SACRAMENTO PLANT

FINAL DATA REPORT
STRAIN GAGE PRESSURE TRANSDUCER
EXPERIMENT 23/R511

NERVA PROGRAM

MASTER

Contract SNP-1

Report No. RN-S-0326

February 1967

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CLASSIFICATION CATEGORY

UNCLASSIFIED

CLASSIFYING OFFICER

W. Weloff

DATE

2-8-1967

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FINAL DATA REPORT

STRAIN GAGE PRESSURE TRANSDUCER EXPERIMENT 23/R511

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ABSTRACT

Four Statham Model PA-812 and four Standard Controls Corporation Model 170-9 pressure transducers were irradiated in the Plum Brook Reactor Facility at Sandusky, Ohio. Both sets of transducers were subject to output signal degradation in excess of 25% of baseline values at a gamma heating rate of 0.5 watts/gm. However, inadvertent pretest water damage of transmission cable assemblies contributed to the signal degradation.

Posttest examinations revealed that physically the strain gage portion of the Statham transducers satisfactorily withstood the exposure.

The integrated fast neutron flux was 9.0×10^{15} n/cm² ($E_n > 1.0$ Mev); the gamma dose was 3.0×10^8 Rads (C).

TABLE OF CONTENTS

	<u>Page No.</u>
Abstract	
I. Introduction	1
II. Summary	2
A. Statham Transducers	3
B. Standard Controls Corporation Transducers	5
C. Dummy Cable/Connector Assemblies	6
D. Gamma Dose and Neutron Fluence	7
III. Technical Discussion	7
A. Description of Test Fixture	7
1. Transducers	8
2. Dummy Cable/Connector Assemblies	8
3. Dosimeters	9
4. Thermocouples	9
5. Test Fixture Assembly	9
B. Test Procedures	10
1. Preirradiation Control Testing	10
2. Radiation Environment Testing	11
3. Posttest Operations	13
C. Test Results	14
1. Discussion of Statham Transducer Test Results	18
2. Discussion of Standard Controls Corporation Test Results	24
3. Dummy Cable/Connector Assemblies	29
4. Temperature Data	31
IV. Conclusions	33
A. Statham Transducers	33
B. Standard Controls Transducers	34
C. Cable/Connector Assemblies	35

TABLE OF CONTENTS (cont.)

	<u>Page No.</u>
V. Recommendations	35
A. Component Design	35
B. Test Design	36

APPENDIX

Dose Calculations	37
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TABLES

	<u>Table No.</u>
Test Data for Statham Transducer S/N 17	I
Test Data for Statham Transducer S/N 14	II
Test Data for Statham Transducer S/N 21	III
Test Data for Statham Transducer S/N 10	IV
Test Data for Standard Controls Transducer S/N 6990	V
Test Data for Standard Controls Transducer S/N 6988	VI
Test Data for Standard Controls Transducer S/N 6993	VII
Sensitivity Values for Statham Pressure Transducers	VIII
Sensitivity Values for Standard Controls Pressure Transducers	IX
Insulation Resistance of Dummy Cables	X

FIGURES

	<u>Figure No.</u>
23/R511 Test Fixture, Top Cover Removed	1
Schematic Diagram of Test Article Locations	2
Cross Section of Statham Pressure Transducer, Model PA812	3
Cross Section of Standard Control Corporation Pressure Transducer, Model 170-9	4
Westinghouse Neutron Dosimeter Assembly Drawing	5
Complete Aerojet Test Fixture for Irradiation Test 23/R511	6
System Schematic of Irradiation Test 23/R511	7
Disassembled Irradiated Statham Pressure Transducer, S/N 17	8
Disassembled Irradiated Statham Pressure Transducer, S/N 14	9
Disassembled Irradiated Statham Pressure Transducer, S/N 21	10
Disassembled Irradiated Statham Pressure Transducer, S/N 10	11
Irradiated Force Summing Tube from Standard Controls Corporation Pressure Transducer, S/N 6990 (Side View)	12
Irradiated Force Summing Tube from Standard Controls Corporation Pressure Transducer, S/N 6990 (Top View)	13
Zero Shift-vs-Test Condition, Statham Transducer S/N 17	14
Zero Shift-vs-Test Condition, Statham Transducer S/N 14	15
Zero Shift-vs-Test Condition, Statham Transducer S/N 21	16
Zero Shift-vs-Test Condition, Statham Transducer S/N 10	17
Zero Shift-vs-Test Condition, Standard Controls Transducer 6993	18
Zero Shift-vs-Test Condition, Standard Controls Transducer 6990	19
Zero Shift-vs-Test Condition, Standard Controls Transducer 6988	20
Sensitivity-vs-Test Condition, Statham Transducer S/N 17	21
Sensitivity-vs-Test Condition, Statham Transducer S/N 14	22
Sensitivity-vs-Test Condition, Statham Transducer S/N 21	23
Sensitivity-vs-Test Condition, Statham Transducer S/N 10	24
Sensitivity-vs-Test Condition, Standard Controls Transducer S/N 6993	25

FIGURES (cont.)

	<u>Figure No.</u>
Sensitivity-vs-Test Condition, Standard Controls Transducers S/N 6990	26
Sensitivity-vs-Test Conditions, Standard Controls Transducers S/N 6988	27
Irradiated Dummy Cable/Connector Assembly, Number 2	28
Irradiated Dummy Cable/Connector Assembly, Number 4	29
Gamma Heating Rates in HT-1	30

I. INTRODUCTION

Prospective pressure transducers for use on NERVA and XE engines were tested to determine their performance characteristics in a radiation environment. The tests were conducted at the Plum Brook Reactor Facility (PBRF) in Sandusky, Ohio during April and May, 1966.

Included in the test were four Statham (Model PA-812) and four Standard Controls Corporation (Model 170-9) strain-gage-type pressure transducers. Stainless-steel-sheathed, magnesium-oxide-insulated, four copper conductor cables were used for transmission lines between the transducers and the instrumentation console. Four extra cable/connector assemblies were included in the capsule for comparative studies.

The radiation test was performed in two parts. The objective of Part I was to determine the maximum radiation level the transducers could be exposed to without exceeding the rated operational temperatures of the units. The objective of Part II was to determine operational or damage thresholds by allowing internal temperatures to exceed the maximum operational values. Failure criteria were as follows:

- a. Signal degradation greater than 25% from baseline values at maximum pressure.
- b. Insulation resistance of zero.
- c. Temperatures in excess of 450°F at the boss seal and 800°F at the cable/connector assembly.

A summary of the results of the pretest, test, and posttest operations, is presented in Section II.

Sections III.A, B, and C describe the test fixture, test procedure, and test results. Conclusions and recommendations are presented in Sections IV and V, respectively.

II. SUMMARY

To determine their operational capabilities and characteristics in a radiation environment, prospective pressure transducers for NERVA engine instrumentation were irradiated in the Plum Brook Reactor Facility at Sandusky, Ohio.

The candidates were four Statham (Model PA-812) and four Standard Controls Corporation (Model 170-9) strain-gage-type pressure transducers. The Statham units have vapor-deposited strain gages on a pressure-sensing diaphragm. These are enclosed in a stainless-steel housing, with a transition portion to connect the bridges with the pin connectors. The Standard Controls transducers contain an aluminum force summing tube, with the strain coils bonded to it. The transducer housing is stainless steel.

To determine transmission cable effects, four sets of dummy cable/connector assemblies were included in the test fixture. The cables were the stainless-steel-sheathed, magnesium-oxide-insulated, four copper-conductor type made by Aero Research Corp. The cable assemblies included Physical Science right-angle connectors.

The transducers and dummy cable/connector assemblies were mounted in an aluminum test fixture fabricated by the Aerojet-General Corp., Sacramento. The test fixture was sent to Westinghouse Astronuclear Laboratories in Large, Pa., where it was integrated with a test capsule designed for use with all tests performed at PBRF.* The capsule was checked for operation in the WANL

*Experiment Design Manual and Hazards Analysis, PBRF. WANL-TNR-173

preirradiation test loop, where except for radiation the test conditions were similar to those used at PBRF.

After the successful completion of system checks, the entire test capsule was shipped to PBRF/Sandusky. On-site equipment checks and acceptance tests were performed, and the system was prepared for insertion into HT-1.

Prior to the irradiation portion of the test, water accidentally leaked into the test fixture. The capsule was withdrawn from the quadrant and inspected. It was subsequently baked with high wattage light bulbs and purged with helium gas. When satisfactory insulation resistance readings were obtained for two of each type of transducer the capsule was rewelded and placed back in quadrant C.

The following text summarizes the pretest and irradiation test results and includes discussions related to the low insulation-resistance values.

A. STATHAM TRANSDUCERS

The Statham transducers used in this experiment had serial numbers 17, 14, 21, and 10. All four transducers demonstrated output signal stability while being pressurized from 0 to 400 psig and heated from 73° to 400°F in the REON Laboratory oven. Insulation resistance degradation was noted during and after heating, but the values recovered to acceptable levels before shipment to PBRF/Sandusky. During checkout at PBRF insulation resistance values of 30, 300, 3000, and 300 megohms were obtained for S/N's 17, 14, 21 and 10, respectively.

Subsequent to the water leak but prior to irradiation, values of 0.3, 0.7, 1000 and 90 megohms were recorded for the same transducers.

Transducers S/N 17 and 14 were not acceptable with respect to insulation resistance. Based on transducer insulation resistance for S/N's 21 and 10, the test was performed, since any additional delays in the test would have postponed the installation of the cryogenic loop.

During Part I of the irradiation test, zero unbalance, sensitivity, and bridge resistance characteristics were normal until the 10 Mw power hold (0.5 watts/gm of nuclear heating). At this point the output signal of all four transducers was degraded more than 25% at maximum pressure. Concurrently, insulation resistance dropped to almost zero and temperatures approached the maximum permissible levels of 450°F at the seal and 800°F at the connector. The test fixture was withdrawn to the seal position.

After the test fixture was withdrawn to the seal position, only S/N 21 recovered its normal zero unbalance output value. S/N 17 had failed completely and was totally inoperable. S/N's 14 and 10 demonstrated normal sensitivity values, but new zero unbalance values categorized them as unacceptable.

Because S/N 21 was still operating normally, Part II of the test was performed.

During Part II of the experiment only S/N 21 did not exceed 25% output signal degradation; however, S/N 21 was in the rear of the capsule and was exposed to only 0.25 watt/gm when the front transducers were in the 0.75 watt/gm position. This was approximated by the fact that the front transducers are approximately 7 in. from the rear transducers and a 7 in. insertion was used in going from the 0.25 watt/gm to the 0.75 watts/gm position. In addition, S/N 21 appeared to perform better in the radiation environment than the other transducers. This improved radiation performance was attributed to the fact that S/N 21 had the least insulation resistance degradation after the water leak accident.

In the 0.75 watt/gm position only one output signal reading was taken, because capsule temperatures started to exceed the 800°F safety limitation in the cable/connector assembly region. At this point, Part II of the test was terminated.

Posttest operations revealed that some of the system degradation in insulation resistance was due to failures in the transition portion of the transducer. It could not be determined if radiation or contamination from dirty water or a combination of both had caused the failure.

Posttest studies also revealed that the vapor-deposited strain gages physically withstood the radiation environment. Three of the four strain gages measured more than 8000 megohms insulation resistance after being removed from their mountings. One unit, (S/N 17), failed completely and measured zero resistance.

B. STANDARD CONTROLS CORP. TRANSDUCERS

The Standard Controls Corp. transducers used in this experiment had serial numbers 6987, 6988, 6990, and 6993. Transducer 6987 became inoperative early in the testing at the REON Laboratory.

The three functional transducers demonstrated normal output signal stability while being heated from 73° to 400°F in the REON Laboratory oven and pressurized from 0 to 400 psig. Insulation resistance degradation was noted during and immediately after the heating test, but subsequently the values recovered to an acceptable level and the units were shipped to Large, Pennsylvania, and PBRF/Sandusky. Values of 200, 9K and 0.5 megohms were obtained for S/N's 6993, 6990, and 6988, respectively. Later measurements indicated the 0.5 megohm reading to be erroneous.

Prior to the irradiation portion of the experiment, but subsequent to water leakage into the test fixture, only S/N 6988 indicated insulation resistance degradation. S/N 6988 measured 10.0 megohms while S/N's 6993 and 6990 measured 2K and 100 megohms, respectively.

During Part I of the radiation portion of the test, zero unbalance, sensitivity and coil resistance characteristics were normal until the fixture was exposed to 0.5 watts/gm of nuclear heating. At this point all three transducers failed. Output signal values at maximum pressure deviated more than 25% from baseline values; insulation resistance values dropped nearly to zero, and maximum temperature limits were approached.

After the test fixture was withdrawn from HT-1 to the seal position, none of the transducers recovered to baseline unbalance values. Sensitivity values were normal, but the new zero unbalance values were not acceptable.

Part II of the test was performed to obtain more information, particularly for the Statham transducers. Sensitivity values for transducers 6988, 6990, and 6993 were stable through the 0.25 watt/gm heat-deposition portion of Part II. No meaningful results were obtained at higher rates due to failure of the transducers.

Posttest operations indicated that the insulation resistance of the transducers was low.

C. DUMMY CABLES/CONNECTOR ASSEMBLIES

The dummy cables and connectors used in this test are described in Section III. Only limited data were obtained after the water leak. All four cables indicated insulation-resistance degradation during heating in the REON oven and in the PBRF reactor. Recovery was sporadic and almost random. Data obtained in posttest operations were totally inconsistent with previous

test data. Future tests of the cables are required to obtain useful data. However, the water leakage problem associated with this test further substantiated the value of hermetically sealed integral cables for optimum transducer performance.

D. GAMMA DOSE AND NEUTRON FLUENCE

Based on information shown in the appendix, gamma dose rates for each portion of the test were calculated. The total exposure time at each dose-rate was obtained and an integrated gamma dose of 3.0×10^8 Rads(C) was obtained for the entire test.

Using four of the neutron dosimeters described in Section III.A.3 average fast-neutron flux values ($E_n > 2.9$ Mev) were obtained for the duration of the experiment. An arithmetic average fast flux was calculated, and using a linear conversion factor of 3.0 to adjust from $E_n > 2.9$ Mev to $E_n > 1.0$ Mev a total neutron fluence of 9.0×10^{15} n/cm² ($E_n > 1.0$ Mev) was obtained as shown in the appendix.

III. TECHNICAL DISCUSSION

A. DESCRIPTION OF TEST FIXTURE

Figure 1 shows the test fixture with the top portion of the cover removed. On the mounting plate are the transducers, cables with connectors, thermocouples, and dosimeters used in the experiment. Figure 2 schematically shows the location of the specific test articles.

1. Transducers

a. Statham Transducers

The Statham pressure transducers (Figure 3) had four silicon-chromium strain gages that were vapor-deposited on silicon-monoxide insulation to form a Wheatstone-type bridge. These deposits were on a 410 stainless-steel diaphragm. The entire element was enclosed in a 410 stainless-steel housing. The strain gages were mounted so that a pressure stimulus on the diaphragm put one leg of each half bridge in tension and the other in compression, resulting in a linear output signal change as a function of pressure on the diaphragm.

b. Standard Controls Corp. Transducers

The Standard Controls Corp. transducers used (Figure 4) were the bonded, strain-gage type, with one active and one dummy gage in each leg of the Wheatstone-type bridge. The strain gage coils were bonded with Pyre-ML varnish to a 2024 aluminum force summing tube. A pressure stimulus within the tube created an unbalance in the bridge, which resulted in a linear millivolt output signal change. The strain-sensing element was contained in a 304 stainless-steel housing.

2. Dummy Cables/Connector Assemblies

The cables used in this experiment were the Aero Research 347-125-4M-F(Cu) 24 type. The code indicates that they were sheathed in SS 347 tubing with a .125-in. outside diameter. In the sheathing were four, 24-gage copper conductors, which were insulated from the sheathing with magnesium oxide (MgO).

The transducer ends of the cables were attached to PS08-10-6S-FI-H3-5405-1/8-B2 Physical Science right-angle connectors. Two features of this connector are the special Inconel socket spring to provide positive contact and the ceramic insert for service up to 1200°F.

3. Dosimeters

Four neutron dosimeters (Figure 5) were mounted in the test fixture. The dosimetry included aluminum-cobalt wires, both bare and cadmium covered for thermal and epithermal flux measurement; sulphur pellets were used for fast flux measurements. As shown in Figure 1, the dosimeters (small, metal cylindrical bars) were close to each of the test items. The appendix presents the dosimetry results for this experiment.

4. Thermocouples

Eleven copper-constantan thermocouples in the test fixture were used to measure temperature gradients over the height of the transducer and across the mounting plate. The thermocouple cables were brought out of the test fixture in the same manner as the transducer cables (Figure 1).

5. Test Fixture Assembly

Figure 6 shows the complete test fixture ready for installation in the test capsule. The test fixture and all associated tubing were fabricated of aluminum. Three, 1-in. tubes extending to the rear contain the transducer and thermocouple cables. Two, 1/4-in. tubes extending from the bottom of the fixture provided system pressurization and purging.

The 2-1/2-in. tube in the center of the test fixture carried water into the fixture for cooling. When the water passed through the fixture below the mounting plate it exited to the inside of the test capsule and flowed back over the top of the fixture for additional cooling:

Figure 7 is a system schematic of throughtube-1 with the connections of the test fixture to the test capsule. The dimensions of the test capsule are also included.

B. TEST PROCEDURES

The test was divided into three phases: preirradiation control testing, radiation environment testing, and posttest operations. The radiation environment portion of the test was in two parts. The objective of the first part was to determine the maximum radiation level that the transducers could be exposed to without exceeding their rated operational temperatures. The objective of the second part was to determine operational or damage thresholds by allowing internal temperatures to exceed the maximum operational values. Test procedures were as follows.

1. Preirradiation Control Testing

Instrumentation was warmed up for 30 minutes prior to calibration or data acquisition.

a. With the transducer function switches and the function selector switch on the console in the operational position, the zero unbalance at zero psig was recorded for each transducer.

b. 50 psig was applied and Step (a) was repeated.

c. Step (a) was repeated for 100, 150, 200, 300 and 400 psig and again at the same pressures in decreasing steps.

d. The bridge resistance and insulation resistance of each transducer and dummy cable were recorded after the function selector switch was moved to the check position.

e. Steps (a) through (d) were repeated for each of the following temperatures: ambient, 200°, 300°, and 400°F.

Between the preirradiation and radiation portion of the test the test fixture developed a leak while it was immersed in the PBRF quadrant water. The leak was caused when hardware being moved through the quadrant water jarred the 23/R511 test fixture. A 1/4-in. swaged fitting on the back plate of the test capsule was cracked, and this crack was not noticed until erratic readings were detected at the start of Part I of the test. The capsule was withdrawn from the quadrant for inspection; the fixture was placed on the concrete apron of the containment vessel and baked with high wattage light bulbs. A purge of helium gas was also used. When further erratic readings were obtained, the capsule was cut open, wiped and baked, and purged again. The open capsule showed evidence of water leakage in the form of rust around the weld areas and on the metal straps used to weld the thermocouples. Subsequent baking and cleaning improved the transducer performance sufficiently to warrant continuation of the test. The following test procedures were followed.

2. Radiation Environment Testing

The parameters measured on each transducer during the test were pressure versus output voltage; insulation resistance between pins a and ground; b and ground; and bridge resistance from pins a to b. Insulation resistance was measured with a Weston 50V megohmmeter; output voltage with a digital volt meter; and resistance with a digital ohmmeter or Wheatstone bridge. Data cycles were made as described in Section III.B.1 with the test fixture in both the seal position and the irradiation position. A data cycle included all the preceding parameters, the input voltage of the test transducers and a reference transducer, the test capsule temperatures, and reactor power level and time correlations. Maximum pressure during the radiation portion of the test was 370 psig.

a. Test: Part I

The test fixture was inserted in HT-1 with the midpoint of the transducer mounting plate located at the point of intersection of the core N-S centerline and the HT-1 horizontal centerline. With the test capsule in this position, the reactor was made critical and brought to 100kw power before a data cycle was taken. Following the 100kw data cycle, the reactor power was increased to 1 and 10 Mw, with two data cycles taken at each power hold. Data cycles were taken after approximately 30 min at the indicated power level to ensure thermal equilibrium. After data acquisition at the 10 Mw power level, the test fixture was withdrawn from HT-1 to the seal position, and two data cycles were taken. Data were to be taken at 20, 25, and 30 Mw, but because of signal failure of the transducers, insulation resistance degradation, and upper limit temperatures, Part I of the test was terminated prior to completion of the specified test operations.

b. Test: Part II

With the fixture in the seal position, reactor power was increased to 60 Mw. After reaching maximum power, the test fixture was repositioned so that the front members of the transducer array were located on the HT-1 centerline at an average heating rate position of 0.25 watts/gm (based on the current flux maps). With the fixture in this position, one complete data cycle was taken. Thereafter, the heating rates were increased in steps of 0.25 watts/gm by moving the fixture toward the core's N-S vertical midplane. One data cycle was taken at each heating rate. The test was terminated when all four transducers had failed relative to temperature or output signal degradation criteria. After termination of the test, the test fixture was withdrawn from HT-1 and stored in the quadrant water, and two data cycles were performed.

3. Posttest Operations

Postirradiation removal of the sample fixture was the same as indicated in Report RN-S-0325. The entire sample holder and fixture were transferred through the underwater door from quadrant C to canal E, canal F, canal J, and into hot cell No. 1. The shroud was removed and the capsule was opened. Insulation resistance measurements for the entire 75 ft of cable/connector assemblies (both dummy and active) were recorded as the test fixture was being opened. After removal of the top cover of the test fixture, the active connectors were removed from the transducers, and insulation-resistance values of the seven disconnected cables associated with the transducers were recorded.

Next, the fixture piping and cables were cut through approximately 2 ft from the irradiated end and a 2-ft portion of cable with the connector was removed. Insulation resistance was recorded for the 2-ft section and for the 73-ft unirradiated section. The transducers were removed from the mounting plate, and pin-to-ground insulation-resistance measurements were made.

The Statham transducers were disassembled (by being cut through just below the hex nut (Figures 8 through 11), and insulation-resistance values of the strain gage and transition portion were recorded.

The insulation resistance of the Standard Controls Corp. transducers was recorded. Transducer S/N 6990 was opened and the force summing tube was removed (Figures 12 and 13).

No anomalies other than darkening from heat were observed in any of the transducers that were disassembled.

C. TEST RESULTS

Test results are presented in Tables I through X and Figures 14 through 27. Tabular data are in chronological order.

Preirradiation data are listed for tests performed at the REON Laboratory in Sacramento and the ATS building, PBRF, Sandusky. The irradiation test data obtained in the reactor containment vessel are divided into two parts. Postirradiation data obtained in the hot cells at PBRF are shown for each step described in Section III.B.

One test information table is included for each transducer. The results from the four dummy cable connector assemblies included in the test fixture are presented in Table X.

Transducer information Tables I through VII include the following data:

1. Location or place where data cycle was performed.
2. Date data cycle was performed.
3. Number of data cycles, if more than one cycle was taken.
4. Reactor power level during the irradiation portion of test.
5. The temperature of the transducer and its environment.

a. In Part I of the radiation portion of the test, due to symmetry of location, all transducers were assumed to have the same temperatures as those instrumented with thermocouples.

b. In Part II of the test the temperatures shown were applied only to those transducers that were instrumented (S/N 10 and S/N 6990).

6. The transducer output signal in millivolts versus the input pressure in lb/sq-in. gage.

7. The insulation resistance in megohms.

8. The bridge resistance in ohms.

Tables I through IV present the data obtained from the four Statham transducers.

Tables V through VII list the data obtained from the three Standard Controls transducers. One Standard Controls transducer failed early in the checkout testing at REON, and no data were obtained for the duration of the test.

All preirradiation and irradiation test results presented were obtained from an integral system of the transducers in the capsule, the Physical Science connectors, and 75 ft of MgO-insulated cable.

Table VIII shows sensitivity values calculated for the four Statham transducers from the preceding test information. Table IX presents values of sensitivity calculated for the three operational Standard Controls transducers.

Table X lists the insulation resistance data obtained for the four dummy cables included in the test fixture. The cables were 75-ft long, insulated with MgO, and were joined to Physical Science right-angle connectors at the transducer end.

Figures 14 through 17 and Figures 18 through 20 are plots of the zero shift values obtained for the Statham and Standard Controls transducers, respectively.

Figures 21 through 24 and Figures 25 through 27 are plots of the sensitivity calculated for the Statham and Standard Control transducers, respectively.

In all figures preirradiation values obtained at room temperature are shown with the dates they were obtained.

Part I of the radiation test was performed on 4-22-66. The values plotted at 0.05 and 0.5 watt/gm correspond to power levels of 1 Mw and 10 Mw, respectively. The zero watt/gm value shown after the 0.5 watt/gm value in Part I of the test corresponds to the seal position measurements after Part I of the test.

Part II of the test was performed on 5-27-66. Figures 14 and 21 are blank in this region due to functional failures of transducer S/N 17 during Part I of the test.

All plotted information was obtained from the preceding test information tables. If two or more values were listed for the same condition and the spread was small, the point was plotted as the arithmetic average of all points. If the spread was large enough, the data were plotted as separate points and connected with dashed lines.

The following material presents a discussion of the test results shown in the tables and figures. The text is divided into four parts: Part 1 for the Statham transducers; Part 2 for the Standard Controls transducers; Part 3 for the dummy cables; and Part 4 for the temperatures obtained. The following material is devoted to the effects of radiation on zero shift, sensitivity, insulation resistance, and bridge-resistance trends. The following definitions are applicable.

1. Zero unbalance: Transducer output signal at room temperature and zero gage pressure.
2. Zero shift: Change in zero unbalance due to any extraneous factor, such as change in temperature or irradiation.
3. Sensitivity: The change in transducer output signal from zero to maximum pressure at any constant temperature.
4. Insulation resistance: The resistance measured between some portion of the transducer circuit and the housing, or fixture chassis (the pin-to-ground resistance).
5. Bridge resistance: The resistance of the Wheatstone-type bridge measured across the input or output pins.
6. Failure criteria for transducer failure:
 - (a) Signal degradation greater than 25% of baseline values at maximum pressure.
 - (b) Total loss of insulation resistance.
7. Maximum Pressure (based on equipment and safety capabilities):
 - (a) 400 psig in the REON Laboratory
 - (b) 380 psig in the ATS building during the equipment checks.
 - (c) 370 psig in the ATS building during the acceptance checks and in the PBRF during Parts I and II of the test.

1. Discussion of Statham Transducer Test Results

The following discussion pertains to data in Tables I through IV, Figures 14 through 17, and Figures 21 through 24. Absolute parameter values of the test transducers in these tables differ, but the trends are similar enough to be treated as a group. Anomalies will be indicated.

a. Zero Unbalance and Zero Shift

Tables I through IV and Figures 14 through 17 show that for preirradiation and low-irradiation conditions ($\leq .05$ w/gm) the zero unbalance and zero-shift values for the subject transducers were relatively small. The zero shift over the range of 73° to 400°F in the REON Laboratory oven was -0.76, -1.3, -0.51, and 0.48 millivolts for transducers S/N 17, 14, 21, and 10, respectively. For the same transducers the zero-shift values from the seal position through the .05 w/gm condition were -0.14, 0.25, 0.27, and 0.36 millivolts, respectively.

Zero unbalance values were consistent until the 10 Mw irradiation (approximately 0.5 watts/gm heating rate) portion of Part I of the test. During and subsequent to the 10 Mw irradiation, the zero shift for all Statham transducers was significant. Transducers 17, 14, 21, and 10 had zero-shift values of 2.93, 7.69, 68.44, and 66.84 millivolts, respectively, on the first half of the 10 Mw data cycle. By the second half of the data cycle these values had deteriorated to 10.97, 77.05, and 83.80 for S/N's 14, 21, and 10, respectively. Because of its failure, S/N 17 was not evaluated on the second half of the data cycle.

After the fixture was returned to the seal position in Part I of the test another data cycle was taken. S/N 17 was no longer operative. S/N's 14, 10, and 21 maintained normal sensitivity characteristics but had significant, semipermanent and permanent zero shifts. Semipermanent describes the transducers that showed partial or complete recovery in the month between Part I and Part II of the test.

After 30 days, when Part II of the test was performed, S/N 14 had not recovered, S/N 21 had recovered fully, and S/N 10 had recovered slightly relative to their original zero-unbalance values.

b. Sensitivity

Table VIII lists the sensitivity values of the four Statham transducers. The values were obtained from the data cycles shown in Tables I through IV. Plots of these values (Figures 21 to 24) were obtained by subtracting zero pressure output signal values from maximum pressure output signal values on the first half of each data cycle. Two values are listed for the 0.5 w/gm and seal position data cycle because of their asymmetry.

The chronological decreases in sensitivity values shown in Table VII and in Figures 21 to 24 between the dates of 2/19 and 4/22 are proportional to the decrease in maximum system pressure as already defined.

Deviations from normal sensitivity values occurred at the 0.5 w/gm power level for S/N's 17, 21, and 10, further indicating failure. S/N 14 maintained a steady sensitivity, but this was coupled with permanent zero shifts of 25% or greater.

By definition, all Statham transducers failed Part I of the test. Because S/N 21 recovered after Part I of the test, Part II was performed in an effort to obtain further useful data.

Prior to Part II of the test only S/N 21 demonstrated baseline values of sensitivity at the seal position. During Part II of the test S/N 21 was the only transducer to operate normally until temperature limitations were exceeded. The explanation is as follows: first, S/N 21 had the highest insulation resistance at the start of Part I of the test (1000 megohms) and was therefore the most radiation-resistant unit if all other

factors were equal; and second, because of its position on the test fixture, S/N 21 was only receiving 0.25 watts/gm when the front transducers were in the 0.75 watt/gm position (based on calculations with current flux maps).

c. Insulation Resistance

Insulation-resistance characteristics of the Statham transducers are discussed relative to preirradiation, irradiation, and post-irradiation operations. Data are included in Tables I through IV.

(1) Preirradiation Insulation Resistance

After the transducers were heated to 400°F in an oven in the REON Laboratory, insulation resistance values of S/N's 17, 14, and 21 did not recover fully. S/N's 17, 14, and 21 were degraded from 700, 800, and 9000 megohms to 9, 9, and 2200 megohms, respectively. S/N 10 recovered fully to 900 megohms. One week after the transducers were heated, the final closure weld was made on the test fixture and insulation-resistance was measured again. S/N's 17, 14, and 21 indicated partial or full recovery with values of 400, 1000, and 5000 megohms, respectively. S/N 10 increased to 1000 megohms.

During the test fixture checkout in the ATS building at PBRF, all four transducers had marked decreases in insulation resistance. Values of 0.9, 100, 1000, and 200 megohms were obtained for S/N's 17, 14, 21, and 10, respectively.

The mechanism for the increases and decreases in insulation resistance of the entire system has not been determined. A possible cause for the decreasing resistance values may have been moisture leakage into the MgO insulation in the cables. The fixture was not hermetically sealed during shipment. High humidity and heating after the units were cooled to

external winter temperatures may have caused moisture degradation of the MgO insulation.

(2) Insulation Resistance During Irradiation

Prior to the radiation portion of this test, a water leak into the test fixture occurred. It is assumed that the degradation of insulation resistance between the time of the acceptance test on 4/13/66 and Part I of the irradiation test on 4/22/66 was due to this leakage. Subsequent degradation during the test is attributed to the gamma heating of the specimens. With the insulation resistance below 0.1 megohms, the transducers continued to operate normally until the 0.5 w/gm portion of the test.

In the seal position just after the 0.5 w/gm irradiation exposure, zero insulation resistance was measured with a 50V Weston megohmmeter for S/N 17. S/N 14 recovered slightly toward the pre water-leak values. S/N's 21 and 10 remained at approximately zero.

One month later, just prior to Part II of the test, the insulation resistance of the transducers was measured with the transducers at the seal position. S/N 17 was inoperative and read zero. S/N's 14 and 21 read 0.9 megohms. S/N 10 read 3.0 megohms.

During Part II of the test, S/N 21 indicated severe insulation resistance degradation

(3) Posttest Insulation Resistance Measurement

As noted in Tables I through IV insulation-resistance measurements for the Statham transducers were made with the fixture as an integral unit. Values of 1.0, 1.0, 5.0 and 8.0 megohms were obtained for S/N's 17, 14, 21 and 10, respectively. After the capsule was opened and

the cable/connector assemblies were disconnected from the transducers, values of 500, 600, 60 and 600 megohms were obtained for the respective cables. Increases of approximately one order of magnitude were expected. These large increases indicated that the transducers had shorts or were defective.

The transducers were removed from the fixture and their insulation resistance was measured. Values of 0.05, 0.0, 0.2 and 5.0 megohms were obtained for S/N's 17, 14, 21 and 10, respectively. The low values confirmed the existence of transducer problems. The transducers were cut open just below the hex nut and the strain gage portion was separated from the connector portion. Insulation resistance measurements of the strain gage portion showed 0.0 megohms for S/N 17. However, S/N's 14, 21, and 10 showed 8K megohms. The connector portion of S/N's 17, 14, 21, and 10 measured 90 to 100; 0.0 to 200, 9 to 10, and 5.0 to 1K megohms, respectively.

These readings indicated that the connector portion of the transducers suffered severe insulation resistance degradation. The suspected cause was the high temperatures attained due to thermal gradients. However, contamination of the insulation during the water leak may have occurred and created shunt paths on the insulation.

The high insulation resistance values of the strain gage portions of S/N's 14, 21, and 10 show the relative reliability of that portion of the transducers. There was no visible reason for the zero insulation resistance reading obtained for S/N 17. Because no reading was obtained at the seal position after Part II of the test, it cannot be determined if the bridge resistance failed under irradiation or while being sectioned. S/N 17 was in the hottest location possible during Part II of the test, and because it was sectioned as carefully as the other transducers, it is believed that the bridge of S/N 17 may have failed under 0.75 watts/gm irradiation. Failure of this unit after Part I of the test indicated a weakness not evident in the other transducers. It was assumed to be an isolated case rather than a trend.

Further measurements of cable and connector insulation resistance were made after checking the transducers. The cables were cut 2 ft from the transducer end. The 2-ft section with the connector attached measured 25.0, 0.9, 100.0, and approximately 50.0 megohms for S/N 17, 14, 21, and 10, respectively. Theoretically, these values should be greater than those for the whole 75-ft portion of cable, but the portions associated with S/N's 17, 14, and 10 had lower values. This indicated problems in the last 2 ft of cable (the irradiated portion) or in the connector. Due to high activation dose rates and limited access time the cables were not disconnected from the connectors for further evaluation.

d. Bridge Resistance

Tables I through IV show the bridge-resistance values obtained for each Statham transducer measured across the input pins. Values on the output side of transducers S/N 17 and 14 were the same. Values on the output side of S/N 21 and 10 were slightly lower because of the temperature compensation resistor in the input portion of the circuit. Due to the amount of test data to be obtained and the limited time during capsule insertion in HT-1, no effort was made to double check the input pin values by measuring the bridge resistance across the output pins. Only input values were measured.

Consistent values of bridge resistance indicate that none of the Statham bridges opened during Part I of the test. During Part II of the test, from the seal position values to the 0.5 watt/gm values, bridge resistances varied 94, 34, and 50 ohms for transducers S/N 17, 21, and 10, respectively. S/N 17, the only transducer with zero insulation on the strain-gage portion during posttest operations, showed the greatest bridge resistance change. This was expected because S/N 17 was in the hottest location on the fixture for Part II of the test. It appears that the strain gage in S/N 17 failed during the 0.75 watt/gm radiation.

2. Discussion of Standard Controls Corp. Test Results

The following discussion pertains to data contained in Tables V through VII. Absolute values for each transducer represented on these tables are different, but differential values and trends are similar enough to discuss the transducers as a group.

a. Zero Unbalance and Zero Shift

Tables V through VII and Figures 18 through 20 show that for preirradiation and low irradiation conditions ($\leq .05$ w/gm) the spread in zero unbalance and zero-shift values for the subject transducers was relatively small. The zero shift over the range of 73° to 400°F in the REON Laboratory oven was 4.76, 2.79, and 3.81 millivolts for transducers S/N 6993, 6990, and 6988, respectively. The zero shifts in the range from zero to .05 w/gm in the PBRF were 0.55, 0.11, and 0.55 millivolts, respectively, for the same transducers.

During and subsequent to the 0.5 w/gm irradiation portion of Part I of the subject test, significant permanent zero-shift values occurred. The transducers were rated as having failed because there was more than a 25% change from baseline values.

Part II data were obtained in spite the failure of the transducers during Part I of the test (primarily to accommodate the Statham transducers). As indicated in the next section, the transducers had permanent zero shift values, but sensitivity values in the Part II seal position were consistent with those obtained in the Part I preirradiation seal position.

b. Sensitivity

Table IX and Figures 25 through 27 show the sensitivity characteristics of the three operational Standard Controls Corporation transducers. These values were obtained from the data cycles shown on Tables V

through VII, and were derived by subtracting zero pressure output signal values from maximum pressure output signal values on the first half of each data cycle.

The same decrease in sensitivity values that occurred in the Statham transducers during the period 2/19 to 4/22 due to the reduction in maximum system pressure was also noted in the Standard Controls transducers. Two sensitivity values are listed for the 10 Mw and seal position data cycles because of the asymmetry. One value was from the increasing pressure steps and the other from the decreasing pressure steps. Failure of all three transducers during the 10 Mw power portion of the test is obvious from the spread in sensitivity values. At the seal position after the 10 Mw irradiation, sensitivity values of transducers S/N 6993 and 6988 were normal. Transducer S/N 6990 did not recover and was not operable.

The sensitivity values listed for the seal position data cycle at the beginning of Part II of the experiment are consistent with those listed for preirradiation values. However, the unacceptable zero unbalance values (greater than 25%) were still evident in all three transducers.

c. Insulation Resistance

Insulation-resistance data for the Standard Controls transducers includes preirradiation, irradiation, and postirradiation operations. These data are shown in Tables V through VII.

(1) Preirradiation Insulation Resistance

After the transducers were temperature tested to 400°F at the REON Laboratory, insulation-resistance values for two of the three units did not return to preheat conditions. S/N's 6993 and 6988 were degraded from 10K and 6K to 90 and 0.8 megohms, respectively. S/N 6990 was not affected and remained at 9K megohms.

One week after the unit was temperature tested in the REON Laboratory the final closure weld was made on the test fixture and insulation-resistance measurements were made again. Transducer S/N 6993 measured 200 megohms showing some recovery; S/N 6990 measured 10K megohms. S/N 6988 measured 0.5 megohms.

Approximately two months later, during the transducer acceptance check in the ATS building at PBRF, the following values of insulation resistance were obtained: S/N 6993 - 10K megohms; S/N 6990 - 200 megohms; S/N 6988 - 700 megohms.

The mechanism for the increases and decreases in insulation resistance has not been determined, but it is believed that the decreasing values were due primarily to moisture from condensation due to temperature changes that may have occurred during shipping.

(2) Insulation Resistance During Irradiation

Prior to the radiation portion of this test, the water leak already described occurred. The insulation resistance degradation shown in the tables was evidently due to this leakage. Subsequent degradation of resistance during the test was the result of gamma heating of the specimens. The transducers, however, continued to operate normally until the 10 Mw power hold (0.5 watt/gm heating rate) was reached despite low values of insulation resistance.

During the 0.5 w/gm irradiation in Part I of the experiment, the insulation resistance of the three transducers dropped to 1.0, 0.3, and 0.0 megohms for S/N 6993, 6990, and 6988, respectively. Together with the values of signal degradation at maximum pressure, all three transducers were considered to have failed.

In the seal position after the 0.5 w/gm irradiation, the transducers recovered some insulation resistance and were measured at 100, 50, and 5 megohms, respectively.

One month later, with the test fixture in the seal position prior to Part II of the test, insulation resistance values of 300, 100, and 20 megohms were obtained for S/N's 6993, 6990, and 6988, respectively. The cause of the increase in insulation resistance was not determined; however, this occurrence was not uncommon during this test and the 23/R510 tests. As was expected, under 0.25 watt/gm irradiation in Part II of the test, insulation-resistance decreased to minimal values and the transducers were considered to have failed.

(3) Posttest Insulation Resistance

Posttest insulation-resistance measurements of the Standard Controls transducer were made before, during, and after disassembly of the test fixture in the hot cell.

As indicated in Tables V through VII, measurements were made with the fixture as an integral unit. Values of 1000, 200, and 100 megohms were obtained for transducers 6993, 6990, and 6988, respectively. After the test fixture was opened and the cables were removed from the transducers, these values increased to 5000, 600, and 1000 megohms for the cable assemblies only. Each increase was within the expected factor of 10. In the Statham cables increases of hundreds of megohms occurred indicating problems with the transducers. These problems were later verified when the connector portions of the Statham transducers were measured.

After the cables were removed from the transducers, the cables were cut through 2 ft from the test fixture end (the irradiated portion). The insulation resistance of the 2-ft portion and the remaining

73-ft portion was measured again. Values of 100, 50, and 50 megohms were obtained for the 2-ft section of cables connected to 6993, 6990, and 6988, respectively. These values were expected to be greater than the entire cable values, but they were significantly lower. Correspondingly low values obtained for the 73-ft portion indicated that the cables were damaged when they were cut through.

Insulation-resistance values for the force summing tubes and the bonded strain gages were not obtained. The information was not vital, and pocket dosimeters indicated that personnel were exposed to excessive doses; therefore, no effort was made to continue the measurements.

d. Coil Resistance

Tables V through VII show the coil-resistance values for each Standard Controls transducer. Except for the 10 Mw portion (0.5 watts/gm) of Part I of the test and the 0.5 watts/gm portion of Part II of the test, the coil values consistently ranged between 1970 and 1980 ohms. During the 10 Mw irradiation portion of Part I, no coil resistance values were obtained. Temperature conditions forced an end to the test before these measurements could be made.

During Part II of the test, in the 0.5 watt/gm position, the coil resistances decreased 75, 37, and 1 ohm from baseline values for transducers S/N's 6993, 6990, and 6988, respectively. S/N 6993 was in the highest radiation field, and S/N 6988 in the lowest. The maximum change in coil resistance occurred in the highest radiation field. No data were obtained in the 0.75 watt/gm position because temperature conditions required termination of the test. No coil resistance measurements were obtained in the hot cell during posttest operations.

3. Dummy Cable/Connector Assemblies

Table X shows the insulation-resistance values obtained for four dummy cables included in the test fixture. These cables are described in Section III.A.2. The Physical Science right-angle connector is an integral part of the cable assemblies (Figure 1).

When the units were heated from 73° to 400°F in a REON Laboratory oven on 10 February 1966, insulation resistance values for cables 1, 2, and 3 were reduced from 10K to 5K megohms, 30.0 to 7.0 megohms, and 10K to 1.2K megohms, respectively. Cable 4 was not affected and remained at 10K megohms. When the units were returned to room temperature full recovery was made by cables 1 and 3. Cable 2 showed a significant increase in resistance value from 7.0 to 1000 megohms.

On 19 February 1966, after the final closure weld, cables 1, 2, and 4 measured 10K megohms. Cable 2 measured 9K megohms. The reason for the continual increase in insulation-resistance value for cable 2 was not determined, but it is not unusual for cables that are baked to increase in insulation resistance.

On 13 April 1966 during the fixture checkout in the ATS building at PBRF, insulation resistance values of 600, 50, 10K, and 10K megohms were obtained for cables 1 through 4, respectively. The reason for the large decrease of values in cables 1 and 2 has not been determined. Moisture leakage into the MgO insulation during shipment from Aerojet to WANL/Large and from WANL to PBRF/Sandusky is the most likely cause.

Just prior to Part I of the test, the water leak described in Section III.B occurred. Cables 1 and 2 were not affected further, but cables 3 and 4 showed degradation to 3K and 2K megohms, respectively.

During Part I of the test, cables 1 through 4 failed during the 0.5 w/gm irradiation exposure. Values of 0.09, 0.5, 0.4, and 0.5 megohms were recorded for cables 1 through 4, respectively. The cause of failure appeared to be gamma heating; however, the MgO insulation may have been permanently damaged during the water leak, thereby contributing to the failure.

In the seal position after Part I of the test, cables 1 and 2 recovered to low values of 0.8 and 8.0 megohms. Cables 3 and 4 recovered to 1K megohms each, indicating a "baking" effect had taken place during irradiation.

One month later, on 27 May 1966, cables 1 and 2 had recovered to 300 and 75 megohms, respectively. Cable 3 remained approximately the same with 800 megohms, and cable 4 increased to 2K megohms. The cause of the time-dependent increases in insulation-resistance values has not been determined.

During Part II of the test, cables 1 through 4 showed complete insulation resistance degradation in the radiation environment.

The posttest operations values of cable insulation resistance shown in Table X are not consistent either with previous data or as a block. The data are considered to be unreliable and indicate a problem area. Heat and radiation have an adverse effect on the operation and characteristics of the cables, but the water leaks superseded this effect.

Posttest operations photographs (Figures 28 and 29) revealed that the ceramic inserts in the connector assemblies were damaged during testing or disassembly. The damage was attributed to excessive heating of the connector during the test.

4. Temperature Data

The temperatures shown in Tables I through VII for the Statham and Standard Controls transducers were obtained using the copper-constantan thermocouples described in Section III.A. These thermocouples were mounted on transducers S/N 10 and 6990 and on the mounting plate as shown in Figure 2.

Temperatures listed for the transducers in the REON Laboratory oven are accurate to within 3 to 5°F. No data were recorded until equilibrium temperatures were attained.

During Part I of the radiation test, heating rates were assumed to be isotropic in the test fixture because of the fixture's position in HT-1. Transducers that were farthest from the center of the mounting plate had temperatures only slightly lower than the instrumented transducers. This was consistent with Figure 30, which shows almost no heating rate decrease for the first 5 in. from the mounting plate centerline along the HT-1 axis. All transducers were within 5 in. of the mounting plate centerline.

The temperatures listed in the test information tables are external wall temperatures. Limitations in the PBRF Data Logger system restricted the maximum temperature measurements to 714°F. Due to internal heat generation by gamma radiation, thermal gradients occurred in the transducers. The specific values reached at the center of the transducers, right-angle connectors, and cables are not known. Insulation-resistance failure during the test indicated that the centerline temperatures were in excess of 1000°F. High temperatures, together with previous moisture degradation, appear to be the prime cause of cable insulation degradation and transducer failure.

For Part I of the test, transducers S/N 17, 14, 6992, and 6990 were assigned the temperatures obtained with thermocouple 108 mounted on transducer S/N 6990. S/N's 21, 10, and 6988 were assigned the temperatures obtained

with thermocouple 105 mounted on transducer S/N 10. During the 0.5 w/gm portion of Part I of the test, a maximum temperature of 714°F was obtained; however, as already indicated, this temperature was a system limitation. Thermocouples 106, 111, and 108 on the Standard Controls transducer had temperatures of 166, 317, and 714°F, respectively, indicating the large axial temperature gradient on the transducers. (Figure 2 shows the thermocouple locations). Thermocouple 104, which was comparable to T/C 108 on the Standard Controls transducer, was not operating satisfactorily. T/C 105 had a lower temperature location, which explains the maximum of 539°F.

During Part II of the test, only thermocouples 100, 101, 106, 107, and 110 were used. Thermocouples 100, 101, 106, 107, and 110 were connected to a Daystron Recorder. Thermocouple 104 was hooked to a Leeds and Northrup Recorder. None of the thermocouples were used with the Data Logger for this portion of the test.

Thermocouple 101, mounted on transducer S/N 10, showed a value of 350°F during the 0.75 watt/gm irradiation. During the 10 Mw irradiation (i.e., 0.5 watt/gm) thermocouple 101 measured 200°F.

Thermocouple 106 mounted on transducer S/N 6990 measured a value of 175°F in the 0.75 watt/gm position. This value was inconsistent, because S/N 6990 was closer to the core center and was therefore exposed to a higher radiation field than S/N 10. The intense radiation and increased temperature apparently caused the thermocouple to malfunction.

Thermocouple 104 read 420°F at the termination of the test. This reading was inconsistent with results obtained in Part I of the test.

IV. CONCLUSIONS

Based on the test results, the following general conclusions are made.

The water leak into the test fixture, and the subsequent insulation-resistance degradation of the cables resulted in the addition of indeterminate variables to the test data. If the leakage had not occurred, performance of the entire system would have been significantly improved. Test results show that the transducers will operate effectively with low values of insulation resistance but only in a low-radiation environment (0.1 watt/gm). The insulating material would have had increased resistance if moisture had not been present. Sensitivity values of the transducers were stable, but unacceptable zero shifts resulted. The degree of these zero shifts would have been reduced if the insulation resistance had been maintained.

The following specific conclusions are made for the Statham and Standard Controls Corporation transducers, and the Aero Research cables with Physical Science connectors.

A. STATHAM TRANSDUCERS

1. Zero unbalance and zero shift values remained stable until the test fixture was exposed to 10 Mw of power (0.5 watts/gm of gamma heat). Only one of four transducers recovered fully to baseline zero unbalance values after this exposure.

2. Sensitivity values remained stable until the test fixture was exposed to 10 Mw of power (0.5 watts/gm). Normal baseline sensitivity values were measured after irradiation, although zero unbalance values were greatly changed.

Changes in zero unbalance, zero shift, and sensitivity in the high-radiation environment may have been associated with the accidental pretest

water damage. Signal shunts due to threshold insulation resistance values may have been the direct cause.

3. Insulation resistance was degraded due to moisture leakage before the experiment and gamma heating during the experiment. The degree of moisture degradation was not determined. Insulation-resistance degradation due to gamma heating was similar to that resulting from oven heating.

a. Insulation resistance degradation of the transition portion of the transducers was permanent and indicated a problem area.

b. Permanent insulation-resistance degradation in three of four Statham strain gages was negligible. No data were available for the fourth.

4. Strain-gage bridge resistances were consistent until the capsule was exposed to high radiation levels (0.5 to 0.75 watt/gm).

5. Based on the results of this test and the NRX series of tests it was assumed that failure of S/N 17 was an isolated case.

B. STANDARD CONTROLS CORP. TRANSDUCERS

1. Zero unbalance and zero shift values remained stable until insulation resistance degradation was extreme. Subsequent to high radiation exposure (0.5 watt/gm) zero unbalance values degraded to unacceptable levels.

2. Sensitivity values were stable until insulation-resistance degradation was extreme. Sensitivity values recovered fully after radiation exposure.

3. Insulation resistance was degraded due to moisture leakage before the experiment and gamma heating during the experiment. The contribution of moisture degradation to total insulation degradation during irradiation could not be determined.

Permanent changes in transducer operating characteristics occurred at 10 Mw of power (0.5 watts/gm).

4. Bridge resistances were stable until the transducers were exposed to 0.5 to 0.75 watt/gm heat deposition. The resistance changes were not permanent, and normal bridge values were observed after the test.

C. CABLES/CONNECTOR ASSEMBLIES

Degradation of the cable and connector insulation resistance was severe during the 0.5 w/gm radiation exposure and the high rate heat-deposition portion of the experiment.

Significant variations in resistance values indicate further cable studies are necessary.

Studies to determine the cause of the right-angle-connector ceramic insert damage are required.

V. RECOMMENDATIONS

Recommendations to advance component design for radiation-environment performance and to ensure integrity of the units in future tests are as follows:

A. COMPONENT DESIGN

1. Incorporate integral swaged cables directly to strain gage connections. This will decrease the weight and cost of right-angle connectors

and the transition portion of transducer. An important side effect will be lower activation dose rate during posttest operations and study.

2. Include a heat sink in the experiment to simulate more closely NERVA and XE nozzle conditions. Heat degradation of the system insulation was a major factor in the failure of the test articles and was the criterion for test termination.

3. Increase the number of thermocouples on future test fixture and test articles.

4. Include gamma microdosimeters on test articles to ascertain exact dose exposure. Compare these with predicted NERVA and XE gamma doses and known NRX gamma doses.

B. TEST DESIGN

1. Construct the test fixture so that on-site replacement of transducers and cables is facilitated.

2. After hermetic construction is complete, perform pressure and temperature checks at the REON Laboratory.

3. Increase the capability and system design of the Data Logger at PBRF to ensure full temperature range measurements.

4. Modify the "off-gas" vent system at PBRF to facilitate longer testing cycles with proportional increases in irradiated "off-gas."

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Table I

TABLE I
TEST DATA FOR STATHAM TRANSDUCER S/N 17

Location	Date	Cycle	Reactor Power Mw	Temp °F	OUTPUT SIGNAL, (mv) VS INPUT PRESSURE psig														Insulation Resistance Megohms		Bridge Resistance Ohms	
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A	Pins B	
REON Laboratory																						
a) Fixture open on top	2/10/66	1		73	3 48	8 91	14 32	19 63	24 90	35 41	45 86	3 35	24 84	19 56	14 29	8 89	3 44	700	-	1,158		
↓	↓	1	-	200	3 05	8 52	13 95	19 22	24 53	35 03	44 45	3 07	24 57	19 28	13 98	8 56	3 12	100		1,167		
		1		300	2 95	8 11	13 85	19 18	24 50	35 04	45 50	3 02	24 56	19 22	13 90	8 48	2 99	80	80	1,166		
		1		400	2 72	8 27	13 76	19 14	24 50	35 16	45 60	3 24	24 62	19 28	13 92	8 45	2 92	9	6	1,186		
		1		75	3 69	9 12	14 55	19 83	25 09	35 56	45 95	35 54	25 05	19 79	14 50	9 11	3 65	9	9	1,160		
b) After final weld	2/19/66	1		AMB	4 31	9 86	15 29	20 67	25 99	36 66	47 17	36 54	25 96	20 61	15 27	9 80	4 24	400	8,000	1,155		
ATS Bldg, PERF																						
a) Equipment Check	3/25/66	1		AMB	3 92	9 10	15 19	20 39	25 99	36 39	44 89	36 59	26 01	20 50	15 39	9 69	4 39		-	1,159		
b) Acceptance Check	4/13/66	1	-	AMB	3 97	9 33	14 65	19 91	25 18	35 50	42 66	35 39	25 91	20 00	14 79	9 41	3 95	0 9	30	1,157		
Part I 23/R511, PERF																						
a) Seal Position	4/20/66	1	0 0	71	4 09	9 44	14 69	19 86	25 00	35 23	42 25	35 17	24 98	19 83	14 65	9 42	4 09	0 2	0 3	1 156		
↓	↓	2	0 0	71	4 09	9 35	14 63	19 83	25 01	35 33	42 20	35 75	25 09	19 88	14 76	9 42	4 19	0 3	0 3	1,160		
		3	0 0	72	3 43	9 11	14 44	19 48	24 64	34 94	41 97	34 97	24 89	19 68	14 37	9 12	3 93	0 0	0 2	1,157		
b) HT 1 Centerline		1	0 1	87	3 96	9 21	14 43	19 77	24 90	35 18	42 15	35 13	24 95	19 85	14 65	9 32	4 04	0 3	0 2	1,156		
↓	↓	2	0 1	87	3 76	9 12		19 60		35 02	42 05	35 02		19 67		9 24	3 90	0 3	0 3	1,155		
		1	1 0	177	4 04	9 41	14 71	19 83	25 12	35 34	42 27	35 29	25 05	19 82	14 70	9 31	4 04	0 3	0 3	1,155		
		2	1 0	177	3 95	-	14 53		24 93	-	42 04		24 96	-	14 63	-	3 96	0 3	0 4	1,155		
		1	10 0	714+	7 02	12 36	18 14	23 60	29 49	41 26	51 99	50 38	44 69		40 54			0 0	0 0			
c) Seal Position		1	0 0	105	308 0		301 0	-	312 0		318 0	-	293 0		313	-	283 0	0 0	0 0	1 160		
Part II 23/R511, PERF																						
a) Seal Position	5/21/66	1	60 0		No meaningful data obtained for Part II														0 0		1,160	
b) 0 25 w/gm		1																0 0		1,164		
↓	↓	2																-	-	-		
c) 0 50 w/gm		1																	0 09	1,254		
↓	↓	2																		-		
d) 0 75 w/gm		1																-	-	-		
Post Test Operations																						
a) Integral System																						
b) 75 ft Cables & Connector (Disconnected from transducer)																						
1) 2 ft Section with connector (x-ducer end)																						
2) 73 ft Section																						
c) Transducer alone in fixture																						
d) Transducer on bench																						
1) Transition portion																						
2) Strain gage portion																						

PINS	
A-GND	B-GND
0 9	1 0
500 0	200 0
25 0	10 0
1-8	
0 05	-
-	
90 0	100 0
0 0	0 0

TEST DATA FOR STATHAM TRANSDUCER S/N 14

Location	Date	Cycle	Reactor Power Mw	Temp °F	SIGNAL OUTPUT, (mv) VS PRESSURE INPUT psig														Insulation Resistance Megohms		Bridge Resistance Ohms			
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A-B				
REO Laboratory																								
a) Fixture open on top	2/10/66	1	-	73	2 15	7 70	13 26	18 73	24 16	34 97	45 73	34 96	24 17	18 74	13 29	74	2 12	800		1 267				
↓	↓	1		200	1 24	6 81	12 29	17 72	23 10	33 78	44 37	33 85	23 14	17 78	12 41	6 87	1 31	200	200	1,276				
		1		300	1 06	6 61	12 10	17 52	22 90	33 60	44 30	33 72	23 10	17 67	12 29	6 75	1 16		30	1,283				
		1		400	0 84	6 41	11 98	17 41	22 86	33 59	44 16	33 62	22 87	17 47	12 02	6 46	0 85	3	3	1,280				
		1		75	2 35	7 90	13 49	19 00	24 45	35 19	45 80	34 96	24 20	18 81	13 35	7 93	2 28	9	9	1,267				
b) After final weld	2/19/66	1		AMB	1 81	7 53	12 11	18 66	24 10	35 13	46 00	35 08	24 17	18 65	13 14	7 50	1 82	1,000	7,000	1 267				
ATG Bldg, PBRF																								
a) Equipment Check	3/25/66	1		AMB	1 49	7 04	12 49	18 03	23 80	34 49	43 4	34 79	23 79	18 19	12 69	6 99	1 39	11	-	1 249				
b) Acceptance Check	4/13/66	1	-	AMB	1 57	7 06	12 51	17 91	23 30	33 98	41 28	34 20	24 10	18 05	12 69	7 18	1 55	100	300	1,267				
Part I 23/R511, PBRF																								
a) Seal Position	4/22/66	1	0 0	71	2 06	7 52	12 89	18 17	23 46	33 98	41 19	34 03	23 47	18 20	12 92	7 57	2 09		09	7 1,266				
↓	↓	2	0 0	71	2 11	7 50	12 88	18 18	23 47	34 06	41 34	34 06	23 61	18 73	13 00	7 53	2 14		03	09 1,266				
		3	0 0	72	2 22	7 58	12 96	18 31	23 60	34 10	41 34	34 13	23 71	18 41	13 05	7 60	2 21		0 0	01 1,260				
b) HT-1 Centerline		1	0 1	87	2 23	7 64	13 07	18 40	23 61	34 18	41 42	34 23	23 77	18 44	13 14	7 71	2 25		0 0	0 0 1,266				
↓	↓	2	0 1	87	2 24	7 14		18 41		34 20	41 34	34 22		18 44		7 75	2 24		0 0	0 0 1,266				
		1	1 0	177	2 30	7 84	13 23	18 45	23 83	34 33	41 46	34 31	23 88	18 48	13 26	7 69	2 31		0 0	0 0 1 266				
↓	↓	2	1 0	177	2 31	13 14	-	23 78	-		41 43		23 85		13 27	-	2 32		0 0	0 0 1,266				
		1	10 0	714+	9 75	16 08	21 93	27 40	32 92	43 50	50 74	43 86	33 66		23 33		13 06		05	0 0				
c) Seal Position		1	0 0	105	10 61		21 23		31 73		49 36	-	31 97		21 43		10 63		8	9	1,273			
Part II 23/R511, PBRF																								
a) Seal Position	5/27/66	1	60 0		10 83	16 25	21 77		32 45		50 41		32 62		21 82	16 36	10 81			0 9	1,274			
b) 0 25 w/gm	↓	1			75 34	95 89	108 58	120 05	134 00	152 99	175 0	182 23	181 62	185 99	190 67	194 52	197 60		-	0 4	1,279			
↓		2					236 25	-	258 00		292 00	-	284 00		284 0					-				
c) 0 50 w/gm	↓	1			No further data obtained																			
d) 0 75 w/gm	↓	1																						
Post Test Operations																								
																			PINS					
																			A-GND	D-GND				
a) Integral System																				1 0	1 0			
b) 75 ft Cables & Connector (Disconnected from transducer)																				600 0	600 0			
1) 2 ft section with connector (x-ducer end)																				0 9	1 0			
2) 73 ft section																				700 0				
c) Transducer alone in fixture																								
d) Transducer on bench																				0 0	0 0			
1) Transition portion																				200 0	0 0			
2) Strain gage portion																				8K	8K			

Table III

TABLE III

TEST DATA FOR STATHAM TRANSDUCER S/N 21

Location	Date	Cycle	Reactor Power, Mw	Temp °F	SIGNAL OUTPUT, (mv) VS PRESSURE INPUT psig														Insulation Resistance Megohms		Bridge Resistance Ohms
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A-B	
REON Laboratory																					
a) Fixture open on top	2/10/66	1		73	3 02	9 61	16 11	22 46	28 73	41 19	53 30	41 07	28 60	22 33	16 02	9 55	3 02	9 000		1,342	
↓	↓	1		200	2 76	9 25	15 69	22 03	28 27	40 57	52 70	40 61	28 27	22 04	15 76	9 33	2 79	200	200	1,378	
		1		300	2 64	9 13	15 51	21 79	27 97	40 25	52 26	40 22	28 00	21 78	15 54	9 15	2 66	100	100	1,411	
		1	-	400	2 51	8 98	15 35	21 58	27 81	40 04	51 98	40 06	27 90	21 75	15 55	9 16	2 71	20	20	1,448	
		1		75	2 98	9 57	16 03	22 38	28 72	41 16	53 35	41 12	28 69	22 40	16 10	9 59	3 00	2 000	2,000	1,342	
b) After final weld	2/19/66	1		AMB	3 13	9 85	16 41	22 87	29 16	41 89	54 25	41 75	29 18	22 79	16 38	9 80	3 14	5,000	8,000	1,339	
ATS Bldg , PBRF																					
a) Equipment Check	3/25/66	1		AMB	3 04	9 39	16 00	22 39	28 89	41 70	51 55	42 00	28 90	22 49	16 29	9 39	3 20	-		1,319	
b) Acceptance Check	4/13/66	1	-	AMB	2 91	9 37	15 77	22 06	28 29	40 83	48 92	40 80	28 87	22 17	15 94	9 50	2 90	1,000	3 000	1,338	
Part I 23/R511, PBRF																					
				T/C #105																	
a) Seal Position	4/22/66	1	0 0	68	2 83	9 27	15 56	21 76	27 96	40 13	48 46	40 14	27 92	12 72	15 55	9 30	2 86	1,000	1,000	1,342	
↓	↓	2	0 0	68	2 86	9 21	15 53	21 78	27 92	40 20	48 51	40 10	27 97	21 74	15 62	9 22	2 88	400	400	1,340	
		3	0 0	70	2 89	9 21	15 54	21 76	28 01	40 22	48 45	40 19	28 00	21 85	15 60	9 22	2 88	500	800	1,339	
b) HT 1 Centerline		1	0 1	82	2 90	9 27	15 55	21 90	27 91	40 14	48 48	40 26	28 10	21 90	15 70	9 37	2 92	70	70	1,339	
↓	↓	2	0 1	82	2 92	9 29		21 90	-	40 14	48 46	40 23		21 90		9 39	2 93	80	90	1,339	
		1	1 0	135	3 03	9 57	15 88	21 88	27 98	40 24	48 32	40 22	28 20	21 89	15 84	9 37	3 08	10	10	1,347	
		2	1 0	135	3 10		15 76		28 15		48 44		28 12		15 88		3 10	10	10	1,347	
		1	10 0	525	71 27	78 89	86 30	92 50	98 95	110 07	118 07	111 87	100 81		87 89		79 91	01	0	-	
c) Seal Position		1	0 0	100	10 44	-	22 20	-	34 20	-	54 16	-	33 91	-	21 49		8 72	0 1	0 1	1,343	
Part II 23/R511, PBRF																					
a) Seal Position	5/27/66	1	60 0		2 77	9 27	15 63		28 07	-	48 73	-	28 20	-	15 66	9 26	2 73		0 9	1,350	
b) 0 25 w/gm		1			2 03	8 48	14 20	20 97	27 00	39 17	47 48	39 14	27 07	20 85	14 77	8 42	2 04	-	0 4	1,366	
↓	↓	2			-	-	14 70	-	26 96	-	47 40	-	27 05	-	14 7	-	-	-	-	-	
c) 0 50 w/gm		1			-2 84	3 53	9 71	15 78	21 57	33 47	41 46	33 17	21 41	15 43	9 21	2 84	-3 31	-	0 09	1,384	
↓	↓	2				-	9 08	-		-	41 20	-		-	8 95	-		-	-	-	
d) 0 75 w/gm		1			-	-	-	-	-		37 48		-		-	-	-	-	-	-	
Post Test Operations																					
a) Internal System																					
b) 75 ft Cables & Connector (Disconnected from transducer)																					
1) 2 ft section with connector (x-ducer end)																					
2) 73 ft section																					
c) Transducer alone in fixture																					
d) Transducer on bench																					
1) Transition portion																					
2) Strain gage portion																					

PINS	
A-GND	D-GND
5 0	5 0
60 0	60 0
100 0	100 0
500 0	500 0
0 2	-
-	-
10 0	9 0
8K	8K

TABLE IV

TEST DATA FOR STATHAM TRANSDUCER S/N 10

Location	Date	Cycle	Reactor Power, Mw	Temp °F	SIGNAL OUTPUT, (mv) VS PRESSURE INPUT, psig															Insulation Resistance Megohms		Bridge Resistance Ohms	
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A-B			
REON Laboratory:																							
a) Fixture open on top	2/10/66	1	-	73	3.37	8.76	14.12	19.38	24.64	35.03	45.37	35.03	24.62	19.40	14.11	8.77	3.34	900	-	1,445			
↓	↓	1	-	200	3.26	8.64	14.02	19.31	24.55	34.91	45.20	34.94	24.53	19.33	14.11	8.76	3.30	100	100	1,478			
		1	-	300	3.50	8.92	14.27	19.55	24.75	35.14	45.40	35.17	24.78	19.55	14.29	8.95	3.53	30	30	1,506			
		1	-	400	3.85	9.29	14.62	19.88	25.17	35.54	45.77	35.36	25.18	19.96	14.72	9.34	3.92	3	3	1,538			
		1	-	75	3.28	8.71	14.06	19.33	24.57	34.98	45.25	34.96	24.57	19.33	14.09	8.74	3.29	900	900	1,445			
b) After final weld	2/19/66	1	-	AMB	3.39	8.93	14.36	19.71	24.93	35.59	46.00	35.47	24.96	19.63	14.32	8.87	3.37	1,000	8,000	1,442			
ATS Bldg, PERF																							
a) Equipment Check	3/25/66	1	-	AMB	3.19	8.59	14.29	19.39	25.00	35.39	43.84	35.59	24.89	19.39	14.05	8.69	3.19	-	-	1,419			
b) Acceptance Check	4/13/66	1	-	AMB	3.10	8.43	13.72	18.93	24.11	35.29	41.44	34.60	24.57	19.05	13.87	8.54	3.08	200	300	1,440			
Part I: 23/R511, PERF					T/C #105																		
a) Seal Position	4/22/66	1	0.0	68	2.96	8.29	13.51	18.65	23.84	34.02	41.07	34.06	23.84	18.66	13.50	8.32	2.99	90	90	1,445			
↓	↓	2	0.0	68	2.99	8.24	13.48	18.70	23.83	34.07	41.09	34.06	23.84	18.70	13.57	8.25	3.00	90	90	1,443			
		3	0.0	70	3.03	8.26	13.49	18.70	23.86	34.12	41.07	34.08	23.94	18.75	13.56	8.26	3.02	100	100	1,442			
		1	0.1	82	3.05	8.34	13.55	18.82	23.88	34.08	41.10	34.17	23.88	18.82	13.68	8.43	3.06	40	40	1,442			
		2	0.1	82	3.08	8.34	-	18.80	-	34.06	41.15	34.09	-	18.82	-	8.42	3.07	50	50	1,442			
↓	↓	1	1.0	135	3.28	8.71	13.92	18.91	24.04	34.27	41.17	34.26	24.21	19.02	13.89	8.51	3.30	9	9	1,449			
		2	1.0	135	3.32	-	13.81	-	24.15	-	41.22	-	24.11	-	13.92	-	3.31	9	9	1,448			
		1	10.0	525	69.80	79.02	86.26	93.11	100.25	111.80	120.30	115.02	107.06	-	98.80	-	86.79	.02	.04	-			
		1	0.0	100	21.04	-	30.86	-	41.16	-	58.46	-	41.60	-	31.47	-	20.71	.1	.1	1,449			
c) Seal Position		1	0.0																				
Part II: 23/R511, PERF					T/C #101																		
a) Seal Position	5/27/66	1	60.0	135	5.39	10.76	16.03	-	26.37	-	43.71	-	26.48	-	16.03	10.73	5.32	-	3.0	1,453			
b) 0.25 w/gm	↓	1	↓	225	11.01	17.96	23.94	29.93	35.85	46.85	55.81	49.81	40.68	37.05	32.43	28.08	23.70	-	0.7	1,469			
2		225		-	-	37.10	-	48.57	-	67.23	-	51.04	-	41.83	-	-	-	-	-				
c) 0.50 w/gm	↓	1	↓	-	No further data obtained.													-	-	0.5	1,503		
2		-															-	-	-	-			
d) 0.75 w/gm	↓	1	↓	350																			
Post Test Operations																							
																		PINS					
																		A-GND	B-GND				
a) Integral System																			8.0	8.0			
b) 75 ft Cables & Connector (Disconnected from transducer)																			600.0	600.0			
1) 2 ft section with connector (x-ducer end)																			0.8-100	0.5-80.0			
2) 73 ft section																			200.0	-			
c) Transducer alone in fixture																			200.0	-			
d) Transducer on bench																			-	-			
1) Transition portion																			5.0	1K			
2) Strain gage portion																			20K	10K			

Table IV

TABLE V

TEST DATA FOR STANDARD CONTROLS TRANSDUCER S/N 6990

Location	Date	Cycle	Reactor Power, Mw	Temp °F	OUTPUT SIGNAL, (mv) VS INPUT PRESSURE, psig																Insulation Resistance Megohms		Bridge Resistance Ohms	
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A-B				
REON Laboratory:																								
a) Fixture open on top	2/10/66	1	-	73	5.18	8.83	12.49	16.09	19.69	26.96	34.30	26.95	19.70	16.09	12.48	8.84	5.19	5,000	-		1,976			
↓	↓	1	-	200	4.07	7.81	11.55	15.27	18.98	26.40	33.93	26.49	19.06	15.35	11.67	7.94	4.18	400	500		1,978			
		1	-	300	3.53	7.39	11.25	15.07	18.90	26.62	34.40	26.76	19.07	15.25	11.43	7.57	3.71	900	900		1,979			
		1	-	400	2.39	6.43	10.43	14.44	18.54	26.61	35.00	27.24	19.21	15.18	11.21	7.15	3.08	100	200		1,980			
		1	-	75	5.53	9.18	12.83	16.43	20.03	27.31	34.60	27.29	20.02	16.41	12.81	9.16	5.51	9,000	9,000		1,976			
b) After final weld	2/19/66	1	-	AMB	5.26	9.01	12.70	16.39	20.00	27.51	34.95	27.45	20.07	16.37	12.71	8.99	5.26	10,000	8,000		1,973			
ATS Bldg., PERF																								
a) Equipment Check	3/25/66	1	-	AMB	5.29	8.99	12.69	16.49	19.99	27.29	33.55	27.29	19.99	16.19	12.69	8.89	5.29	-	-		1,979			
b) Acceptance Check	4/13/66	1	-	AMB	5.25	8.85	12.43	16.02	19.56	27.03	31.84	27.03	19.94	16.12	12.57	8.95	5.26	200	300		1,976			
Part I: 23/R511, PERF																								
a) Seal Position	4/22/66	1	0.0	71	4.25	7.86	11.42	15.01	18.62	25.82	30.84	25.82	18.62	15.12	11.47	7.90	4.28	100	200		1,975			
↓	↓	2	0.0	71	4.23	7.79	11.38	14.94	18.61	25.73	30.76	25.78	18.59	15.02	11.44	7.81	4.25	100	100		1,971			
		3	0.0	72	4.43	7.97	11.54	15.15	18.73	25.99	30.94	25.94	18.75	15.18	11.62	8.00	4.46	200	300		1,977			
		1	0.1	87	4.48	8.06	11.61	15.24	18.82	25.98	30.94	26.01	18.83	15.25	11.74	8.16	4.50	60	60		1,975			
b) HT-1 Centerline		2	0.1	87	4.51	8.08	-	15.24	-	25.99	31.04	26.05	-	15.30	-	8.17	4.53	70	70		1,976			
↓	↓	1	1.0	177	4.14	7.85	11.43	14.84	18.50	25.66	30.70	25.72	18.55	14.92	11.40	7.70	4.15	20	20		1,975			
		2	1.0	177	4.14	-	11.35	-	18.54	-	30.72	-	18.52	-	11.41	-	4.14	10	20		1,976			
		1	10.0	714+	Overload, no readings available													0.3	.05		-			
c) Seal Position		1	0.0	105	Overload, no readings available													50	40		621			
Part II: 23/R511, PERF																								
a) Seal Position	5/27/66	1	60.0	150	-66.0	-62.5	-58.7	-	-48.6	-	-36.8	-	-50.67	-	-56.72	-61.43	-63.97	-	100		1,971			
b) 0.25 w/gm	↓	1		150	-40.80	-76.99	-46.64	-41.57	-39.79	-25.79	-19.93	-23.24	-744.85	-486	-444.4	-455.5	-483.5	-	7		1,970			
↓		2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
c) 0.50 w/gm		1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	1,943			
↓	↓	2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
d) 0.75 w/gm		1		180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Post Test Operations																								
a) Integral System																								
b) 75 Cables & Connector (Disconnected from transducer)																								
1) 2 ft section with connector (x-ducer end)																								
2) 73 ft section																								
c) Transducer alone in fixture																								
d) Transducer on bench																								
1) Transition portion																								
2) Strain gage portion																								

PINS	
A-GND	B-GND
200.0	200.0
600.0	600.0
50.0	60.0
90.0	90.0
0.1	-
-	-
-	-
-	-

Table V

TABLE VI

TEST DATA FOR STANDARD CONTROLS TRANSDUCER S/N 6988

Location	Date	Cycle	Reactor Power, Mw	Temp. °F	OUTPUT SIGNAL, (mv) VS INPUT PRESSURE, psig														Insulation Resistance Megohms		Bridge Resistance Ohms
					0	50	100	150	200	300	400/370	300	200	150	100	50	0	ABCD to Fixture	ABCD to Chassis	Pins A-B	
REON Laboratory:																					
a) Fixture open on top	2/10/66	1	-	73	5.52	9.17	12.83	16.42	20.00	27.23	34.55	27.24	20.00	16.39	12.82	9.18	5.54	6,000	-	1,975	
↓	↓	1	-	200	4.07	7.81	11.55	15.24	18.94	26.34	33.83	26.43	19.00	15.29	11.64	7.91	4.17	800	900	1,977	
↓	↓	1	-	300	3.21	7.04	10.90	14.72	18.53	26.23	34.00	26.36	18.70	14.90	11.08	7.32	2.38	500	500	1,979	
↓	↓	1	-	400	1.71	5.74	9.78	13.77	17.84	25.93	34.40	26.50	18.47	14.42	10.45	6.41	2.33	0.3	0.8	1,978	
↓	↓	1	-	75	5.87	9.53	13.16	16.73	20.33	27.60	34.83	27.52	20.29	16.67	13.07	9.37	5.75	0.8	2.0	1,975	
b) After final weld	2/19/66	1	-	AMB	5.73	9.48	13.20	16.86	20.45	27.94	35.36	27.88	20.54	16.85	13.20	9.49	5.77	0.5	8,000	1,973	
ATS Bldg., PBRF																					
a) Equipment Check	3/25/66	1	-	AMB	4.10	7.49	11.19	15.49	18.99	26.59	32.30	26.29	19.04	15.39	11.69	8.29	4.49	-	-	2,000	
b) Acceptance Check	4/13/66	1	-	AMB	5.82	9.41	12.97	16.53	20.04	27.49	32.28	27.50	20.44	16.79	13.11	9.50	5.83	700	700	1,976	
Part I: 23/R511, PBRF																					
T/C #105																					
a) Seal Position	4/22/66	1	0.0	68	5.36	8.96	12.51	16.08	19.70	26.86	31.89	26.88	19.69	16.19	12.56	9.00	5.39	10.0	8.0	1,974	
↓	↓	2	0.0	68	5.36	8.90	12.51	16.05	19.67	26.76	31.84	26.89	19.67	16.12	12.55	8.94	5.38	10.0	10.0	1,972	
↓	↓	3	0.0	70	5.47	8.99	12.53	16.13	19.70	26.90	31.90	26.88	19.72	16.15	12.60	9.01	5.46	30.0	30.0	1,973	
b) HT-1 Centerline		1	0.1	82	5.38	8.94	12.49	16.10	19.65	26.75	31.75	26.80	19.70	16.12	12.61	9.04	5.38	10.0	10.0	1,973	
↓	↓	2	0.1	82	5.38	8.94	-	16.07	-	26.76	31.82	26.80	-	16.12	-	9.03	5.40	0.0	0.0	1,973	
↓	↓	1	1.0	135	4.81	8.52	12.07	15.45	19.60	26.23	31.30	26.31	19.15	15.52	12.02	8.34	4.79	0.0	0.0	1,973	
↓	↓	2	1.0	135	-	-	-	-	-	-	31.3	-	19.17	-	12.02	-	4.78	0.0	0.0	1,973	
↓	↓	1	10.0	525	-6.07	-3.42	0.09	3.40	6.75	13.60	25.75	75.40	87.49	-	93.12	-	311.0	0.0	0.0	-	
c) Seal Position		1	0.0	100	20.0	-	33.0	-	41.75	-	54.0	-	37.0	-	32.0	-	27.0	5.0	5.0	1,973	
Part II: 23/R511 PBRF																					
a) Seal Position	5/22/66	1	60.0		-3.30	+0.35	3.94	-	11.14	-	23.37	-	11.14	-	3.97	0.35	-3.32	-	20	1,975	
b) 0.25 w/gm	↓	1			-5.43	-1.99	+2.09	5.38	9.43	16.74	21.81	16.51	9.08	5.32	1.09	-2.05	-5.74	-	.2	1,975	
↓	↓	2					1.65	-	8.21	-	20.12	-	7.43	-	3.02	-	-	-	-	-	
c) 0.50 w/gm	↓	1			20.75	31.79	26.85	27.87	34.80	39.03	40.26	35.25	28.41	24.66	19.99	16.61	13.41	-	.8	1,974	
↓	↓	2			-	-	19.99	-	-	-	39.27	-	-	-	20.0	-	-	-	-	-	
d) 0.75 w/gm	↓	1			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Post Test Operations																		PINS			
																		A-GND	D-GND		
a) Integral System																			100.0	100.0	
b) 75 ft cables & connector (Disconnected from transducer)																			1K	1K	
1) 2 ft section with connector (x-ducer end)																			50.0	70.0	
2) 73 ft section																			80.0	-	
c) Transducer alone in fixture																			5.0	-	
d) Transducer on bench																			-	-	
1) Transition portion																			-	-	
2) Strain gage portion																			-	-	

Table VI

TEST DATA FOR STANDARD CONTROLS TRANSDUCER S/N 6993

Table VII

TABLE VIII

SENSITIVITY VALUES FOR STATHAM PRESSURE TRANSDUCERS

Location	Date	Cycle	Reactor Power, Mw	Temp., °F	Sensitivity (mv)			
					Transducer Serial No.			
					17	14	21	10
REON Laboratory								
a) Fixture open on top	2/10/66	1	---	73	42.38	43.58	50.28	42.00
↓		1	---	200	41.40	43.13	49.94	41.94
		1	---	300	42.55	43.24	49.62	41.90
		1	---	400	42.88	43.32	49.97	41.92
		1	---	73	42.26	43.45	50.37	41.97
b) After final weld	2/19/66	1	---	Amb	42.86	44.19	51.12	42.71
ATS Bldg, PBRF								
a) Equipment Check	3/25/66	1	---	Amb	40.96	41.91	48.51	40.63
b) Acceptance Check	4/13/66	1	---	Amb	38.69	39.71	46.01	38.34
Part I: Test 23/R511, PBRF								
a) Seal Position	5/27	1	0.0		38.16	39.13	45.63	38.11
↓		2	0.0		38.11	39.24	45.65	38.10
		3	0.0		38.54	39.12	45.56	38.04
b) HT-1 Centerline		1	0.1		38.19	39.19	45.58	38.05
↓		2	0.1		38.29	39.10	45.54	38.07
		1	1.0		38.23	39.16	45.29	37.89
		2	1.0		37.99	39.12	45.34	37.90
↓		1	10.0		44.97/-	40.99/-	46.80/-	50.50/-
					---	37.68	38.16	33.51
c) Seal Position		1	0.0		10.0/ 35.0	38.75/ 38.72	43.72/ 45.44	37.42/ 37.75
Part II: Test 23/R511, PBRF								
a) Seal Position	5/27/66	1	60.0		---	39.58	45.96	38.32
b) 0.25 w/gm		1	60.0		---	99.66	45.45	44.80
↓		2	60.0		---	---	---	---
c) 0.50 w/gm		1	60.0		---	---	44.30	---
↓		2	60.0		---	---	---	---
d) 0.75 w/gm		1	60.0		---	---	---	---

Table VIII

TABLE IX

SENSITIVITY VALUES FOR STANDARD CONTROLS PRESSURE TRANSDUCERS

Location	Date	Cycle	Reactor	Temp	Sensitivity (mv)		
			Power		Transducer	Serial No.	
			(Mw)	(°F)	6983	6990	6988
REON Laboratory							
a) Fixture open on top	2/10/66	1	---	73	28.93	29.12	29.03
↓		1	---	200	32.16	29.86	29.76
		1	---	300	30.62	30.87	31.89
		1	---	400	31.32	32.61	32.69
		1	---	73	28.89	29.07	28.96
b) After final weld	2/19/66	1	---	Amb	29.52	29.69	29.63
ATS Bldg., PBRF							
a) Equipment Check	3/25/66	1	---	Amb	27.96	28.26	28.20
b) Acceptance Check	4/13/66	1	---	Amb	26.42	26.59	26.46
Part I: Test 23/R511, PBRF							
a) Seal Position	4/22/66	1	0.0		26.38	26.59	26.53
↓		2	0.0		26.34	26.53	26.48
		3	0.0		26.28	26.51	26.43
b) HT-1 Centerline		1	0.1		26.28	26.46	26.37
↓		2	0.1		26.29	26.53	26.44
		1	1.0		26.38	26.56	26.49
		2	1.0		26.36	26.58	---
		1	10.0		24.7/ 3.56	---	31.82/ 286.0
c) Seal Position		1	0.0		24.0/ 26.38	---	34.0/ 27.0
Part II: Test 23/R511, PBRF							
a) Seal Position	5/27/66	1	60.0		26.65	29.20	26.67
b) 0.25 w/gm		1	60.0		28.21	20.87	27.24
↓		2	60.0		---	---	---
c) 0.50 w/gm		1	60.0		---	---	19.51
↓		2	60.0		---	---	---
d) 0.75 w/gm		1	60.0		---	---	---
					---	---	---

Table IX

TABLE X

INSULATION RESISTANCE OF DUMMY CABLES

Location	Date	Cycle	Reactor	Temp,	Insulation Resistance,			
			Power, Mw		°F (oven)	megohms		
					1	2	3	4
REON Laboratory								
a) Fixture open on top	2/10/66	1	-	73	>10K	30	10K	10K
		1	-	200	>10K	0.8	1K	>10K
		1	-	300	8K	0.8	800	10K
		1	-	400	5K	7.0	1.2K	10K
		1	-	73	>10K	1K	>10K	>10K
b) After final weld	2/19/66	1	-	Amb	710K	9K	>10K	>10K
ATS Bldg, PBRF								
a) Equipment Check	3/25/66	1	-	Amb	-	-	-	-
b) Acceptance Check	4/13/66	1	-	Amb	600	50	10K	10K
PART I: Test 23/R511 PBRF								
a) Seal Position	4/22/66	1	0.0	125	600	200	3K	2K
		2	0.0	125	300	100	900	900
		3	0.0	125	600	100	400	800
b) HT-1 Centerline		1	0.1	Unknown	50	40	50	50
		2	0.1	Unknown	100	100	200	300
		1	1.0	Unknown	40	40	40	50
		2	1.0	Unknown	50	40	40	60
		1	10.0	Unknown	.09	0.5	0.4	0.5
c) Seal Position		1	0.0	Unknown	0.8	8	1K	1K
PART II, Test 23/R511, PBRF								
a) Seal Position	5/27/66	1	60.0	125	300	75	800	2K
b) 0.25 w/gm		1	60.0	125	9	7	50	30
		2	60.0	Unknown	-	-	-	-
c) 0.50 w/gm		1	60.0	Unknown	5	1	1	0
		2	60.0	Unknown	-	-	-	-
d) 0.75 w/gm		1	60.0	Unknown	-	-	-	-
Post Test Operations								
a) Integral System	6/9/66			Amb	8K	500	100	1-8K
b) 75 ft Cable & Connector				Amb	3K	500	100	9K
1) 2 ft Section & Connector				Amb	50	25	50	-
2) 73 ft Section				Amb	70	60	300	80

Table X

Figure 1

23/R511 Test Fixture, Top Cover Removed

Schematic Diagram of Test Article Locations

Figure 2

Cross Section of Statham Pressure Transducer, Model PA812

Figure 3

Cross Section of Standard Control Corporation Pressure Transducer,
Model 170-9

Figure 4

Westinghouse Neutron Dosimeter Assembly Drawing

Figure 5

Complete Aerojet Test Fixture for Irradiation Test 23/R511

Figure 6

[illegible]

Figure 8

Disassembled Irradiated Statham Pressure Transducer, S/N 17

Figure 9

Disassembled Irradiated Statham Pressure Transducer, S/N 14

Figure 10

Disassembled Irradiated Statham Pressure Transducer, S/N 21

Figure 11

Disassembled Irradiated Statham Pressure Transducer, S/N 10

Figure 12

Irradiated Force Summing Tube from Standard Controls Corporation
Pressure Transducer, S/N 6990 (Side View)

Figure 13

Irradiated Force Summing Tube from Standard Controls Corporation
Pressure Transducer, S/N 6990 (Top View)

Zero Shift-vs-Test Condition, Statham Transducer S/N 17

Figure 14

Zero Shift-vs-Test Condition, Statham Transducer S/N 14

Figure 15

Zero Shift-vs-Test Condition, Statham Transducer S/N 21

Figure 16

Zero Shift-vs-Test Condition, Statham Transducer S/N 10

Figure 17

Zero Shift-vs-Test Condition, Standard Controls Transducer 6993

Figure 18

Zero Shift-vs-Test Condition, Standard Controls Transducer 6990

Figure 19

Zero Shift-vs-Test Condition, Standard Controls Transducer 6988

Figure 20

VALUES REPRESENT CHANGE IN OUTPUT SIGNAL
OVER FULL-PRESSURE RANGE AT CONSTANT
TEMPERATURE OR HEATING RATE

Sensitivity-vs-Test Condition, Statham Transducer S/N 17

Figure 21

Sensitivity-vs-Test Condition, Statham Transducer S/N 14

Figure 22

VALUES REPRESENT CHANGE IN OUTPUT
SIGNAL OVER FULL-PRESSURE RANGE AT
CONSTANT TEMPERATURE OR HEATING
RATE

Sensitivity-vs-Test Condition, Statham Transducer S/N 21

VALUES REPRESENT CHANGE IN OUTPUT
SIGNAL OVER FULL-PRESSURE RANGE AT
CONSTANT TEMPERATURE OR HEATING
RATE

Sensitivity-vs-Test Condition, Statham Transducer S/N 10

Figure 24

VALUES REPRESENT CHANGE IN OUTPUT
SIGNAL OVER FULL-PRESSURE RANGE AT
CONSTANT TEMPERATURE OR HEATING
RATE

Sensitivity-vs-Test Condition, Standard Controls Transducer S/N 6993

VALUES REPRESENT CHANGE IN OUTPUT
SIGNAL OVER FULL-PRESSURE RANGE AT
CONSTANT TEMPERATURE OR HEATING
RATE

Sensitivity-vs-Test Condition, Standard Controls Transducers S/N 6990

Figure 26

Sensitivity-vs-Test Conditions, Standard Controls Transducers S/N 6988

Figure 27

Figure 28

Irradiated Dummy Cable/Connector Assembly, Number 2

Figure 29

Irradiated Dummy Cable/Connector Assembly, Number 4

Gamma Heating Rates in HT-1

Figure 30

APPENDIX

DOSE CALCULATIONS

I. GAMMA DOSE

Calorimetry measurements shown in Figure 30 indicate that at 60 Mw of power the gamma heating rate at the centerline of HT-1 (flooded) with the control rods at a bank height of 18 inches is approximately 3 watts/gm. For the calculations presented a direct ratio of gamma heating to power was assumed, and values of 1 watt/gm at 20 Mw; 0.5 watt/gm at 10 Mw; and 0.05 watt/gm at 1 Mw were used.

Table I shows the time-correlated power levels and the gamma dose for each portion of the irradiation test. The gamma dose for Part I of the test was 1.66×10^8 Rads (C). The gamma dose for Part II of the test was 1.36×10^8 Rads (C). The total gamma dose was 3.02×10^8 Rads (C).

II. NEUTRON FLUENCE

Using the dosimeters described in Section III.A.3, average fast-flux values ($E_n > 2.9$ Mev) of 3.3×10^{11} , 2.2×10^{11} , 1.8×10^{11} , and 0.8×10^{11} neutrons/cm²-sec were obtained for both parts of the test. The arithmetic average of these was 2.05×10^{11} neutrons/cm²-sec. The total period of irradiation was 1.46×10^4 sec. A total neutron fluence of 3.0×10^{15} neutrons/cm² ($E_n > 2.9$ Mev) was obtained. Using a conversion factor of 3 (based on a watt fission spectrum), a total fluence of 9×10^{15} neutrons/cm² ($E_n > 1.0$ Mev) was obtained.

TABLE I

CALCULATION OF GAMMA DOSE - 23/R511

<u>Time</u>	<u>ΔT, hr</u>	<u>Gamma Heating Rate, watts/gm</u>	<u>Total γ Heat, (watt hr/gm)</u>	<u>Gamma Dose,* x 10⁻⁸ [Rads (C)]</u>
23:10 @ 100 Kw				
	0.90	.005	.0045	0.0163
00:44 @ 1 Mw				
	1.26	.05	.0670	0.2410
01:50 @ 10 Mw				
	0.80	.5	.4000	1.400
02:38 End Part I				<hr/>
Dose Part I				1.657
15:04 @ .25 w/gm				
	0.70	.25	.175	0.63
15:46 @ .50 w/gm				
	0.38	.50	.190	0.69
16:09 @ .75 w/gm				
	0.016	.75	.012	0.04
16:10 End Part II				<hr/>
Dose Part II				1.36
Total Dose				3.02

* $3.6 \times 10^8 \frac{\text{R/Hr}}{\text{watt/gm}}$ was used as a conversion factor.