SNPO-C
Looff
Records

NUCLEAR ROCKET OPERATIONS

SACRAMENTO PLANT

REPORT NO. RN-S-0439

TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

NONNUCLEAR QUALIFICATION-EVALUATION TEST

RESULTS ON ROSEMOUNT MODEL 134AJ

RESISTANCE TEMPERATURE TRANSDUCER

NERVA PROGRAM

CONTRACT SNP-1

DECEMBER 1967

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

REPORT NO. RN-S-0439

NONNUCLEAR QUALIFICATION-EVALUATION TEST
RESULTS ON ROSEMOUNT MODEL 134AJ
RESISTANCE TEMPERATURE TRANSDUCER

NERVA PROGRAM

CONTRACT SNP-1

NUCLEAR ROCKET OPERATIONS

DECEMBER 1967

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

CLASSIFICATION CATEGORY

UNCLASSIFIED

W.P. Gilles
CLASSIFYING OFFICER

12/18/67
DATE

AEROJET-GENERAL CORPORATION
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

DISTRIBUTION ONE

PAGE BLANK

REPORT NO. RN-S-0439

NONNUCLEAR QUALIFICATION-EVALUATION TEST
RESULTS ON ROSEMOUNT MODEL 134AJ
RESISTANCE TEMPERATURE TRANSDUCER

H. A. Fox, Jr.

A handwritten signature in cursive script, appearing to read "C. M. Rice".

C. M. Rice
Program Manager
Nuclear Rocket Operations

ABSTRACT

Three resistance temperature transducers (AGC PN 1116474) were selected for testing from a shipment procured in accordance with paragraph 4.2.1 of AGC Specification 90088. They were modifications of a former design (AGC PN 248635) used successfully in past NRX tests. In addition to the qualification-evaluation tests performed, additional experiments and analyses were conducted to determine the thermal emf effects that result from the use of sheathed cable containing nickel-clad conductors.

CONTENTS

	<u>Page</u>
I. Introduction	1
II. Conclusions and Recommendations	1
III. Technical Discussion	2
A. General	2
B. Tests	2
1. Calibration	2
2. Determination of Calibration Error	7
3. Repeatability	7
4. Insulation Resistance	8
5. Thermal Emf	9
6. Vibration	9
7. Stability	10
8. Time Constant	14
9. Current Maximum	14
10. Operating Pressure	15
11. Examination	15
12. Potential Problems from the Use of Nickel-Clad Conductors	15

TABLES

<u>Number</u>		<u>Page</u>
1	Transducers and Qualification Evaluation Tests Performed	4
2	Calibration Results, SN 881003	5
3	Calibration Results, SN 881005	6
4	Calibration Results, SN 881006	6
5	Repeatability Test Results	8
6	Magnitude of EMF	16
7	Results of Thermal EMF Test	18

FIGURES

<u>Number</u>		<u>Page</u>
1	Former Design of Radiation Resistant Temperature Transducer	3
2	Current Design of Radiation Resistant Temperature Transducer	3
3	Circuit for Determining Calibration Error	7
4	Vibration Test, Electrical Circuit	10
5	Ambient Temperature Test	11
6	Liquid Nitrogen Test	12
7	Test Equipment	13
8	Cable Thermal EMF Test	17
9	Test Circuit to Determine Thermal Effects	17

I. INTRODUCTION

The platinum resistance temperature transducers (RTT), AGC PN 1116474, were modified to include, as an integral part of the transducer, two 2-conductor sheathed cables (AS9702FAA-14). The three transducers, although selected at random for testing, contained cables from one of each of three cable suppliers. The objective of the nonnuclear qualification-evaluation tests was to determine the suitability of the redesigned RTT for use in NRX and XE engine tests.

All tests were conducted in accordance with paragraph 4.5, Quality Conformance Inspection, of AGC Specification 90088, Transmitter, Temperature, Electrical Resistance-Platinum, Radiation Resistant.

II. CONCLUSIONS AND RECOMMENDATIONS

A. The three transducers selected for nonnuclear qualification-evaluation testing met all test objectives and qualification test requirements.

B. A transducer error of as much as 1.5°R at liquid hydrogen temperatures can be expected if the nickel-clad wire, when used in a cable, is used in the signal circuit rather than the excitation circuit.

C. The future use of nickel-cladding for conductor identification should be discouraged because of the possible measurement errors introduced by thermocouple action. Nickel-clad conductors, if they must be employed, should be used in the excitation circuit, and copper conductors should be used in the signal circuits.

III. TECHNICAL DISCUSSION

A. GENERAL

There are several reasons for modifying RTT's to incorporate sheathed cables:

1. To remove the connector itself, which permits moisture penetration and is a source of unreliability. Moisture can produce both shunting of the signal and excitation that results in errors of unknown magnitude.
2. To eliminate the vibration vulnerable interface between the platinum element lead wire and connector (see Figure 1).
3. To reduce transducer mass (see Figure 1).

The modified design replaces the connector by incorporating two 2-conductor cables, each of which contains one nickel-clad conductor (see Figure 2). The purpose of the nickel cladding was for conductor identification. Because the stem construction of the test articles was the same as the previously qualified AGC 248635 design, environmental tests other than vibration were not considered necessary and were not conducted. Table 1 includes a list of the transducers used and the qualification-evaluation tests performed on each.

B. TESTS

1. Calibration

Calibration tests were performed at the Rosemount Engineering Company in accordance with paragraph 4.6.3 of AGC Specification 90088.

Figure 1 - Former Design of Radiation Resistant Temperature Transducer

Figure 2 - Current Design of Radiation Resistant Temperature Transducer

TABLE 1
TRANSDUCERS AND QUALIFICATION
EVALUATION TESTS PERFORMED

<u>RTT SN</u>	<u>RTT P.O. No.</u>	<u>Cable Supplier*</u>	<u>Cable P.O.</u>
881003	203648	ARI	203652-01
881005	203648	CSI	203428-01
881006	203648	SEMCO	203429-01

<u>Test</u> ¹	<u>Performed in Accordance With Paragraph of AGC 90088</u>	<u>Test Facility*</u>
1. Calibration	4.6.3, 3.5.1, Table 1	REC ²
2. Repeatability	4.6.4, 3.4.2(b)	REC
3. Insulation Resistance	4.6.5, 3.4.2(h)	REC-MSL
4. Thermal emf	4.6.6, 3.4.2(f)	REC
5. Vibration	4.6.7, 3.4.3(d)	AGC NRO
6. Stability	4.6.8, 3.4.2(a)	AGC Xducer
7. Time Constant	4.6.9, 3.4.2(d)	AGC MSL
8. Current Resistance	4.6.10, 3.4.2(g)	AGC MSL
9. Operating Pressure	4.6.2, 3.4.2(c)	REC
10. Examination	4.6.1	REC

* ARI - Aero Research Instruments, Chicago, Illinois.
 CSI - Continental Sensing, Inc., Melrose Park, Illinois.
 SEMCO - Scientific Engineering & Manufacturing Co., Inc.,
 N. Hollywood, California.
 REC - Rosemount Engineering Co., Minneapolis, Minnesota.
 MSL - AGC Measurement Standards Laboratory, Sacramento, California.
 NRO - AGC Nuclear Rocket Operations Laboratory, Sacramento, California
 XDUCER - AGC Transducer Laboratory, Sacramento, California.

1. All standards and measuring equipment used for calibration and testing are directly traceable to the National Bureau of Standards.
2. Tests performed at REC were made under the surveillance and approval of NRO Quality Assurance, Department 7340 (Reference: Product Inspection Plan for AGC P.O. 203648-0912-01).

This requirement consisted of subjecting the transducer to: (1) one temperature between 0 and 60°R; (2) one temperature between 110 and 210°R; and (3) the ice point (491.67°R). The resulting resistance-versus-temperature relationship was to conform to the requirements of Table I of AGC Specification 90088.

Tables 2, 3, and 4 list the calibration data obtained for RTT SN 881003, 881005, and 881006, respectively.

TABLE 2

CALIBRATION RESULTS, SN 881003

	<u>Calibration Points</u>	<u>Helium</u>	<u>LN₂</u>	<u>Ice</u>
(a)	Nominal temperature, °R	8	139	492
(b)	Excitation current	100 μ a	100 μ a	100 μ a
(c)	RTT resistance, ohms	1.0929	259.35	1380.55
(d)	RTT measured temperature, °R	7.57	138.98	49.185
*(e)	Temperature standard resistance, ohms	1.0940	4.7975	- - - -
(f)	Temperature standard, measured temperature, °R	7.57	139.02	491.67
(g)	Error - RTT versus temperature standard	-0.001 Ω	-0.04°R	+0.18°R
(h)	Tolerance/AGC 90088, Table I	** <u>+0.145Ω</u>	<u>+0.20°R</u>	<u>+0.35°R</u>

*Item (e) is a reference transducer used by REC to determine the temperature of the test points with high accuracy.

**Table I of AGC 90088 does not include resistance tolerances below 35°R.

The tolerance value shown was provided by REC and accepted by AGC for the liquid helium point.

TABLE 3

CALIBRATION RESULTS, SN 881005

<u>Calibration Points</u>	<u>Helium</u>	<u>LN₂</u>	<u>Ice</u>
(a) Nominal temperature, °R	8	139	492
(b) Excitation current	100 μ a	100 μ a	100 μ a
(c) RTT resistance, ohms	1.1683	259.20	1380.19
(d) RTT measured temperature, °R	7.57	138.93	491.73
*(e) Temperature standard resistance, ohms	1.0940	4.7963	- - -
(f) Temperature standard measured temperature, °R	7.57	139.00	491.67
(g) Error - RTT versus temperature standard	+0.074 Ω	-0.07°R	+0.06°R
(h) Tolerance/AGC 90088, Table I	** <u>+0.145Ω</u>	<u>+0.20°R</u>	<u>+0.35°R</u>

TABLE 4

CALIBRATION RESULTS, SN 881006

<u>Calibration Points</u>	<u>Helium</u>	<u>LN₂</u>	<u>Ice</u>
(a) Nominal temperature, °R	8	139	492
(b) Excitation current	100 μ a	100 μ a	100 μ a
(c) RTT resistance, ohms	1.1818	259.62	1379.2
(d) RTT measured temperature, °R	7.57	139.21	491.41
*(e) Temperature standard resistance, ohms	1.0940	4.8054	- - -
(f) Temperature standard measured temperature, °R	7.57	139.06	491.67
(g) Error - RTT versus temperature standard	+0.088 Ω	+0.15°R	-0.26°R
(h) Tolerance/AGC 90088, Table I	** <u>+0.145Ω</u>	<u>+0.20°R</u>	<u>+0.35°R</u>

*Item (e) is a reference transducer used by REC to determine the temperature of the test points with high accuracy.

**Table I of AGC 90088 does not include resistance tolerances below 35°R. The tolerance value shown was provided by REC and accepted by AGC for the Liquid Helium point.

2. Determination of Calibration Error

The circuit and process for determining calibration error is shown in Figure 3.

Figure 3 - Circuit for Determining Calibration Error

The RTT resistance (R), item (c) in Tables 1, 2, and 3, is determined by

$$R = \frac{E_x}{I} .$$

The temperature, item (d), is then interpolated from the resistance/temperature relationship of AGC 90088, Table I. The RTT temperature, (d), is compared to the temperature standard, (f), and the error, item (g), is the result, except for the liquid helium point, where the resistance of the RTT, item (d), is compared with the temperature standard resistance, item (e).

3. Repeatability

Repeatability tests were performed at Rosemount Engineering in accordance with paragraphs 4.6.4 and 3.4.2(b) of AGC specification 90088. This requirement consisted of lowering transducer temperature from an ambient to a known temperature below 210°R at least three times. After each temperature change, the transducer is permitted to stabilize at the ice point where the repeatability of the transducer is compared to the temperature standard.

The requirement is that the measurement must not shift by more than $\pm 0.1^\circ$ from the ice-point measurement made during calibration tests, item (d) of Tables 1, 2, and 3. Data obtained from this test are shown in Table 5. The test circuit and the method of obtaining data are the same as shown in Figure 3.

TABLE 5
REPEATABILITY TEST RESULTS

<u>RTT SN</u>	<u>Ice Point Res</u>	<u>Test Temp, °R</u>	<u>Calib Temp. °R</u>	<u>Degree Shift</u>
881003	1380.65	491.88	491.85	+0.03
881005	1380.19	491.73	491.73	00.00
881006	1379.20	491.41	491.41	00.00

All transducers were within the repeatability requirements

4. Insulation Resistance

Insulation tests were performed by Rosemount Engineering and the Aerojet Measurement Standards Laboratory in accordance with paragraph 4.6.5 and 2.4.2(h) of AGC specification 90088. This requirement consisted of a measurement between the transducer lead-wires and case to be performed at room temperature with dry external surfaces. The emf potential for this test was to be 50, ± 5 vdc. The specification tolerance was 10 megohms minimum.

<u>Serial Number</u>	<u>REC Reading, Megohms</u>	<u>MSL Reading, Megohms</u>
881003	>200	2,700
881005	>200	9,500
881006	>200	20,000

All measurements were far in excess of the specification requirements.

5. Thermal Emf

Thermal emf tests were performed by Rosemount Engineering in accordance with paragraphs 4.6.6 and 3.4.2(f) of AGC Specification 90088. This requirement consisted of immersing the probes in liquid nitrogen for one minute for temperature stabilization, at which time the thermal emf measurement was made. The tolerance requirement was 30 microvolts maximum. The thermal emf's measured were -20.7, -7.8, and -0.6 microvolts for SN 881003, 881005, and 881006, respectively. The emf's recorded are the summation of the effect of joining the platinum/copper and the platinum/nickel-clad copper junctions. Section III,B,12 further explains a potential problem of using nickel cladding on conductors.

6. Vibration

Vibration tests were performed at the NRO Laboratory in accordance with paragraphs 4.6.7 and 3.4.3(d) of AGC specification 90088. This requirement consisted of subjecting the transducers to several vibration conditions while in a simulated mounting configuration. The vibration rate consisted of the sinusoidal level superimposed on the Gaussian random level for 37.7 g rms, with a frequency range of 5 to 2000 Hz. Amplitude of vibration was within 10% of the specified values, and the frequency was monitored within one percent. This test was performed along each of the three mutually perpendicular axes. The test period was divided into two equal parts of at least 30 minutes each, with one excursion of superimposed sinusoidal vibration from 5 to 2000 Hz for each part. Acceleration density was $0.5 \text{ g}^2/\text{Hz}$ with a double amplitude displacement limited to one inch and the amplitude limited to the three-sigma level. The two parts of the test were conducted under the following conditions: (1) standard atmospheric conditions (approximately 14.7 psig and 537°R; and (2) at 140°R (liquid nitrogen point), $\pm 5^\circ$, allowing 30 minutes minimum for temperature stabilization.

The transducers were excited with one milliamp constant current by a swamping resistor connected in series with the transducer element. This allowed the operators to monitor the emf drop across the elements, to observe noise, and to monitor the temperature of the transducer at the liquid nitrogen point (see Figure 4).

Figure 4 - Vibration Test, Electrical Circuit

Figure 5 shows the vibration fixture used for the standard atmospheric test condition (a), and Figure 6 shows the fixture used for test condition (b), liquid nitrogen temperature. The three transducers and the equipment used during one phase of test condition (b) are shown in Figure 7. The three transducers were simultaneously exposed to the vibration requirements and were found to be physically and electrically functional: noise or loss of signal was not noted. The transducers were considered to have met all vibration test objectives.

7. Stability

Stability tests were conducted by the Aerojet Transducer Laboratory in accordance with paragraphs 4.6.8 and 3.4.2(a) of AGC

Figure 5 - Ambient Temperature Test

Figure 6 - Liquid Nitrogen Test

Figure 7 - Test Equipment

specification 90088. The transducers were to be subjected to a known temperature between 35 and 60°R, 110 and 210°R, and the ice point (491.67°R). The requirement was that the transducer must remain stable (within $\pm 0.02^\circ$) for an unspecified length of time. The test duration was 10 sec. Although variations in temperature were not noted at 49°R, 139.23°R, and 491.67°R, the test was of insufficient length to provide conclusive results.

8. Time Constant

Time constant tests were performed at the Measurement Standards Laboratory in accordance with paragraphs 4.6.9 and 3.4.2(d) of AGC specification 90088. This requirement consisted of quickly plunging the transducer sensing element from air at 537°R, $\pm 3^\circ$, into hot water at 635°R, $\pm 10^\circ$, flowing transversely to the sensing element at three feet per second. The requirement was that the response time must not exceed 250 milliseconds. The time constant for SN 881003, 881005, and 881006 was 246, 249, and 246 milliseconds, respectively. Each transducer met the time-constant requirement.

9. Current Maximum

Current maximum tests were performed at the Measurements Standards Laboratory in accordance with paragraphs 4.6.10 and 3.4.2(g) of AGC specification 90088. This test required that the transducer be connected to an electrical power supply so an accurately controlled direct-current flow of 20, $\begin{smallmatrix} +0 \\ -2 \end{smallmatrix}$, milliamps would be permitted to flow for a period of ten minutes. The requirement was that no damage or open circuits would result from this test. Each of the transducers were exposed to 20 milliamps for ten minutes with no damage or open circuits.

10. Operating Pressure

This test was performed by Rosemount Engineering in accordance with paragraphs 4.6.2 and 3.4.2(c) of AGC specification 90088. The requirement consisted of mounting the transducer in a test fixture and subjecting the probe to a pressure of 2000 psig using gaseous helium. The requirement was that a visual check should be made for leakage by using a soap solution, or equivalent. No visual indication of leakage was observed on the three transducers at either the transducer mount or through transducer welds.

11. Examination

The examination test was performed by Rosemount Engineering in accordance with paragraph 4.6.1 of AGC specification 90088. The requirement was that the transducer be examined and physically inspected to assure conformance with the applicable drawing (1116474) and to the requirements of specification 90088. All transducers conformed to the requirements and were found acceptable.

Test data sheets, calibration certification documents, validity of test equipment certification, and associated SIR's for these tests are on file in NRO Department 7760.

12. Potential Problems From the Use of Nickel-Clad Conductors

A thermal emf effect was noted that resulted from the use of nickel-clad copper conductors during the metallic sheathed evaluation tests described in RN-S-0392*. Although all RTT's tested passed the nonnuclear qualification-evaluation tests successfully, the fact that nickel-clad copper

*Qualification-Evaluation Test Results of Metal Sheathed, Ceramic Insulated, Radiation Resistant Electrical Cables

conductors were used in their construction resulted in additional tests to determine: (1) under what conditions the emf generated by the conductors would pose a problem, and (2) what procedures must be followed to eliminate or reduce the problem.

This thermocouple effect is the result of joining two dissimilar metals, in this case the nickel cladding on the copper conductors. When joined at the sensing element lead wires, an emf is generated that is proportional to the differential temperature between these junctions and the opposite end of the cables. The magnitude of this emf is also a function of the cladding thickness, which varies between cable suppliers and supplier lots. Typical examples of the magnitude are shown in Table 6, which is data referenced from RN-S-0392.

TABLE 6
MAGNITUDE OF EMF

<u>Cable No.</u>	<u>Supplier</u>	<u>Emf Measured (mv)</u>
1	ARI	0.319
2	ARI	0.295
3	CSI	0.092
4	CSI	0.096
5	SEMCO	0.665
6	SEMCO	0.670

The test setup used to determine the thermal emf effects of sheathed cable containing copper and nickel-clad copper conductors is shown in Figure 8. These error voltages were not observed during the thermal effects tests (see Section III,B,5), which shows that if the conductors are wired properly (viz., nickel-clad lead for excitation and copper for signal) the thermocouple effect is cancelled and does not degrade the accuracy of the transducer.

Figure 8 - Cable Thermal EMF Test

Since there are two such emf generators on a four-wire RTT, the effects can be nullified by proper polarization if the cables on a specific transducer contain cables from the same supplier and lot and if the conductors are not crossed during installation. Figure 9 shows the test circuit used to determine the thermal effects on transducers containing cable from each of the three suppliers.

Figure 9 - Test Circuit to Determine Thermal Effects

The test requirements were to: (1) immerse the RTT in liquid nitrogen (to sheath cables) and allow to stabilize; (2) record emf (normal configuration) Condition A; (3) reverse wires B and C, record emf (Condition B); (4) record emf difference between 2 and 3 (Condition D); (5) repeat steps 1, 2, 3, and 4 at liquid neon temperature; (6) remove the constant-current supply and perform steps 2, 3, and 4 at liquid neon point; and (7) note the differential temperature. The results obtained are shown in Table 7.

TABLE 7
RESULTS OF THERMAL EMF TEST

<u>Requirements Number</u>	<u>Condition Circuit</u>	<u>*Emf at LN₂ Point $\Delta t = 396^\circ\text{R}$</u>	<u>*Emf at LNe Point $\Delta t = 485^\circ\text{R}$</u>	<u>*Emf from No. 6 Requirement</u>	<u>Cable Type</u>
S/N 881006					
2	A	260.070	17.385	0.0025	SEMCO
3	B	259.360	16.688	-0.699	SEMCO
4	D	-0.710	-0.697	-0.697	SEMCO
S/N 881005					
2	A	260.180	17.420	0.005	CSI
3	B	259.450	16.713	-0.705	CSI
4	D	-0.730	-0.707	-0.700	CSI
S/N 881003					
2	A	260.140	17.306	0.008	ARI
3	B	259.820	17.046	-0.251	ARI
4	D	-0.320	-0.260	-0.243	ARI

*All emf's are in millivolts

To determine the relative thermal emf effect at liquid hydrogen, a separate three-point calibration was made on a SEMCO cable in accordance with Figure 8. The emf's measured in millivolts were: 0.664 at liquid nitrogen temperature ($\Delta t = 396^\circ\text{R}$); 0.662 at liquid neon temperature ($\Delta t = 485^\circ\text{R}$); and 0.628 at liquid helium temperature ($\Delta t = 528^\circ\text{R}$).

From this simple test it was observed that increasing the Δt beyond the liquid nitrogen point resulted in a decreasing thermal emf error, which indicates that the maximum thermal emf error can be expected to occur at approximately the liquid nitrogen point.

RTT SN 881005 (see Table 7) was supposed to contain CSI cable. From the emf generated it appears that the cable on this transducer was either SEMCO cable or CSI cable from a different lot. At present there is no explanation for this effect.

Utilizing the data obtained from SN 881006 (see Table 7), the following three-point sample error analysis was made for Condition B. From Table 1 of AGC specification 90088 (resistance temperature characteristics), the sensitivity (S_1) equals 3.314 mv/°R at the liquid nitrogen point (T_1) (139.23°R). That is, with 1 milliamp constant current excitation, the nominal emf generated at (T_1) is 260.19 mv (V_1). The emf generated for Condition B on SN 881006 was 259.360 mv (VB_1). Therefore, the error (E) equals:

$$ET_1 \text{ (LN}_2 \text{ point)} = \frac{V_1 - VB_1}{S_1}, = \frac{260.190 - 259.360}{3.314}, = \frac{0.830}{3.314} = 0.25^\circ \text{ ET}_1 \text{ (139.23}^\circ\text{R)}_{\text{LN}_2}$$

$$ET_2 \text{ (LNe point)} = \frac{V_2 - VB_2}{S_2}, = \frac{17.533 - 16.688}{1.194}, = \frac{0.845}{1.194} = 0.708^\circ \text{ ET}_2 \text{ (49.00}^\circ\text{R)}_{\text{LNe}}$$

Because the sensitivity of the thermoelectric effect drops beyond the liquid nitrogen point, the V-VB factor remains relatively constant. (See the similarity between $V_1 - VB_1$ and $V_2 - VB_2$). From a linear extrapolation, the V-VB factor at the liquid hydrogen point equals 0.847, therefore the error equals:

$$ET_3 \text{ (LH}_2 \text{ point)} = \frac{0.847}{S_3}, = \frac{0.847}{0.583}, = 1.45^\circ \text{ ET}_3 \text{ (36.81}^\circ\text{R)}_{\text{LH}_2}$$

The results of the tests show that errors up to $+1.50^{\circ}\text{R}$ are possible at liquid hydrogen temperatures if the transducers are improperly wired. This effect was not noted during the initial calibration of the RTT's, which indicates that the emf effects of the nickel clad conductors are cancelled out and do not affect the accuracy of the transducer if properly wired.

However, based on the emf test results, the use of nickel-clad conductors in RTT's should be discontinued to preclude introducing errors into the data inadvertently.