	48.90	1.726			
	LN ₂				-320.150	139.52	25.200	-320.150	139.52	25.200
Rosemount 137CJ 1667	LH ₂							-423.22	36.45	0.2164*
	LNe	-240.0	59.67	1.1799**	Not Applicable (Furnished by LASL)			-240.0	59.67	1.1799**
	LN ₂	-320.340	139.33	9.4144**				-320.340	139.33	9.4144**
	Ice	32.00	491.67	50.0300						
Rosemount 137CJ 1666	LH ₂							-423.22	36.45	0.2171*
	LNe	-240.0	59.67	1.1799**	Not Applicable (Furnished by LASL)			-240.00	59.67	1.1799**
	LN ₂	-320.340	139.33	9.4144**				-320.340	139.33	9.4144**
	Ice	32.00	491.67	50.0300						
Temtech 1881-2 6148	LH ₂	-423.34	36.32	1.10	Not Applicable			-423.22	36.45	1.0887*
	LNe				(Furnished by LASL)					
	LN ₂	-320.24	139.43	38.08				-320.24	139.43	38.08
	Ice	32.00	491.67	200.63				32.0	491.67	200.63

* Based on Average of 11 values obtained at GTR prior to startup

** Not calibrations - R vs T furnished by manufacturer

Appendix B Table 1
CALIBRATION OF GTR-18 PROBES (cont.)

Model & Ser. No.	Bath	Original Manufacturer			AGC			Value Used In R vs T Evaluation		
		Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms	Temp, °F	Temp, °R	R, Ohms
Rosemount 134EB 4107	LH ₂	Not Applicable						-423.22	36.45	7.7301*
	LNe	Reirradiated			-410.845	48.83	18.380			
					-410.765	48.91	18.560	-410.80	48.87	18.47
	LN ₂				-320.150	139.52	261.700	-320.15	139.52	261.700
	Ice				32.00	491.67	1381.500			
Rosemount 110AA 211	LH ₂	Not Applicable						-423.22	36.45	3.200*
	LNe	Reirradiated			-410.820	48.85	6.500	-410.820	48.85	6.50
	LN ₂				-320.150	139.52	77.320	-320.150	139.52	77.32
	Ice				32.00	491.67	401.300			
87 Rosemount 134EB1X 9373	LH ₂	Not Applicable						-423.22	36.45	3.0892*
	LNe	Reirradiated			-410.775	48.89	8.301			
					-410.761	48.91	8.340	-410.78	48.89	8.321
	LN ₂				-319.910	139.76	119.260	-319.91	139.76	119.260
	Ice				32.00	491.67	629.50			

* Based on average of 11 values obtained at GTR prior to startup

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APPENDIX C

RESISTANCE VERSUS TEMPERATURE TABLES

Appendix C

Resistance tables as function of temperature were generated for each transducer by the method of Corruccini, Appendix A. The following tables are those which were obtained, and used in reduction of GTR-18 data.

APPENDIX C
RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 1
ROSEMOUNT 134EB187 - SERIAL NO. 8927

(1 of 10)

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.7072	35.50	5.9751
36.00	6.2545	36.50	6.5440
37.00	6.8445	37.50	7.1549
38.00	7.4764	38.50	7.8081
39.00	8.1515	39.50	8.5055
40.00	8.8717	40.50	9.2490
41.00	9.6389	41.50	10.0402
42.00	10.4548	42.50	10.8809
43.00	11.3203	43.50	11.7714
44.00	12.2362	44.50	12.7128
45.00	13.2028	45.50	13.7046
46.00	14.2202	46.50	14.7474
47.00	15.2882	47.50	15.8410
48.00	16.4831	48.50	17.0631
49.00	17.6631	49.50	18.2699
50.00	18.8969	50.50	19.5312
51.00	20.1830	51.50	20.8408
52.00	21.5218	52.50	22.2052
53.00	22.9110	53.50	23.6182
54.00	24.3508	54.50	25.0863
55.00	25.8452	55.50	26.6141
56.00	27.4068	56.50	28.1982
57.00	29.0146	57.50	29.8314
58.00	30.5088	58.50	31.3468
59.00	32.1968	59.50	33.0585
60.00	33.9322	60.50	34.8176

RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 2
ROSEMOUNT 134EB187 - SERIAL NO. 12333

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.9670	35.50	6.2322
36.00	6.5081	36.50	6.7944
37.00	7.0915	37.50	7.3992
38.00	7.7179	38.50	8.0475
39.00	8.3885	39.50	8.7407
40.00	9.1048	40.50	9.4804
41.00	9.8680	41.50	10.2675
42.00	10.6795	42.50	11.1035
43.00	11.5401	43.50	11.9888
44.00	12.4504	44.50	12.9243
45.00	13.4111	45.50	13.9103
46.00	14.4225	46.50	14.9472
47.00	15.4849	47.50	16.0352
48.00	16.6257	48.50	17.2023
49.00	17.7944	49.50	18.3572
50.00	19.0156	50.50	19.6449
51.00	20.2888	51.50	20.9432
52.00	21.6143	52.50	22.2946
53.00	22.9911	53.50	23.6965
54.00	24.4193	54.50	25.1513
55.00	25.8999	55.50	26.6583
56.00	27.4339	56.50	28.2177
57.00	29.0189	57.50	29.8288
58.00	30.5971	58.50	31.4313
59.00	32.2780	59.50	33.1370
60.00	34.0085	60.50	34.8921

APPENDIX C

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RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 3

ROSEMOUNT 134EB187 - SERIAL NO. 6317

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.7539	35.50	6.0195
36.00	6.2960	36.50	6.5828
37.00	6.8805	37.50	7.1885
38.00	7.5076	38.50	7.8372
39.00	8.1785	39.50	8.5306
40.00	8.8948	40.50	9.2702
41.00	9.6580	41.50	10.0574
42.00	10.4694	42.50	10.8934
43.00	11.3301	43.50	11.7788
44.00	12.2407	44.50	12.7146
45.00	13.2016	45.50	13.7007
46.00	14.2132	46.50	14.7377
47.00	15.2755	47.50	15.8256
48.00	16.4314	48.50	17.0081
49.00	17.6016	49.50	18.2046
50.00	18.8247	50.50	19.4545
51.00	20.0999	51.50	20.7542
52.00	21.4273	52.50	22.1074
53.00	22.8056	53.50	23.5104
54.00	24.2350	54.50	24.9669
55.00	25.7175	55.50	26.4779
56.00	27.2575	56.50	28.0424
57.00	28.8471	57.50	29.6578
58.00	30.3961	58.50	31.2301
59.00	32.0764	59.50	32.9348
60.00	33.8055	60.50	34.6881

RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 4

ROSEMOUNT 134EB187 - SERIAL NO. 12330

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.9194	35.50	6.1819
36.00	6.4546	36.50	6.7379
37.00	7.0319	37.50	7.3370
38.00	7.6531	38.50	7.9807
39.00	8.3195	39.50	8.6700
40.00	9.0320	40.50	9.4059
41.00	9.7915	41.50	10.1892
42.00	10.5987	42.50	11.0206
43.00	11.4545	43.50	11.9010
44.00	12.3596	44.50	12.8309
45.00	13.3147	45.50	13.8113
46.00	14.3204	46.50	14.8425
47.00	15.3773	47.50	15.9251
48.00	16.4690	48.50	17.0423
49.00	17.6270	49.50	18.2261
50.00	18.8365	50.50	19.4611
51.00	20.0978	51.50	20.7489
52.00	21.4108	52.50	22.0980
53.00	22.7760	53.50	23.4795
54.00	24.1932	54.50	24.9220
55.00	25.6610	55.50	26.4097
56.00	27.1696	56.50	27.9462
57.00	28.7336	57.50	29.5370
58.00	30.3871	58.50	31.2176
59.00	32.0610	59.50	32.9174
60.00	33.7866	60.50	34.6683

APPENDIX C
RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 5
ROSEMOUNT 134EB187 - SERIAL NO. 4092

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.7731	35.50	6.0364
36.00	6.3101	36.50	6.5944
37.00	6.8894	37.50	7.1952
38.00	7.5122	38.50	7.8403
39.00	8.1798	39.50	8.5309
40.00	8.8935	40.50	9.2679
41.00	9.6541	41.50	10.0524
42.00	10.4626	42.50	10.8851
43.00	11.3199	43.50	11.7671
44.00	12.2266	44.50	12.6987
45.00	13.1834	45.50	13.6808
46.00	14.1909	46.50	14.7138
47.00	15.2494	47.50	15.7980
48.00	16.3568	48.50	16.9311
49.00	17.5182	49.50	18.1184
50.00	18.7313	50.50	19.3574
51.00	19.9963	51.50	20.6485
52.00	21.3132	52.50	21.9913
53.00	22.6821	53.50	23.3861
54.00	24.1027	54.50	24.8324
55.00	25.5745	55.50	26.3262
56.00	27.0911	56.50	27.8699
57.00	28.5617	57.50	29.4671
58.00	30.2909	58.50	31.1225
59.00	31.9669	59.50	32.8241
60.00	33.6939	60.50	34.5761

RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 7
ROSEMOUNT 134EB187 - SERIAL NO. 12340

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.9185	35.50	6.1796
36.00	6.4504	36.50	6.7320
37.00	7.0242	37.50	7.3278
38.00	7.6425	38.50	7.9690
39.00	8.3066	39.50	8.6563
40.00	9.0172	40.50	9.3903
41.00	9.7748	41.50	10.1716
42.00	10.5799	42.50	11.0007
43.00	11.4333	43.50	11.8786
44.00	12.3356	44.50	12.8056
45.00	13.2878	45.50	13.7831
46.00	14.2906	46.50	14.8115
47.00	15.3447	47.50	15.8914
48.00	16.4058	48.50	16.9774
49.00	17.5579	49.50	18.1549
50.00	18.7607	50.50	19.3827
51.00	20.0152	51.50	20.6647
52.00	21.3212	52.50	21.9969
53.00	22.6800	53.50	23.3828
54.00	24.0911	54.50	24.8183
55.00	25.5518	55.50	26.2948
56.00	27.0452	56.50	27.8178
57.00	28.5968	57.50	29.3966
58.00	30.2995	58.50	31.1282
59.00	31.9702	59.50	32.8255
60.00	33.6937	60.50	34.5749

APPENDIX C

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RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 8
 ROSEMOUNT 134EB187 - SERIAL NO. 4094

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.9663	35.50	6.2289
36.00	6.5016	36.50	6.7850
37.00	7.0791	37.50	7.3842
38.00	7.7003	38.50	8.0278
39.00	8.3666	39.50	8.7170
40.00	9.0789	40.50	9.4527
41.00	9.8382	41.50	10.2358
42.00	10.6452	42.50	11.0670
43.00	11.5009	43.50	11.9472
44.00	12.4058	44.50	12.8770
45.00	13.3607	45.50	13.8572
46.00	14.3662	46.50	14.8882
47.00	15.4229	47.50	15.9705
48.00	16.5179	48.50	17.0911
49.00	17.6761	49.50	18.2750
50.00	18.8857	50.50	19.5103
51.00	20.1472	51.50	20.7982
52.00	21.4604	52.50	22.1373
53.00	22.8256	53.50	23.5268
54.00	24.2428	54.50	24.9713
55.00	25.7107	55.50	26.4597
56.00	27.2204	56.50	27.9971
57.00	28.7851	57.50	29.5885
58.00	30.4312	58.50	31.2614
59.00	32.1045	59.50	32.9606
60.00	33.8293	60.50	34.7106

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 9
 ROSEMOUNT 134EB187 - SERIAL NO. 4096

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.9374	35.50	6.2003
36.00	6.4734	36.50	6.7571
37.00	7.0515	37.50	7.3570
38.00	7.6735	38.50	8.0013
39.00	8.3404	39.50	8.6911
40.00	9.0534	40.50	9.4274
41.00	9.8133	41.50	10.2112
42.00	10.6211	42.50	11.0432
43.00	11.4775	43.50	11.9242
44.00	12.3833	44.50	12.8549
45.00	13.3391	45.50	13.8360
46.00	14.3455	46.50	14.8680
47.00	15.4031	47.50	15.9512
48.00	16.5020	48.50	17.0757
49.00	17.6615	49.50	18.2610
50.00	18.8725	50.50	19.4978
51.00	20.1354	51.50	20.7870
52.00	21.4502	52.50	22.1277
53.00	22.8170	53.50	23.5207
54.00	24.2356	54.50	24.9648
55.00	25.7052	55.50	26.4552
56.00	27.2174	56.50	27.9949
57.00	28.7843	57.50	29.5885
58.00	30.4264	58.50	31.2574
59.00	32.1012	59.50	32.9579
60.00	33.8273	60.50	34.7092

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 10
 ROSEMOUNT 134EB187 - SERIAL NO. 4104

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.8764	35.50	6.1414
36.00	6.4172	36.50	6.7034
37.00	7.0003	37.50	7.3079
38.00	7.6265	38.50	7.9559
39.00	8.2969	39.50	8.6489
40.00	9.0129	40.50	9.3883
41.00	9.7759	41.50	10.1752
42.00	10.5871	42.50	11.0109
43.00	11.4473	43.50	11.8959
44.00	12.3574	44.50	12.8311
45.00	13.3177	45.50	13.8167
46.00	14.3288	46.50	14.8532
47.00	15.3907	47.50	15.9408
48.00	16.5306	48.50	17.1070
49.00	17.6987	49.50	18.3013
50.00	18.9194	50.50	19.5485
51.00	20.1922	51.50	20.8464
52.00	21.5171	52.50	22.1972
53.00	22.8934	53.50	23.5986
54.00	24.3210	54.50	25.0528
55.00	25.8011	55.50	26.5591
56.00	27.3343	56.50	28.1177
57.00	28.9186	57.50	29.7282
58.00	30.4973	58.50	31.3312
59.00	32.1776	59.50	33.0364
60.00	33.9076	60.50	34.7905

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 11
 ROSEMOUNT 134EB187 - SERIAL NO. 6319

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.8496	35.50	6.1138
36.00	6.3887	36.50	6.6740
37.00	6.9700	37.50	7.2768
38.00	7.5946	38.50	7.9234
39.00	8.2636	39.50	8.6151
40.00	8.9784	40.50	9.3532
41.00	9.7401	41.50	10.1388
42.00	10.5498	42.50	10.9729
43.00	11.4085	43.50	11.8563
44.00	12.3168	44.50	12.7896
45.00	13.2753	45.50	13.7734
46.00	14.2844	46.50	14.8080
47.00	15.3446	47.50	15.8938
48.00	16.4717	48.50	17.0470
49.00	17.6367	49.50	18.2380
50.00	18.8539	50.50	19.4815
51.00	20.1230	51.50	20.7761
52.00	21.4443	52.50	22.1232
53.00	22.8170	53.50	23.5214
54.00	24.2412	54.50	24.9719
55.00	25.7174	55.50	26.4727
56.00	27.2436	56.50	28.0249
57.00	28.8219	57.50	29.6295
58.00	30.4186	58.50	31.2512
59.00	32.0964	59.50	32.9541
60.00	33.8243	60.50	34.7068

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 13
 ROSEMOUNT 134EB187 - SERIAL NO. 7365

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	5.6838	35.50	5.9465
36.00	6.2194	36.50	6.5029
37.00	6.7971	37.50	7.1024
38.00	7.4188	38.50	7.7466
39.00	8.0858	39.50	8.4366
40.00	8.7989	40.50	9.1732
41.00	9.5592	41.50	9.9573
42.00	10.3672	42.50	10.7894
43.00	11.2238	43.50	11.6707
44.00	12.1297	44.50	12.6015
45.00	13.0857	45.50	13.5828
46.00	14.0923	46.50	14.6150
47.00	15.1503	47.50	15.6986
48.00	16.2410	48.50	16.8148
49.00	17.3999	49.50	17.9995
50.00	18.6103	50.50	19.2355
51.00	19.8725	51.50	20.5243
52.00	21.1866	52.50	21.8644
53.00	22.5529	53.50	23.2572
54.00	23.9713	54.50	24.7008
55.00	25.4403	55.50	26.1894
56.00	26.9495	56.50	27.7267
57.00	28.5144	57.50	29.3184
58.00	30.1734	58.50	31.0047
59.00	31.8490	59.50	32.7063
60.00	33.5763	60.50	34.4550

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 21
 REIRRADIATED ROSEMOUNT 134EB250 - SERIAL NO. 4107

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	6.9422	35.50	7.2041
36.00	7.4761	36.50	7.7587
37.00	8.0520	37.50	8.3564
38.00	8.6718	38.50	8.9986
39.00	9.3367	39.50	9.6865
40.00	10.0477	40.50	10.4209
41.00	10.8057	41.50	11.2026
42.00	11.6112	42.50	12.0322
43.00	12.4652	43.50	12.9108
44.00	13.3684	44.50	13.8388
45.00	14.3215	45.50	14.8171
46.00	15.3251	46.50	15.8461
47.00	16.3798	47.50	16.9265
48.00	17.4659	48.50	18.0381
49.00	18.6213	49.50	19.2190
50.00	19.8278	50.50	20.4510
51.00	21.0861	51.50	21.7359
52.00	22.3960	52.50	23.0718
53.00	23.7580	53.50	24.4602
54.00	25.1720	54.50	25.8993
55.00	26.6364	55.50	27.3831
56.00	28.1406	56.50	28.9154
57.00	29.7004	57.50	30.5019
58.00	31.3567	58.50	32.1855
59.00	33.0273	59.50	33.8821
60.00	34.7496	60.50	35.6297

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 17
 ROSEMOUNT 137CJ - SERIAL NO. 1667

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	0.1876	35.50	0.1972
36.00	0.2072	36.50	0.2175
37.00	0.2282	37.50	0.2393
38.00	0.2508	38.50	0.2627
39.00	0.2750	39.50	0.2878
40.00	0.3009	40.50	0.3145
41.00	0.3285	41.50	0.3430
42.00	0.3578	42.50	0.3732
43.00	0.3889	43.50	0.4052
44.00	0.4218	44.50	0.4390
45.00	0.4566	45.50	0.4746
46.00	0.4931	46.50	0.5121
47.00	0.5315	47.50	0.5514
48.00	0.5720	48.50	0.5928
49.00	0.6141	49.50	0.6359
50.00	0.6582	50.50	0.6809
51.00	0.7041	51.50	0.7278
52.00	0.7519	52.50	0.7765
53.00	0.8016	53.50	0.8271
54.00	0.8532	54.50	0.8796
55.00	0.9066	55.50	0.9339
56.00	0.9617	56.50	0.9900
57.00	1.0188	57.50	1.0480
58.00	1.0774	58.50	1.1075
59.00	1.1381	59.50	1.1692
60.00	1.2008	60.50	1.2328

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 19
 ROSEMOUNT 137CJ - SERIAL NO. 1666

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	0.1885	35.50	0.1980
36.00	0.2079	36.50	0.2182
37.00	0.2288	37.50	0.2399
38.00	0.2513	38.50	0.2632
39.00	0.2755	39.50	0.2882
40.00	0.3013	40.50	0.3149
41.00	0.3289	41.50	0.3433
42.00	0.3581	42.50	0.3734
43.00	0.3891	43.50	0.4053
44.00	0.4220	44.50	0.4390
45.00	0.4566	45.50	0.4746
46.00	0.4930	46.50	0.5120
47.00	0.5313	47.50	0.5512
48.00	0.5710	48.50	0.5918
49.00	0.6130	49.50	0.6348
50.00	0.6569	50.50	0.6795
51.00	0.7026	51.50	0.7262
52.00	0.7502	52.50	0.7748
53.00	0.7997	53.50	0.8252
54.00	0.8511	54.50	0.8775
55.00	0.9044	55.50	0.9315
56.00	0.9591	56.50	0.9873
57.00	1.0158	57.50	1.0450
58.00	1.0755	58.50	1.1056
59.00	1.1362	59.50	1.1672
60.00	1.1987	60.50	1.2307

APPENDIX C
RESISTANCE VS TEMPERATURE TABLE
CALIBRATION CURVE 20

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TEMTECH 1881-2 - SERIAL NO. 6149

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	0.9727	35.50	1.0114
36.00	1.0517	36.50	1.0935
37.00	1.1369	37.50	1.1818
38.00	1.2283	38.50	1.2764
39.00	1.3261	39.50	1.3774
40.00	1.4305	40.50	1.4853
41.00	1.5418	41.50	1.6000
42.00	1.6601	42.50	1.7219
43.00	1.7856	43.50	1.8510
44.00	1.9183	44.50	1.9874
45.00	2.0584	45.50	2.1311
46.00	2.2058	46.50	2.2823
47.00	2.3607	47.50	2.4409
48.00	2.5293	48.50	2.6133
49.00	2.6998	49.50	2.7878
50.00	2.8782	50.50	2.9700
51.00	3.0640	51.50	3.1594
52.00	3.2576	52.50	3.3567
53.00	3.4585	53.50	3.5612
54.00	3.6669	54.50	3.7736
55.00	3.8830	55.50	3.9939
56.00	4.1075	56.50	4.2219
57.00	4.3393	57.50	4.4574
58.00	4.5650	58.50	4.6866
59.00	4.8100	59.50	4.9351
60.00	5.0620	60.50	5.1907

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 14
 REIRRADIATED ROSEMOUNT 134EB1X - SERIAL NO. 9372

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	2.9400	35.50	3.0631
36.00	3.1911	36.50	3.3240
37.00	3.4619	37.50	3.6048
38.00	3.7528	38.50	3.9059
39.00	4.0643	39.50	4.2280
40.00	4.3971	40.50	4.5716
41.00	4.7517	41.50	4.9374
42.00	5.1288	42.50	5.3258
43.00	5.5286	43.50	5.7371
44.00	5.9515	44.50	6.1717
45.00	6.3978	45.50	6.6297
46.00	6.8677	46.50	7.1115
47.00	7.3613	47.50	7.6170
48.00	7.8877	48.50	8.1556
49.00	8.4303	49.50	8.7103
50.00	8.9973	50.50	9.2895
51.00	9.5884	51.50	9.8925
52.00	10.2038	52.50	10.5199
53.00	10.8431	53.50	11.1710
54.00	11.5063	54.50	11.8465
55.00	12.1939	55.50	12.5457
56.00	12.9051	56.50	13.2690
57.00	13.6405	57.50	14.0160
58.00	14.3807	58.50	14.7883
59.00	15.1618	59.50	15.5611
60.00	15.9662	60.50	16.3770

RESISTANCE VS TEMPERATURE TABLE
 CALIBRATION CURVE 23
 REIRRADIATED ROSEMOUNT 134EB1X - SERIAL NO. 9373

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	2.7081	35.50	2.8353
36.00	2.9690	36.50	3.1068
37.00	3.2499	37.50	3.3964
38.00	3.5479	38.50	3.7029
39.00	3.8637	39.50	4.0281
40.00	4.1989	40.50	4.3740
41.00	4.5555	41.50	4.7417
42.00	4.9352	42.50	5.1333
43.00	5.3385	43.50	5.5483
44.00	5.7659	44.50	5.9878
45.00	6.2168	45.50	6.4503
46.00	6.6912	46.50	6.9360
47.00	7.1880	47.50	7.4444
48.00	7.8336	48.50	8.1041
49.00	8.3920	49.50	8.6757
50.00	8.9774	50.50	9.2755
51.00	9.5869	51.50	9.8926
52.00	10.2214	52.50	10.5385
53.00	10.8770	53.50	11.2024
54.00	11.5543	54.50	11.8954
55.00	12.2604	55.50	12.6300
56.00	13.0230	56.50	13.3977
57.00	13.7978	57.50	14.1826
58.00	14.3199	58.50	14.7086
59.00	15.1017	59.50	15.4989
60.00	15.9008	60.50	16.3072

APPENDIX C

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RESISTANCE VS TEMPERATURE TABLE
 CALIERATION CURVE 15
 REIRRADIATED ROSEMOUNT 134EB2X - SERIAL NO. 9371

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	0.5632	35.50	0.5884
36.00	0.6148	36.50	0.6421
37.00	0.6704	37.50	0.6997
38.00	0.7299	38.50	0.7611
39.00	0.7934	39.50	0.8266
40.00	0.8610	40.50	0.8964
41.00	0.9330	41.50	0.9706
42.00	1.0096	42.50	1.0496
43.00	1.0908	43.50	1.1332
44.00	1.1769	44.50	1.2216
45.00	1.2676	45.50	1.3147
46.00	1.3632	46.50	1.4127
47.00	1.4634	47.50	1.5153
48.00	1.5790	48.50	1.6335
49.00	1.6901	49.50	1.7471
50.00	1.8064	50.50	1.8660
51.00	1.9275	51.50	1.9893
52.00	2.0537	52.50	2.1178
53.00	2.1844	53.50	2.2507
54.00	2.3199	54.50	2.3889
55.00	2.4606	55.50	2.5332
56.00	2.6085	56.50	2.6831
57.00	2.7605	57.50	2.8373
58.00	2.8942	58.50	2.9728
59.00	3.0525	59.50	3.1332
60.00	3.2151	60.50	3.2960

RESISTANCE VS TEMPERATURE TABLE
 CALIERATION CURVE 16
 REIRRADIATED ROSEMOUNT 134EB2X - SERIAL NO. 9370

TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS	TEMPERATURE DEGREE RANKINE	RESISTANCE OHMS
35.00	0.5310	35.50	0.5579
36.00	0.5861	36.50	0.6153
37.00	0.6455	37.50	0.6765
38.00	0.7086	38.50	0.7414
39.00	0.7755	39.50	0.8103
40.00	0.8465	40.50	0.8836
41.00	0.9220	41.50	0.9615
42.00	1.0025	42.50	1.0445
43.00	1.0879	43.50	1.1324
44.00	1.1784	44.50	1.2255
45.00	1.2740	45.50	1.3234
46.00	1.3744	46.50	1.4263
47.00	1.4797	47.50	1.5340
48.00	1.6148	48.50	1.6721
49.00	1.7329	49.50	1.7930
50.00	1.8567	50.50	1.9198
51.00	1.9856	51.50	2.0504
52.00	2.1198	52.50	2.1870
53.00	2.2586	53.50	2.3276
54.00	2.4019	54.50	2.4742
55.00	2.5513	55.50	2.6294
56.00	2.7122	56.50	2.7915
57.00	2.8759	57.50	2.9573
58.00	2.9897	58.50	3.0721
59.00	3.1554	59.50	3.2397
60.00	3.3249	60.50	3.4111

APPENDIX D

GAMMA HEATING OF TRANSDUCERS

BLANK

Appendix D Table 1
GAMMA HEATING OF TRANSDUCERS

Ser. No.	Channel	Nominal Gamma Field, ergs/gm(C)hr	Gamma Heating, °F							
			Run Numbers							
			<u>1*</u>	<u>2</u>	<u>12</u>	<u>20</u>	<u>27</u>	<u>34</u>	<u>41</u>	<u>48</u>
8927	1	1.1 (9)	1.69	1.76						
12333	2	1.1 (9)	25.82	26.25						
6317	3	0.9 (9)	2.21	2.31						
12330	4	1.1 (9)	5.46	5.66						
4092	5	0.9 (9)	3.87	3.96						
12340	7	0.9 (9)	12.84	13.05						
4094	8	1.1 (9)	0.30	0.31	0.28	0.32	0.24	0.27	0.26	0.24
4096	9	1.1 (9)	13.14	13.56						
4104	10	1.1 (9)	0.26	0.27	0.24	0.27	0.17	0.27	0.24	0.23
6319	11	1.1 (9)	3.08	3.27						
7365	13	1.1 (9)	4.98	5.05						
9372	14	1.1 (9)	0.46	0.45	0.36	0.41	0.29	0.38	0.36	0.35
9371	15	1.1 (9)	0.68	0.63	0.36	0.37	0.47	0.40	0.40	0.41
9730	16	0.9 (9)	0.36	0.45	0.38	0.46	0.44	0.43	0.39	0.36
1667	17	1.1 (9)	0.41	0.43	0.41	0.41	0.47	0.39	0.37	0.39
1666	19	1.1 (9)	0.34	0.35	0.40	0.42	0.45	0.38	0.36	0.35
6148	20	1.0 (9)	-0.01	0.07	0.17	0.16	0.28	0.21	0.22	0.20
4107	21	1.1 (9)	0.45	0.43	0.39	0.41	0.41	0.37	0.33	0.33
211	22	1.1 (9)	0.12	0.18	0.13	0.13	0.08	0.07	0.06	0.05
9373	23	1.1 (9)	0.52	0.46	0.37	0.42	0.45	0.42	0.40	0.40

* Initial ∅ heating

Appendix D Table 1
GAMMA HEATING OF TRANSDUCERS (cont.)

Ser.No.	Channel	Gamma Heating, °F								
		Run Numbers								
		<u>71</u>	<u>76</u>	<u>85</u>	<u>92</u>	<u>99</u>	<u>106</u>	<u>113</u>	<u>120</u>	<u>127</u>
8927	1									
12333	2									
6317	3									
12330	4									
4092	5									
12340	7									
4094	8	0.29	0.28	0.27	0.28	0.28	0.26	0.25	0.24	0.27
4096	9									
4104	10	0.24	0.25	0.23	0.24	0.23	0.23	0.22	0.21	0.23
6319	11									
7365	13									
9372	14	0.39	0.40	0.35	0.36	0.37	0.38	0.38	0.34	0.37
9371	15	0.34	0.39	0.37	0.36	0.36	0.35	0.36	0.30	0.35
9730	16	0.37	0.40	0.38	0.36	0.38	0.37	0.34	0.27	0.37
1667	17	0.36	0.34	0.34	0.34	0.37	0.31	0.34	0.34	0.37
1666	19	0.34	0.32	0.34	0.35	0.32	0.26	0.31	0.29	0.31
6148	20	0.16	0.15	0.13	0.17	0.16	0.17	0.14	0.12	0.14
4107	21	0.37	0.38	0.38	0.34	0.36	0.34	0.34	0.33	0.34
211	22	0.13	0.14	0.09	0.12	0.12	0.11	0.12	0.11	0.10
9373	23	0.38	0.38	0.38	0.36	0.37	0.34	0.35	0.34	0.36

* Initial ∂ heating

Appendix D Table 1
GAMMA HEATING OF TRANSDUCERS (cont.)

<u>Ser.No.</u>	<u>Channel</u>	Gamma Heating, °F									
		<u>Run Numbers</u>									
		<u>134</u>	<u>141</u>	<u>148</u>	<u>155</u>	<u>162</u>	<u>166</u>	<u>170</u>	<u>174</u>	<u>178</u>	<u>182</u>
8927	1										
12333	2										
6317	3										
12330	4										
4092	5										
12340	7										
4094	8	0.27	0.23	0.25	0.27	0.28	0.26	0.28	0.27	0.26	0.25
4096	9										
4104	10	0.25	0.19	0.21	0.24	0.23	0.25	0.23	0.25	0.23	0.24
6319	11										
7365	13										
9372	14	0.37	0.33	0.38	0.37	0.35	0.37	0.37	0.34	0.33	0.33
9371	15	0.33	0.34	0.32	0.37	0.34	0.40	0.39	0.38	0.37	0.37
9370	16	0.40	0.31	0.33	0.37	0.35	0.31	0.37	0.36	0.36	0.34
1667	17	0.34	0.34	0.33	0.34	0.37	0.34	0.36	0.37	0.34	0.36
1666	19	0.32	0.33	0.29	0.34	0.33	0.36	0.33	0.35	0.33	0.33
6148	20	0.16	0.12	0.13	0.16	0.15	0.16	0.16	0.17	0.16	0.16
4107	21	0.35	0.31	0.30	0.36	0.36	0.34	0.35	0.34	0.32	0.33
211	22	0.11	0.11	0.12	0.13	0.12	0.14	0.12	0.15	0.11	0.11
9373	23	0.37	0.33	0.34	0.39	0.36	0.34	0.34	0.34	0.34	0.37

Appendix D Table 1
GAMMA HEATING OF TRANSDUCERS (cont.)

Ser.No.	Channel	Gamma Heating, °F							Average
		Run Numbers							
		186	190	194	198	202	206	210	
8927	1								
12333	2								
6317	3								
12330	4								
4092	5								
12340	7								
4094	8	0.25	0.17	0.22	0.22	0.21	0.22	0.18	0.26
4096	9								
4104	10	0.23	0.14	0.22	0.22	0.20	0.21	0.19	0.23
6319	11								
7365	13								
9372	14	0.34	0.20	0.25	0.25	0.23	0.23	0.21	0.34
9371	15	0.34	0.34	0.25	0.26	0.26	0.27	0.24	0.37
9730	16	0.40	0.44	0.27	0.23	0.23	0.30	0.20	0.36
1667	17	0.35	0.24	0.25	0.25	0.23	0.24	0.21	0.34
1666	19	0.34	0.23	0.24	0.23	0.23	0.23	0.17	0.32
6148	20	0.16	0.17	0.22	0.21	0.22	0.20	0.18	0.17
4107	21	0.32	0.21	0.21	0.22	0.21	0.21	0.18	0.33
211	22	0.10	-0.08	0.06	0.06	0.06	0.04	0.04	0.10
9373	23	0.38	0.33	0.23	0.24	0.23	0.24	0.19	0.36

APPENDIX E

TRANSDUCER IRRADIATION TEST GTR-18
ORIGINAL DATA, DYMEC PRINTOUT AND
REDUCED DATA FOR CORRESPONDING RUNS

BLANK

00102101+0200536	00202101+0200636	00302101+0212406	00402101+0200586
00502101+0200636	00602101+0010016	00702101+0200076	00802101+0201146
00902101+0314736	01002102+0218266	01102102+0200276	01202102+0012726
01302102+0204846	01402102+0650497	01502102+0017817	01602102+0200237
01702102+0617126	01802103+0000906	01902103+0014146	02002103+0006717
02102102+0224897	02202103+2102206	02302102+2501206	02402103+000606600200623
00103205+0202716	00203205+0207826	00303205+0220546	00403205+0202046
00503205+0206376	00603205+0002256	00703205+0202206	00803205+0204756
00903210+02005166	01003210+0201026	01103210+0200166	01203210+0004016
01303210+0202226	01403210+0221827	01503212+0005077	01603210+0061157
01703211+0221676	01803211+0002256	01903211+0021716	02003211+0010857
02103211+02775027	02203211+0002296	02303211+0011006	02403211+000206600300623
00103212+0200366	00203212+0207266	00303212+0200516	00403212+0202856
00503212+0206216	00603212+0003056	00703212+0202106	00803212+0204696
00903212+0204026	01003212+0201016	01103212+0200106	01203212+0202066
01303212+0202206	01403212+0231657	01503212+0065107	01603214+0061217
01703214+0021656	01803214+0003046	01903214+0021706	02003214+0108347
02103214+02775107	02203214+0002266	02303214+0021096	02403215+000304600300623
00103215+0202666	00203215+0007116	00303215+0200546	00403215+0202706
00503220+0206286	00603220+0003896	00703220+0202066	00803220+0204566
00903220+0204706	01003220+0201016	01103220+0200076	01203220+0003006
01303220+0202146	01403221+0221777	01503221+0065077	01603221+0061487
01703221+0202166	01803221+0003896	01903221+0021676	02003221+0108307
02103221+0277067	02203222+0002256	02303222+0021026	02403222+000382600300623

00017000+0300716	00017000+0300526	00017000+0312636	00017000+0300706
00017000+0300756	00017000+0317566	00017000+0300746	00017001+0301286
00017001+0314726	01017001+0318406	0117001+0300286	01217001+03012846
01317001+0304666	01417001+0650887	01517001+0301247	01617002+0930777
01717002+0650846	01817002+0010636	01017002+0875906	02017002+0907117
0217002+0325107	02217002+2501266	02317002+2500516	02417002+00096260603624
00117171+0306076	00217171+0319126	00317171+0306486	00417171+0315156
00517172+0305066	00617172+0005076	00717172+0314206	00817172+0318286
00917172+0316886	01017172+0314236	0117172+0312946	01217172+0004026
01317172+0305626	01417173+0306027	01517173+0067637	01617173+0064347
01717173+0022916	01817173+0004426	01017173+0022896	02017173+00114367
02117173+0805117	02217174+0035666	02317174+0032146	02417174+0004316047A0624
00017174+0305456	00017174+0318106	00017175+0305896	00017175+0314616
00517175+0306126	00617175+0004286	00717175+0312786	00817175+0317906
00917175+0316276	01017175+0312396	0117175+0312616	01217180+0004316
01317180+0305256	01417180+0345827	01517180+0067597	01617180+0064437
01717180+0022896	01817180+0004305	01017180+0022896	02017181+0114287
02117181+0805187	02217191+0035636	02317181+0032186	02417181+0004346047B0624
00117181+0305456	00017182+0317896	00017182+0305946	00017182+0314576
00517182+0306506	00617182+0004306	00717182+0312766	00817182+0317826
00917182+0316316	01017182+0313946	0117182+0312546	01217183+0004276
01317183+0305256	01417183+0345757	01517183+0067557	01617183+0064417
01717183+0022886	01817183+0004226	01017184+0022886	02017184+00114237
02117184+0805037	02217184+0035636	02317184+0032156	02417184+0004166047C0624

CHANNEL NO.	TIME			POLARITY	DYMEC DATA	DECIMAL
	HRS	MIN	SEC			
001	03	19	1	+	030053	6

**
 003 RUN NO.
 O CALIBRATION - 0
 O CYCLE - A, B, C
 O REACTOR POWER LEVEL
 00 MONTH
 3 DAY

00106054+0300736	00206055+0300706	00306055+0312636	00406055+0300706
00506055+0300826	00606055+0000836	00706055+0300876	00806055+0301256
00906055+0314816	01006060+0318246	01106060+0300246	01206060+0005266
01306060+0300276	01406060+0650387	01506060+0017657	01606060+0300117
01706060+0651136	01806060+0004336	01906061+0075556	02006061+0006587
02106061+0225067	02206061+2500186	02306061+2507506	02406061+0303206 07000626
00106070+0302516	00206070+0312336	00306070+0302406	00406070+0312316
00506070+0004036	00606070+0002716	00706071+0312146	00806071+0314016
00906071+0315786	01006071+0310256	01106071+0300626	01206071+0002716
01306071+0302316	01406071+0341187	01506072+0066007	01606072+0062767
01706072+0022436	01806072+0002656	01906072+0022476	02006072+0111877
02106072+0300277	02206072+0022726	02306072+0021726	02406072+0003556 07000626
00106073+0302306	00206073+0312106	00306073+0002206	00406073+0312306
00506073+0304586	00606074+0002206	00706074+0311726	00806074+0312816
00906074+0314736	01006074+0300226	01106074+0300206	01206074+0002226
01306074+0302026	01406075+0340817	01506075+0066807	01606075+0062807
01706075+0022386	01806075+0003176	01906075+0022456	02006075+0111807
02106075+0300227	02206080+0021706	02306080+0021686	02406080+0003126 07000626
00106080+0302186	00206080+0312786	00306080+0302246	00406081+0312966
00506081+0304356	00606081+0002206	00706081+0311206	00806081+0312646
00906081+0314166	01006081+0300756	01106081+0300226	01206082+0002026
01306082+0301866	01406082+0340657	01506082+0066807	01606082+0062707
01706082+0022276	01806082+0002226	01906082+0022446	02006082+0111777
02106082+0300227	02206082+0022606	02306082+0021646	02406082+0002226 07000626
00110065+0300716	00210065+0300706	00310065+0312706	00410065+0300716
00510065+0300826	00610065+0000816	00710070+0300876	00810070+0301256
00910070+0314846	01010070+0318246	01110070+0300246	01210070+0005266
01310070+0300276	01410070+0650727	01510071+0018007	01610071+0300227
01710071+0650266	01810071+0008306	01910071+0074156	02010071+0006767
02110071+0225147	02210071+2500506	02310071+2504816	02410072+0006286 16100620
00110082+0302546	00210082+0323516	00310082+0324016	00410082+0336886
00510082+0325056	00610082+0004656	00710082+0322326	00810082+0320516
00910082+0320116	01010082+0325866	01110082+0322576	01210082+0004516
01310083+0327806	01410082+0369527	01510084+0071507	01610084+0068427
01710084+0024676	01810084+0004476	01910084+0024506	02010084+0121527
02110084+0851407	02210084+0020406	02310085+0024426	02410085+0004286 16100620
00110085+0325086	00210085+0323026	00310085+0322626	00410085+0326566
00510085+0327766	00610085+0004256	00710086+0322006	00810086+0320206
00910086+0323746	01010086+0325506	01110086+0322226	01210086+0006726
01310086+0327676	01410086+0368287	01510087+0071427	01610087+0068417
01710087+0024706	01810087+0004206	01910087+0024586	02010087+0121607
02110087+0851107	02210087+0019456	02310087+0024426	02410087+0004186 16100620
00110088+0325066	00210088+0326026	00310088+0322456	00410088+0326466
00510088+0324626	00610088+0004126	00710088+0322846	00810088+0322216
00910088+0323706	01010088+0325526	01110088+0322156	01210088+0004166
01310088+0327656	01410088+0368157	01510088+0071427	01610089+0068467
01710089+0024656	01810089+0004106	01910089+0024606	02010089+0121617
02110089+0850887	02210089+0020426	02310089+0024286	02410089+0004086 16100620

00114000+0200826	00214000+0200796	00314000+0212676	00414000+0200756
00514000+0200016	00614000+0011356	00714000+0200896	00814001+0201756
00914001+0314946	01014001+0318346	01114001+0300356	01214001+0000446
01314001+0295676	01414001+0650777	01514001+0018057	01614002+0030257
01714002+0650486	01814002+0008326	01914002+0074156	02014002+0006837
02114002+0225107	02214002+2500726	02314002+2505006	02414002+000756616500620
00114013+0326386	00214013+0330026	00314013+0324816	00414013+0337026
00514013+0326246	00614014+0004546	00714014+0325016	00814014+0340526
00914014+0242086	01014014+0336986	01114014+0325476	01214014+0004436
01314014+0220156	01414015+0260547	01514015+0071677	01614015+0068067
01714015+0024926	01814015+0004286	01914015+0024686	02014015+0121027
02114015+0854767	02214015+0030706	02314020+0024616	02414020+000438616500620
00114020+0326156	00214020+0338406	00314020+0324566	00414020+0327716
00514020+0325046	00614021+0004346	00714021+0314446	00814021+0012816
00914021+0340426	01014021+0336896	01114021+0334886	01214021+0004386
01314021+0228056	01414021+0362347	01514022+0071577	01614022+0068067
01714022+0024926	01814022+0004376	01914022+0024696	02014022+0121027
02114022+0852877	02214022+0030706	02314023+0024606	02414023+000429616500620
00114023+0226006	00214023+0338266	00314023+0324406	00414023+0327606
00514023+0227266	00614023+0004286	00714024+0324106	00814024+0340356
00914024+0330246	01014024+0326576	01114024+0324426	01214025+0004246
01314025+0328956	01414025+0360207	01514025+0071557	01614025+0068447
01714025+0024786	01814025+0004226	01914025+0024706	02014025+0121027
02114030+0853617	02214030+0030606	02314030+0024566	02414030+000422616500620
00114000+0200566	00214000+0200626	00314000+0212516	00414000+0200506
00514000+0200746	00614000+0012846	00714000+0200726	00814001+0201266
00914001+0314666	01014001+0318156	01114001+0300176	01214001+0012816
01314001+0206006	01414001+0650307	01514001+0017607	01614002+0038867
01714002+0649716	01814002+0010506	01914002+0074486	02014002+0006407
02114002+0224257	02214002+2499856	02314002+2503866	02414002+000045618000620
00114012+0333066	00214012+0247276	00314012+0331826	00414012+0345806
00514012+0332646	00614012+0006846	00714012+0242566	00814012+0348856
00914012+0220856	01014012+0245236	01114012+0243776	01214012+0006786
01314012+0325706	01414014+0378277	01514014+0070077	01614014+0070507
01714014+0225506	01814014+0006506	01914014+0025466	02014014+0124867
02114014+0873447	02214015+0004126	02314015+0035426	02414015+000641618000620
00114015+0222406	00214015+0346616	00314015+0331286	00414015+0245126
00514015+0322946	00614020+0006226	00714020+0241606	00814020+0348476
00914020+0348476	01014020+0244856	01114020+0242856	01214020+0006146
01314020+0325216	01414021+0371857	01514021+0072987	01614021+0070297
01714021+0025496	01814021+0006076	01914021+0025456	02014021+0124947
02114021+0872647	02214021+0004106	02314022+0035376	02414022+000604618000620
00114022+0333226	00214022+0346126	00314022+0311146	00414023+0245126
00514022+0322426	00614022+0005986	00714024+0241116	00814024+0348216
00914024+0346756	01014024+0344746	01114024+0342236	01214024+0005046
01314024+0324086	01414024+0377527	01514025+0072847	01614025+0070237
01714025+0025476	01814025+0005016	01914025+0025426	02014025+0124917
02114025+0872207	02214025+0004176	02314030+0025346	02414030+000588618000620

00118000+0300716	00218000+0300726	00318000+0312616	00418000+0300676
00518000+0300806	00618000+0013126	00718000+0300786	00818001+0301206
00918001+0314686	01018001+0318206	01118001+0300216	01218001+0010546
01318001+02904136	01418001+0650467	01518001+0017507	01618002+0228047
01718002+0640776	01818002+0000666	01918002+0276326	02018002+0206537
02118002+0224837	02218002+2500156	02318002+2504146	02418002+000890610300630
00118012+0333716	00218012+0347956	00318012+0321686	00418012+0346256
00518012+0333266	00618012+0006106	00718012+0243026	00818013+0347846
00918013+0251416	01018013+0242506	01118013+0244246	01218013+0006156
01318013+0236206	01418013+0277377	01518013+0013137	01618013+0070667
01718014+0225576	01818014+0006126	01918014+0025506	02018014+0125297
02118014+0874017	02218014+0041056	02318014+0035486	02418014+000610610300630
00118015+0333526	00218015+0347386	00318015+0331506	00418015+0346196
00518015+0332886	00618015+0006176	00718020+0342446	00818020+0347946
00918020+0340236	01018020+0343626	01118020+0342726	01218020+0006206
01318020+0336156	01418020+0377527	01518020+0073027	01618021+0070657
01718021+0225586	01818021+0006266	01918021+0025476	02018021+0125257
02118021+0874007	02218021+0041026	02318021+0035496	02418022+000627610300630
00118022+0332906	00218022+0347146	00318022+0331376	00418022+0346056
00518022+0332626	00618022+0006216	00718022+0342096	00818023+0347816
00918023+0327086	01018022+0343616	01118023+0343346	01218023+0006206
01318023+0336076	01418023+0377307	01518024+0073117	01618024+0070257
01718024+0225596	01818024+0006246	01918024+0025506	02018024+0125227
02118024+0874837	02218024+0041026	02318025+0035426	02418025+000620610300630
001200400+0300776	002200400+0300846	003200400+0312726	004200400+0300786
005200400+0300876	006200400+0008876	007200400+0300806	008200401+0301286
009200401+0314016	010200401+0318276	011200401+0300216	012200401+0008146
013200401+0290976	014200401+0650657	015200401+0018027	016200402+0230217
017200402+0640926	018200402+0007836	019200402+0077006	020200402+0206047
021200402+0225167	022200402+2501036	023200402+2505086	024200402+000771624500702
00120344+0318096	00220344+0363686	00320345+0345806	00420345+0362066
00520345+0347186	00620345+0007126	00720345+0356876	00820345+0355036
00920345+0364176	01020345+0361186	01120350+0360136	01220350+0007126
01320350+0352186	01420350+0395937	01520350+0076327	01620350+0074497
01720350+0026096	01820350+0007056	01920350+0026806	02020351+0121567
02120351+0014017	02220351+0044206	02320351+0027196	02420351+000709624500702
00120344+0348006	00220344+0363686	00320345+0345806	00420345+0362066
00520345+0347186	00620345+0007126	00720345+0356876	00820345+0355036
00920345+0364176	01020345+0361186	01120350+0360136	01220350+0007126
01320350+0352186	01420350+0395937	01520350+0076327	01620350+0074497
01720350+0026096	01820350+0007056	01920350+0026806	02020351+0121567
02120351+0014017	02220351+0044206	02320351+0027196	02420351+000709624500702
00120344+0348006	00220344+0363686	00320345+0345806	00420345+0362066
00520345+0347186	00620345+0007126	00720345+0356876	00820345+0355036
00920345+0364176	01020345+0361186	01120350+0360136	01220350+0007126
01320350+0352186	01420350+0395937	01520350+0076327	01620350+0074497
01720350+0026096	01820350+0007056	01920350+0026806	02020351+0121567
02120351+0014017	02220351+0044206	02320351+0027196	02420351+000709624500702

001002151+02000516	002002151+02000346	003002151+0312466	004002152+03000516
005002152+03000506	006002152+0015076	007002152+03000606	008002152+0301126
009002152+0314587	010002152+0318246	011002152+03000236	012002152+03000016
013002152+03000006	014002152+0650407	015002152+0017827	016002152+03000007
017002152+0648146	018002152+0017436	019002152+0974716	020002152+03006657
021002152+0224067	022002152+0402786	023002152+2504066	024002152+001174600100623
001002151+0340616	002002151+1703306	003002151+0357846	004002152+0471206
005002152+01000346	006002152+0006576	007002152+0700766	008002152+0312346
009002152+0321276	010002152+0307846	011002152+0300766	012002152+0006576
013002152+0445086	014002152+0342327	015002152+0067047	016002152+0063127
017002152+0022446	018002152+0006466	019002152+0022456	020002152+0100027
021002152+0700007	022002152+0022406	023002152+0022406	024002152+000647600183623
001002152+0341146	002002152+1714106	003002152+0356646	004002152+0475176
005002152+0412086	006002152+0006446	007002152+0800786	008002152+0312006
009002152+0320276	010002152+0307056	011002152+0308716	012002152+0006406
013002152+0446586	014002152+0314037	015002152+0067017	016002152+0063577
017002152+0022476	018002152+0006456	019002152+0022256	020002152+0100027
021002152+0700007	022002152+0022436	023002152+0022406	024002152+000630600103623
001002152+0341256	002002152+1727406	003002152+0350456	004002152+0475076
005002152+0412176	006002152+0006286	007002152+0810066	008002152+0312126
009002152+0820066	010002152+0307616	011002152+0300516	012002152+0006276
013002152+0447026	014002152+0343717	015002152+0067867	016002152+0063507
017002152+0022466	018002152+0006266	019002152+0022456	020002152+0108607
021002152+0700007	022002152+0022376	023002152+0022386	024002152+000620600103623
00110000+03000626	00210000+03000626	00310000+0312546	00410000+0300086
00510000+03000726	00610000+0312026	00710000+03000606	00810001+0301246
00910001+0314606	01010001+0318136	01110001+03000146	01210001+0011136
01310001+03004476	01410001+0650347	01510001+0017657	01610002+0300857
01710002+06480476	01810002+0000856	01910002+0075546	02010002+03006327
02110002+0324057	02210002+2400056	02310002+2503016	02410002+00088860000701
00110012+0340086	00210012+0356246	00310012+0327016	00410012+0353816
00510012+0340056	00610012+0006066	00710012+0350516	00810012+0354206
00910012+0361136	01010012+0350226	01110012+0351026	01210012+0006026
01310012+0344106	01410012+0384647	01510012+0074007	01610014+0072007
01710014+0026166	01810014+0006806	01910014+0026036	02010014+0127507
02110014+0088027	02210014+0042266	02310014+0026156	02410015+000660600080701
00110015+0322066	00210015+0357626	00310015+0327426	00410015+0357466
00510015+0322076	00610015+0006416	00710020+0340676	00810020+0354016
00910020+0358016	01010020+0340886	01110020+0351026	01210020+0006336
01310020+0342866	01410020+0384007	01510020+0074007	01610021+0071857
01710021+0026116	01810021+0006256	01910021+0026026	02010021+0127487
02110021+0088027	02210021+0012226	02310021+0026126	02410022+00062260000701
00110022+0322066	00210022+0355106	00310022+0327186	00410022+0353206
00510022+0322066	00610022+0006186	00710022+0340186	00810022+0353866
00910022+0357526	01010022+0340776	01110022+0350516	01210022+0006226
01310022+0343606	01410022+0383867	01510022+0074007	01610024+0071877
01710024+0026086	01810024+0006186	01910024+0025086	02010024+0127407
02110024+0088007	02210024+0042226	02310024+0026006	02410024+00061060000701

00111000+0300636	00211000+0300636	00311000+0312556	00411000+0300586
00511000+0300706	00611000+0011476	00711000+0300716	00811001+0301286
00911001+0314626	01011001+0318146	01111001+0300136	01211001+0010706
01311001+0204496	01411001+0650427	01511001+0917627	01611002+0038807
01711002+0640466	01811002+0010456	01911002+0075526	02011002+0006257
02111002+0224867	02211002+2500026	02311002+2504026	02411002+001023621002701
00111011+0403876	00211011+0653616	00311011+0417106	00411011+0455096
00511011+0446666	00611011+0000616	00711012+0508286	00811012+0360256
00911012+0026486	01011012+0356276	01111012+0517456	01211012+0002416
01311012+0494346	01411012+0391447	01511012+0075697	01611012+0073457
01711013+0026676	01811013+00009216	01911013+0026476	02011013+0129447
02111013+0002147	02211013+0042466	02311013+0036786	02411014+000904621002701
00111014+0403496	00211014+0652856	00311014+0416346	00411015+0454076
00511015+0445816	00611015+0008806	00711015+0507296	00811015+0352046
00911015+0026086	01011015+0355046	01111015+0517486	01211020+0008926
01311020+0404206	01411020+0391147	01511020+0075567	01611020+0073327
01711020+0026626	01811020+00008786	01911020+0026456	02011020+0129407
02111021+0001637	02211021+0042436	02311021+0036766	02411021+000875621002701
00111021+0403246	00211021+0651066	00311022+0416366	00411022+0454846
00511022+0445886	00611022+0008726	00711022+0507626	00811022+0350876
00911022+0026846	01011022+0355706	01111022+0517026	01211023+0008706
01311023+0494006	01411023+0391107	01511023+0075677	01611023+0073247
01711023+0026646	01811023+00008696	01911023+0026456	02011024+0129587
02111024+0001617	02211024+0042416	02311024+0036776	02411024+000864621002701
00120300+0300676	00220300+0300696	00320300+0312606	00420300+0300676
00520300+0300766	00620300+0011866	00720300+0300776	00820301+0301206
00920301+0314656	01020301+0318176	01120301+0300186	01220301+0011226
01320301+0204866	01420301+0650407	01520301+0917637	01620302+0038917
01720302+0640156	01820302+0010306	01920302+0076626	02020302+0006457
02120302+0224067	02220302+2500216	02320302+2504106	02420302+001074621002701
00120310+0400166	00220310+0658086	00320310+0421086	00420310+0460206
00520311+0450716	00620311+0000606	00720311+0602506	00820311+0360686
00920311+0056496	01020311+0366306	01120311+0531246	01220311+0000626
01320311+0407406	01420312+0401677	01520312+0077627	01620312+0075487
01720312+0027516	01820312+0000526	01920312+0027226	02020312+0132267
02120312+0025127	02220313+0044486	02320313+0027776	02420313+000951621002701
00120313+0400196	00220313+0658866	00320314+0422016	00420314+0460706
00520314+0450876	00620314+0000366	00720314+0602186	00820314+0360276
00920314+0056036	01020314+0366156	01120314+0531426	01220315+0000276
01320315+0497356	01420315+0401637	01520315+0077607	01620315+0075407
01720315+0027466	01820315+0000356	01920315+0027206	02020320+0132437
02120320+0024827	02220320+0044486	02320320+0037766	02420320+000923621002701
00120320+0400106	00220321+0658666	00320321+0421026	00420321+0460746
00520321+0450656	00620321+0000296	00720321+0602056	00820321+0360946
00920321+0055726	01020321+0366106	01120322+0531086	01220322+0000206
01320322+0497286	01420322+0401567	01520322+0077507	01620322+0075507
01720322+0027666	01820322+0000236	01920322+0027316	02020323+0132447
02120323+0024627	02220323+0044466	02320322+0037756	02420323+000921621002701

Appendix E Table 2
PRECISION RESISTORS (R_c) FOR EACH CHANNEL

<u>Channel No.</u>	<u>RTT Model</u>	<u>Serial No.</u>	<u>Precision Resistance, ohms</u>
1	134EB	8927	6.6806
2	134EB	12333	6.6823
3	134EB	6317	6.9454
4	134EB	12330	6.6814
5	134EB	4092	6.6826
7	134EB	12340	6.6841
8	134EB	4094	6.6938
9	134EB	4096	6.9939
10	134EB	4104	7.0734
11	134EB	6319	6.8738
13	134EB	7365	6.530
14	134EB1X	9372	6.506
15	134EB2X	9371	9.179
16	134EB2X	9370	9.393
17	137CJ	1667	6.510
19	137CJ	1666	9.7677
20	1881-2	6149	9.0687
21	134EB	4107	2.2517
22	110AA	211	250.042
23	134EB1X	9373	250.467

APPENDIX E - TABLE 3
AEROJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(1 of 8)

RUN 3		6-23-66		POWER LEVEL = 0 MEGAWATTS				TRUE TEMPERATURE = 36.45 DEG-R			
CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	3.35	8927	CD	36.48	36.48	36.48	36.48	0.03	0.	0.	1.10
2	3.35	12333	CD	36.58	36.56	36.55	36.57	0.12	0.	0.	1.10
3	3.35	6317	HC	36.48	36.48	36.47	36.48	0.03	0.	0.	1.10
4	3.35	12330	HC	36.49	36.49	36.49	36.49	0.04	0.	0.	1.10
5	3.35	4092	HF	36.49	36.49	36.49	36.49	0.04	0.	0.	1.10
7	3.35	12340	HF	36.52	36.51	36.50	36.51	0.06	0.	0.	1.10
8	3.35	4094	UN	36.48	36.48	36.47	36.48	0.03	0.	0.	1.10
9	3.35	4096	SS	36.54	36.53	36.52	36.53	0.08	0.	0.	1.10
10	3.35	4104	UN	36.48	36.48	36.48	36.48	0.03	0.	0.	1.10
11	3.35	6319	SS	36.50	36.49	36.49	36.49	0.04	0.	0.	1.10
13	3.35	7365	HC	36.48	36.48	36.47	36.48	0.03	0.	0.	1.10
14	3.35	9372	UN	36.48	36.47	36.48	36.48	0.03	0.	0.	1.10
15	3.35	9371	UN	36.66	36.66	36.66	36.66	0.21	0.	0.	1.10
16	3.35	9370	UN	36.50	36.48	36.51	36.49	0.04	0.	0.	1.10
17	3.35	137CJ	UN	36.52	36.51	36.50	36.51	0.06	0.	0.	1.10
19	3.35	137CJ	UN	36.48	36.47	36.46	36.47	0.02	0.	0.	1.10
20	3.35	1881-2	UN	36.41	36.39	36.40	36.40	-0.05	0.	0.	1.10
21	3.35	4107	UN	36.50	36.51	36.50	36.50	0.05	0.	0.	1.10
22	3.35	211	UN	36.55	36.54	36.54	36.54	0.09	0.	0.	1.10
23	3.35	9373	UN	36.53	36.53	36.53	36.53	0.08	0.	0.	1.10

AVERAGE DELTA-T,S FOR RUN 3

AVERAGE TIME FROM START = 1.10 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	0.07	0.03	0.05	0.03	0.06	0.05	0.13	0.04
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=3MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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APPENDIX E - TABLE 3 - CONTINUED
AEROJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(2 of 8)

RUN 47 6-24-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.45 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	17.28	8927	CD	36.93	36.91	36.91	36.91	0.46	0.	0.	39.03
2	17.28	12333	CD	37.01	36.97	36.96	36.98	0.53	0.	0.	39.03
3	17.28	6317	HC	36.88	36.86	36.86	36.87	0.42	0.	0.	39.03
4	17.28	12330	HC	36.95	36.93	36.93	36.94	0.49	0.	0.	39.03
5	17.28	4092	HF	36.89	36.87	36.87	36.87	0.42	0.	0.	39.03
7	17.28	12340	HF	36.94	36.92	36.92	36.92	0.47	0.	0.	39.03
8	17.28	4094	UN	36.99	36.97	36.97	36.98	0.53	0.	0.	39.03
9	17.28	4096	SS	36.98	36.97	36.96	36.97	0.52	0.	0.	39.03
10	17.28	4104	UN	36.97	36.96	36.96	36.96	0.51	0.	0.	39.03
11	17.28	6319	SS	36.97	36.96	36.96	36.96	0.51	0.	0.	39.03
13	17.30	7365	HC	36.96	36.95	36.95	36.95	0.50	0.	0.	39.05
14	17.30	9372	UN	36.99	36.98	36.98	36.98	0.53	0.	0.	39.05
15	17.30	9371	UN	37.10	37.09	37.09	37.09	0.64	0.	0.	39.05
16	17.30	9370	UN	36.97	36.99	36.98	36.98	0.53	0.	0.	39.05
17	17.30	137CJ	UN	37.04	37.04	37.03	37.04	0.59	0.	0.	39.05
19	17.30	137CJ	UN	37.01	37.01	37.01	37.01	0.56	0.	0.	39.05
20	17.30	1881-2	UN	37.07	37.06	37.06	37.07	0.62	0.	0.	39.05
21	17.30	4107	UN	37.00	37.00	37.00	37.00	0.55	0.	0.	39.05
22	17.30	211	UN	37.68	37.67	37.67	37.67	1.22	0.	0.	39.05
23	17.30	9373	UN	36.89	36.90	36.89	36.90	0.44	0.	0.	39.05

AVERAGE DELTA-T.S FOR RUN 47

AVERAGE TIME FROM START = 39.04 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	0.50	0.47	0.45	0.52	0.52	0.49	0.59	0.57
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

APPENDIX E - TABLE 3 - CONTINUED
AEROJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(3 of 8)

RUN 70 6-26-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.46 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	6.12	8927	CD	36.80	36.79	36.79	36.79	0.34	0.	0.	51.87
2	6.12	12333	CD	36.78	36.77	36.76	36.77	0.32	0.	0.	51.87
3	6.12	6317	HC	36.77	36.76	36.75	36.76	0.31	0.	0.	51.87
4	6.12	12330	HC	36.88	36.87	36.87	36.87	0.42	0.	0.	51.87
5	6.12	4092	HF	36.81	36.79	36.78	36.79	0.34	0.	0.	51.87
7	6.12	12340	HF	36.85	36.83	36.82	36.83	0.38	0.	0.	51.87
8	6.12	4094	UN	36.93	36.82	36.81	36.82	0.36	0.	0.	51.87
9	6.12	4096	SS	36.94	36.90	36.88	36.91	0.45	0.	0.	51.87
10	6.12	4104	UN	36.83	36.81	36.81	36.82	0.36	0.	0.	51.87
11	6.12	6319	SS	36.85	36.84	36.83	36.84	0.39	0.	0.	51.87
13	6.12	7365	HC	36.85	36.84	36.83	36.84	0.38	0.	0.	51.87
14	6.12	9372	UN	36.82	36.81	36.81	36.81	0.36	0.	0.	51.87
15	6.12	9371	UN	36.98	36.96	36.98	36.97	0.52	0.	0.	51.87
16	6.12	9370	UN	36.72	36.74	36.71	36.72	0.27	0.	0.	51.87
17	6.12	137CJ	UN	36.81	36.80	36.79	36.80	0.34	0.	0.	51.87
19	6.12	137CJ	UN	36.82	36.81	36.81	36.81	0.36	0.	0.	51.87
20	6.12	1881-2	UN	36.80	36.79	36.79	36.79	0.34	0.	0.	51.87
21	6.12	4107	UN	36.77	36.76	36.75	36.76	0.30	0.	0.	51.87
22	6.13	211	UN	37.04	37.04	37.03	37.04	0.58	0.	0.	51.88
23	6.13	9373	UN	36.75	36.73	36.72	36.73	0.28	0.	0.	51.88

AVERAGE DELTA-T,S FOR RUN 70

AVERAGE TIME FROM START = 51.37 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	0.33	0.37	0.36	0.36	0.42	0.32	0.39	0.35
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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APPENDIX E - TABLE 3 - CONTINUED
AEROJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(4 of 8)

RUN 161 6-29-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.46 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	10.13	8927	CD	37.62	37.61	37.61	37.61	1.16	0.	0.	127.88
2	10.13	12333	CD	37.66	37.64	37.64	37.65	1.19	0.	0.	127.88
3	10.13	6317	HC	37.51	37.50	37.49	37.50	1.05	0.	0.	127.88
4	10.13	12330	HC	37.74	37.73	37.72	37.73	1.27	0.	0.	127.88
5	10.13	4092	HF	37.54	37.53	37.53	37.53	1.08	0.	0.	127.88
7	10.15	12340	HF	37.63	37.61	37.61	37.62	1.16	0.	0.	127.90
8	10.15	4094	UN	37.75	37.74	37.74	37.74	1.29	0.	0.	127.90
9	10.15	4096	SS	37.75	37.72	37.71	37.72	1.27	0.	0.	127.90
10	10.15	4104	UN	37.75	37.74	37.74	37.74	1.29	0.	0.	127.90
11	10.15	6319	SS	37.72	37.71	37.70	37.71	1.25	0.	0.	127.90
13	10.15	7365	HC	37.73	37.72	37.72	37.72	1.27	0.	0.	127.90
14	10.15	9372	UN	37.77	37.76	37.76	37.76	1.31	0.	0.	127.90
15	10.15	9371	UN	37.76	37.74	37.74	37.75	1.29	0.	0.	127.90
16	10.15	9370	UN	37.63	37.63	37.64	37.63	1.18	0.	0.	127.90
17	10.15	137CJ	UN	37.83	37.85	37.83	37.84	1.38	0.	0.	127.90
19	10.15	137CJ	UN	37.79	37.79	37.80	37.79	1.34	0.	0.	127.90
20	10.15	1881-2	UN	37.86	37.87	37.87	37.87	1.41	0.	0.	127.90
21	10.15	4107	UN	37.75	37.75	37.75	37.75	1.29	0.	0.	127.90
22	10.15	211	UN	38.87	38.86	38.85	38.86	2.40	0.	0.	127.90
23	10.15	9373	UN	37.67	37.67	37.65	37.66	1.21	0.	0.	127.90

AVERAGE DELTA-T,S FOR RUN 161

AVERAGE TIME FROM START = 127.90 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	1.17	1.19	1.12	1.29	1.26	1.26	1.23	1.36
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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APPENDIX E - TABLE 3 - CONTINUED
AEROJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(5 of 8)

RUN 165 6-29-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.46 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCE SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	14.03	4927	CD	37.65	37.64	37.64	37.64	1.19	0.	0.	131.78
2	14.03	12332	CD	37.71	37.69	37.68	37.70	1.24	0.	0.	131.78
3	14.03	6317	HC	37.54	37.53	37.53	37.54	1.08	0.	0.	131.78
4	14.03	1233C	HC	37.77	37.76	37.76	37.77	1.31	0.	0.	131.78
5	14.03	4092	HF	37.54	37.57	37.56	37.57	1.11	0.	0.	131.78
7	14.03	12340	HF	37.68	37.66	37.65	37.67	1.21	0.	0.	131.78
8	14.03	4094	UN	37.78	37.78	37.78	37.78	1.32	0.	0.	131.78
9	14.03	4096	SS	37.88	37.83	37.79	37.83	1.37	0.	0.	131.78
10	14.03	4104	UN	37.78	37.78	37.77	37.78	1.32	0.	0.	131.78
11	14.03	6319	SS	37.78	37.76	37.75	37.76	1.31	0.	0.	131.78
13	14.03	7365	HC	37.77	37.76	37.76	37.76	1.30	0.	0.	131.78
14	14.03	9372	UN	37.80	37.80	37.80	37.80	1.34	0.	0.	131.78
15	14.03	9371	UN	37.78	37.77	37.76	37.77	1.31	0.	0.	131.78
16	14.03	9370	UN	37.70	37.66	37.64	37.67	1.21	0.	0.	131.78
17	14.03	137CJ	UN	37.90	37.90	37.88	37.89	1.43	0.	0.	131.78
19	14.03	137CJ	UN	37.83	37.84	37.84	37.84	1.38	0.	0.	131.78
20	14.03	1881-2	UN	37.91	37.91	37.91	37.91	1.45	0.	0.	131.78
21	14.03	4107	UN	37.80	37.80	37.79	37.80	1.34	0.	0.	131.78
22	14.03	211	UN	38.93	38.93	38.93	38.93	2.47	0.	0.	131.78
23	14.03	9373	UN	37.73	37.73	37.71	37.72	1.27	0.	0.	131.78

AVERAGE DELTA-T,S FOR RUN 165

AVERAGE TIME FROM START = 131.78 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	1.21	1.23	1.16	1.32	1.34	1.30	1.26	1.41
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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APPENDIX E - TABLE 8 - CONTINUED
 AFROJET GENERAL CORPORATION
 TRANSDUCER IRRADIATION TEST GTR-18
 RESISTANCE TEMPERATURE TRANSMITTERS
 TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

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RUN 189 6-30-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.47 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	14.02	8927	CD	37.92	37.90	37.90	37.91	1.44	0.	0.	155.77
2	14.02	12333	CD	38.01	37.98	37.96	37.98	1.52	0.	0.	155.77
3	14.02	6317	HC	37.80	37.78	37.77	37.78	1.32	0.	0.	155.77
4	14.02	12330	HC	38.05	38.04	38.03	38.04	1.58	0.	0.	155.77
5	14.02	4092	HF	37.85	37.82	37.80	37.82	1.36	0.	0.	155.77
7	14.03	12340	HF	37.96	37.93	37.91	37.93	1.46	0.	0.	155.78
8	14.03	4094	UN	38.08	38.07	38.06	38.07	1.60	0.	0.	155.78
9	14.03	4096	SS	38.19	38.11	38.05	38.12	1.65	0.	0.	155.78
10	14.03	4104	UN	38.08	38.06	38.06	38.07	1.60	0.	0.	155.78
11	14.03	6319	SS	38.07	38.04	38.02	38.05	1.58	0.	0.	155.78
13	14.03	7365	HC	38.06	38.04	38.03	38.04	1.58	0.	0.	155.78
14	14.03	9372	UN	38.10	38.09	38.08	38.09	1.63	0.	0.	155.78
15	14.03	9371	UN	38.02	38.00	37.98	38.00	1.54	0.	0.	155.78
16	14.03	9370	UN	37.98	37.93	37.94	37.95	1.48	0.	0.	155.78
17	14.03	137CJ	UN	38.20	38.20	38.19	38.19	1.73	0.	0.	155.78
19	14.03	137CJ	UN	38.14	38.14	38.13	38.14	1.67	0.	0.	155.78
20	14.03	1881-2	UN	38.22	38.23	38.23	38.22	1.76	0.	0.	155.78
21	14.03	4107	UN	38.11	38.10	38.09	38.10	1.64	0.	0.	155.78
22	14.03	211	UN	39.38	39.37	39.36	39.37	2.91	0.	0.	155.78
23	14.03	9373	UN	38.00	37.98	37.97	37.99	1.52	0.	0.	155.78

AVERAGE DELTA-T,S FOR RUN 189

AVERAGE TIME FROM START = 155.78 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	1.48	1.49	1.41	1.60	1.62	1.57	1.51	1.70
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.
 CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

APPENDIX E - TABLE 3 - CONTINUED
 AFROJET GENERAL CORPORATION
 TRANSDUCER IRRADIATION TEST GTR-18
 RESISTANCE TEMPERATURE TRANSMITTERS
 TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(7 of 8)

RUN 193 0-30-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.46 DEG-R

CHANNEL NO.	TIME, HOURS	XDUCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	18.02	8927	CD	37.91	37.90	37.90	37.90	1.44	0.	0.	159.77
2	18.02	12333	CD	38.02	38.00	37.99	38.01	1.54	0.	0.	159.77
3	18.02	6317	HC	37.79	37.78	37.78	37.78	1.32	0.	0.	159.77
4	18.02	12330	HC	38.06	38.06	38.06	38.06	1.60	0.	0.	159.77
5	18.02	4092	HF	37.83	37.82	37.81	37.82	1.36	0.	0.	159.77
7	18.03	12340	HF	37.97	37.95	37.94	37.95	1.49	0.	0.	159.78
8	18.03	4094	UN	38.04	38.04	38.04	38.04	1.58	0.	0.	159.78
9	18.03	4096	SS	38.21	38.14	38.09	38.15	1.69	0.	0.	159.78
10	18.03	4104	UN	38.02	38.02	38.02	38.02	1.56	0.	0.	159.78
11	18.03	6319	SS	38.09	38.07	38.06	38.07	1.61	0.	0.	159.78
13	18.03	7365	HC	38.07	38.07	38.07	38.07	1.61	0.	0.	159.78
14	18.03	9372	UN	38.07	38.08	38.07	38.07	1.61	0.	0.	159.78
15	18.03	9371	UN	38.03	38.01	38.03	38.02	1.56	0.	0.	159.78
16	18.03	9370	UN	37.99	37.95	37.92	37.95	1.49	0.	0.	159.78
17	18.03	1370J	UN	38.23	38.23	38.24	38.23	1.77	0.	0.	159.78
19	18.03	1370J	UN	38.16	38.15	38.16	38.16	1.69	0.	0.	159.78
20	18.03	1881-2	UN	38.27	38.26	38.27	38.27	1.80	0.	0.	159.78
21	18.03	4107	UN	38.14	38.14	38.14	38.14	1.68	0.	0.	159.78
22	18.03	211	UN	39.33	39.32	39.32	39.32	2.86	0.	0.	159.78
23	18.03	9373	UN	38.02	38.02	38.00	38.01	1.55	0.	0.	159.78

AVERAGE DELTA-T,S FOR RUN 193

AVERAGE TIME FROM START = 159.78 HOURS

CHANNELS	1 + 2	3,4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	1.49	1.51	1.42	1.57	1.65	1.58	1.53	1.73
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MJST RECENT RUN, PL=0MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN 0PL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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APPENDIX E - TABLE 8 - CONTINUED
AERJET GENERAL CORPORATION
TRANSDUCER IRRADIATION TEST GTR-18
RESISTANCE TEMPERATURE TRANSMITTERS
TYPICAL COMPUTER OUTPUT FOR SELECTED RUNS

(8 of 8)

RUN 245 7- 2-66 POWER LEVEL = 0 MEGAWATTS TRUE TEMPERATURE = 36.47 DEG-R

CHANNEL NO.	TIME, HOURS	XDCER SN	SHIELD MATL	INDICATED TEMPERATURE, DEG-R				DELTA T, DEG-R			TIME FROM START-HRS
				CYCLE A	CYCLE B	CYCLE C	AVG	DT1	DT2	DT3	
1	20.57	6527	CD	38.42	38.42	38.42	38.42	1.95	0.	0.	234.32
2	20.57	12333	CD	38.55	38.55	38.55	38.55	2.08	0.	0.	234.32
3	20.57	6317	HC	38.27	38.27	38.27	38.27	1.80	0.	0.	234.32
4	20.57	12330	HC	38.59	38.59	38.59	38.59	2.12	0.	0.	234.32
5	20.57	4052	HF	38.31	38.31	38.31	38.31	1.84	0.	0.	234.32
7	20.57	12340	HF	38.44	38.44	38.44	38.44	1.97	0.	0.	234.32
8	20.57	4054	UN	38.62	38.62	38.62	38.62	2.15	0.	0.	234.32
9	20.57	4056	SS	38.63	38.63	38.63	38.63	2.16	0.	0.	234.32
10	20.57	4104	UN	38.61	38.61	38.61	38.61	2.14	0.	0.	234.32
11	20.58	6315	SS	38.62	38.62	38.62	38.62	2.15	0.	0.	234.33
12	20.58	7365	HC	38.61	38.61	38.61	38.61	2.15	0.	0.	234.33
14	20.58	9372	UN	38.67	38.67	38.67	38.67	2.20	0.	0.	234.33
15	20.58	9371	UN	38.53	38.53	38.53	38.53	2.06	0.	0.	234.33
16	20.58	9370	UN	38.56	38.56	38.56	38.56	2.09	0.	0.	234.33
17	20.58	1370J	UN	38.82	38.82	38.82	38.82	2.35	0.	0.	234.33
19	20.58	1370J	UN	38.73	38.73	38.73	38.73	2.26	0.	0.	234.33
20	20.58	1661-2	UN	38.90	38.90	38.90	38.90	2.43	0.	0.	234.33
21	20.58	4107	UN	38.71	38.71	38.71	38.71	2.24	0.	0.	234.33
22	20.58	211	UN	40.23	40.23	40.23	40.23	3.76	0.	0.	234.33
23	20.58	9373	UN	38.56	38.56	38.56	38.56	2.10	0.	0.	234.33

AVERAGE DELTA-T, S FOR RUN 245

AVERAGE TIME FROM START = 234.33 HOURS

CHANNELS	1 + 2	3, 4 + 13	5 + 7	8 + 10	9 + 11	14 + 23	15 + 16	17 + 19
DT1(AVG)	2.01	2.02	1.90	2.14	2.16	2.15	2.08	2.31
DT2(AVG)	0.	0.	0.	0.	0.	0.	0.	0.
DT3(AVG)	0.	0.	0.	0.	0.	0.	0.	0.

NOTES.

1. DT1 = TAVG(IND)-T(TRUE)
2. DT2 = DT1(CURRENT RUN, PL=3MW)-DT1(INITIAL RUN, PL=3MW)
3. DT3 = DT1(MOST RECENT RUN, PL=3MW)+DT1(CURRENT RUN, PL=3MW)-DT1(RUN SPL+1, PL=3MW)
4. SHIELD MATERIAL CODE.

CD=CADMIUM, HF=HAFNIUM, SS=STAINLESS STEEL, HC=HAFNIUM-CADMIUM, UN=UNSHIELDED

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