SMTC
Subsided
Pd 10-

Records

REON

20 & 1.6. 04/05
program 1.00
test 1.00

ROCKET ENGINE OPERATIONS - NUCLEAR

REPORT NO. RN-S-0037

TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

FINAL TEST REPORT

ON

RADIATION EFFECTS TEST 25/A002

PERFORMED ON

9 PRESSURE TRANSDUCERS

AT GTR

MASTER

AUGUST 1963

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-0037
FINAL TEST REPORT ON
RADIATION EFFECTS TEST 25/A002
PERFORMED ON 9 PRESSURE TRANSDUCERS
AT GTR

ROCKET ENGINE OPERATIONS - NUCLEAR

AUGUST 1963

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.

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

ABSTRACT

Four Giannini, potentiometer-type, pressure transducers, four Servonics, potentiometer-type pressure transducers and one Statham, unbonded, strain-gage type, pressure transducer were tested in GTR in August 1963 for 68 hours. Temperatures during the test ranged from ambient to 250⁰F and external pressure was atmospheric. Neutron and gamma dose were measured, the transducers were stimulated with dry nitrogen pressure and responses were recorded at intervals throughout the test. The cooperation of GD/FW in the preparation of Figures 6 through 19 is gratefully acknowledged.

W. D. Stinnett
REON Technical Systems Manager

TABLE OF CONTENTS

- I. SUMMARY AND RECOMMENDATIONS
- II. DESCRIPTION OF TEST EQUIPMENT
- III. TEST RESULTS
- IV. DISCUSSION OF RESULTS
- V. CONCLUSIONS

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>
1	Manifold Transducer
2	Electro-Pneumatic Schematic
3	Simplified Insulation Resistance Circuitry
4	Pressure Transducer Test System
5	Pressure Transducers Mounted
6	Linearity as a Function of Radiation Exposure for Servionics Model No. 2121-01-01 Pressure Transducer - Serial 1004 (Component 1)
7	Linearity as a Function of Radiation Exposure for Servionics Model No. 2121-01-01 Pressure Transducer - Serial 1005 (Component 2)
8	Linearity as a Function of Radiation Exposure for Servionics Model No. 2121-01-01 Pressure Transducer - Serial 1006 (Component 3)
9	Linearity as a Function of Radiation Exposure for Servionics Model No. 2121-01-01 Pressure Transducer - Serial 1007 (Component 4)
10	Linearity as a Function of Radiation Exposure for Giannini Model No. 46126551 Pressure Transducer - Serial 029-1 (Component 5)
11	Linearity as a Function of Radiation Exposure for Giannini Model No. 46126551 Pressure Transducer - Serial 029-2 (Component 6)
12	Linearity as a Function of Radiation Exposure for Giannini Model No. 46126551 Pressure Transducer - Serial 029-3 (Component 7)
13	Linearity as a Function of Radiation Exposure for Giannini Model No. 46126551 Pressure Transducer - Serial 029-4 (Component 8)
14	Linearity as a Function of Radiation Exposure for Statham Model No. PA 732 TC-1000-360 Pressure Transducer (Component 9)
15	Output Volts vs Radiation for Statham Model No. PG732TC Pressure Transducer (Component 9)
16	Insulation Resistance vs Irradiation for Servionics Pressure Transducer (Components 1-4)
17	Insulation Resistance vs Irradiation for Giannini Pressure Transducers (Components 5-8)
18	Insulation Resistance vs Irradiation for Statham Pressure Transducer (Component 9)
19	Resistance of Pressure Transducers
20	Statham Transducer Circuitry

I. SUMMARY AND RECOMMENDATIONS

Four Giannini, four Servonics and one Satham pressure transducers were mounted on a common manifold on the north pallet in GTR and exposed for 68 hours. The total flux received was 1.81×10^{16} n/cm² ($E > 2.9$ MEV) and 20.6×10^{10} ergs/gm(C) gamma. Insulation resistance and output readings were taken at 4 hour intervals during the test and stimuli of 0, 100, 300, 500 and 735 psia were supplied to all transducers during each data cycle.

Three of the four Giannini transducers performed satisfactorily while the fourth began reading anomalously about midway through the test. The anomalous readings were of a nature which indicated either foreign matter present on the winding or a lifted wiper. The failure is considered random.

All four Servonics pressure transducers performed satisfactorily throughout the test.

The Satham transducer showed a decrease in response of about 4% of full scale and developed an up-scale shift of approximately 1/8 of full scale.

All transducers suffered loss of insulation resistance during irradiation, recovering partially after reactor shutdown. In every case, however, insulation resistance was at least 1000 times as great as the corresponding transducer-sensor element resistance.

It is recommended that similar Servonics and Giannini transducers be modified as necessary for cryogenic temperature survival and then tested in a cryogenic and radiation environment. The principle change required would be evacuation of the low pressure side of the sensing element.

II. DESCRIPTION OF TEST EQUIPMENT

The nine transducers were connected to the manifold shown in Figure 1. The manifold with transducers and cabling in place, was positioned directly in front of the north pallet on GTR, covered with a sheet metal enclosure and supplied with forced air cooling from a duct through the pallet and into the bottom of the sheet metal enclosure. Air was exhausted through the opening between the enclosure and the reactor water closet. This afforded moving air in intimate contact with the transducers, cabling and manifold.

Shielded leads were used to transmit signals and excitation. Each pressure transducer was temperature-monitored by means of a copper-constantan thermocouple and recorded on a Minneapolis-Honeywell multi-channel, strip-chart recorder.

Figure 1 shows a simplified schematic of the signal circuitry and pressure stimulus application. Stimuli of 0, 100, 300, 500 and 735 psi were provided along with Heise gages to monitor these pressures. Transducer output was read on a Non Linear Systems digital voltmeter Model M-24.

Figure 2

Electro-Pneumatic Schematic

Each Servonics and each Giannini transducer was fitted with two copper Constantan thermocouples and the Statham transducer was fitted with one thermocouple making a total of seventeen. Temperature recording from these thermocouples was made with a Minneapolis Honeywell multi-channel strip chart recorder.

Eight individual, Harrison Labs, Model 801C, regulated dc power supplies, each set at 5 volts, were used to excite the potentiometer type transducers. A ninth, set at 10 volts, was used to excite the strain gage type transducer. This was done to avoid interaction between transducer outputs in the event of failure of one transducer.

Insulation leakage currents were measured by means of circuitry shown in the simplified schematic of Figure 3.

Figure 3

Simplified Insulation Resistance Circuitry

Insulation resistance was computed by dividing the microammeter current into 10 volts. Note that the guard leakage current is shunted around the microammeter.

Figure 4 is a photograph of the pressure transducer test system while Figure 5 is a close-up of the manifold with transducers and cabling in place.

III. TEST RESULTS

Figures 6 through 14 show the individual transducer outputs plotted against the stimuli before, during, and after irradiation. Note that a zero pressure stimulus was applied at both the beginning and the end of each data run. Also note that in the case of Giannini Serial No. 029-2, the irradiation readings are at 8.62×10^{15} n/cm², the point of failure, and that in the case of the Satham transducer irradiation readings are shown at 1.98×10^{15} n/cm², 8.62×10^{15} n/cm² and 1.81×10^{16} n/cm².

Figure 15 shows the output of the Satham transducer as a function of irradiation for the several stimuli pressures used. It is to be noted that the Satham transducer was a 1000 psi unit operating up to 735 psi while the Servonics and the Giannini units were 750 psi transducers operating up to 735 psi.

Figures 16, 17, and 18 show the insulation resistance of the various transducers as a function of irradiation. The upper section of each of these three figures gives the temperature observed at the time each insulation resistance leakage current reading was recorded.

Figure 19 shows "before and after" transducer resistances with their corresponding temperatures.

PRESSURE TRANSDUCER TEST SYSTEM
FIGURE 4

PRESSURE TRANSDUCERS MOUNTED
FIGURE 5

Linearity As A Function of Radiation Exposure for
Servonics Model No. 2121-01-01 Pressure Transducer -
Serial 1004 (Component 1)

FIGURE 6

Linearity As a Function of Radiation Exposure for
Servonics Model No. 2121-01-01 Pressure Transducer -
Serial 1005 (Component 2)

FIGURE 7

Linearity As A Function of Radiation Exposure for
Servonics Model No. 2121-01-01 Pressure Transducer -
Serial 1006 (Component 3)

FIGURE 8

Linearity As A Function of Radiation Exposure for
 Servonics Model No. 2121-01-01 Pressure Transducer -
 Serial 1007 (Component 4)

FIGURE 9

Linearity As A Function of Radiation Exposure for
 Giannini Model No. 46126551 Pressure Transducer -
 Serial 029-1 (Component 5)

FIGURE 10

Linearity As A Function of Radiation Exposure for
Giannini Model No. 46126551 Pressure Transducer -
Serial 929-2 (Component 6)

FIGURE 11

Linearity As A Function of Radiation Exposure for
Giannini Model No. 46126551 Pressure Transducer -
Serial 029-3 (Component 7)

FIGURE 12

Linearity As A Function of Radiation Exposure for
Giannini Model No. 461265J1 Pressure Transducer -
Serial 029-4 (Component 8)

FIGURE 13

Linearity As A Function of Radiation Exposure for
 Statham Model No. FA 732 TC-1000-350
 Pressure Transducer (Component 9)

FIGURE 14

FIGURE 15

FIGURE 16

Insulation Resistance vs Irradiation for Giannini Pressure Transducers (Components 5-8)

FIGURE 17

Insulation Resistance vs Irradiation for Statham
Pressure Transducer (Component 9)

FIGURE 18

<u>COMPONENT NO.</u>	<u>COMPONENT</u>	<u>LAB RUN TEMP 73°F</u>	<u>PRE-IRRADI- ATION RUN TEMP 92°F</u>	<u>POST-IRRADI- ATION RUN 1 TEMP 110°F</u>	<u>POST-IRRADI- ATION RUN 2 TEMP 101°F</u>
1	Servonics 1004	507.2	512.4	504.6	499.7
2	Servonics 1005	492.2	497.1	491.8	487.1
3	Servonics 1006	492.4	495.4	492.2	487.4
4	Servonics 1007	470.3	476.9	468.8	464.7
5	Giannini 029-1	965.6	977.2	984.1	976.7
6	Giannini 029-2	933.5	936.8	947.7	937.2
7	Giannini 029-3	945.8	953.6	961.4	954.0
8	Giannini 029-4	892.0	895.5	907.3	900.2
9	Statham	337.5	337.8	340.1	340.3

RM-S-0037

Figure 19
Resistances of Pressure Transducers

IV. DISCUSSION OF RESULTS

The Servonics and the Giannini pressure transducers are regarded as "second generation" units. They were made by the vendors to perform a specific control instrumentation function for NERVA and were built to cover a pressure range for this application.

The Servonics and the Giannini transducers were vibration tested at the vendors' plants. Tests were observed by Aerojet representatives. In the non-operating test, the transducers survived 4g rms sinusoidal vibration along each axis at frequencies from 20 to 50 cps and 20g from 50 to 2000 cps. Changes of not greater than 1% of full scale in either zero or sensitivity resulted. During operating tests the same transducers were subjected to 4g rms sinusoidal vibration from 10 cps to 500 cps and each met the performance requirements during such tests.

Briefly, the Servonics and Giannini transducers are both of the helical Bourdon tube sensing element type. They are known as "off center" types in the industry, since the center of rotation of the Bourdon tube is not coincident with the center line of the body of the transducer. This feature permits a relatively long wiper arm which results in improved linearity. The potentiometer element of each transducer contains about 250 turns of resistance wire which establishes a nominal resolution of 0.4%. Nominal resistance of the Servonics potentiometer is 500 ohms while that of the Giannini is 1000 ohms. The vendors of these transducers used known, radiation-resistant, raw materials and eliminated or held to a minimum the use of materials with long half lives. Both types of transducers are devoid of organics.

The Statham transducer was an "off the shelf" unbonded strain gage type transducer. Being a strain gage instrument, it is resolutionless.

All the potentiometer-type transducers with the exception of Giannini serial No. 029-2 (component No. 6) performed throughout the test without incident. Figure 11 shows that at 8.62×10^{15} n/cm² exposure, Serial No. 029-2 (Component No. 6) began to develop a fallacious output. Furthermore, the readings were erratic. Figure 17, showing insulation resistance, indicates no anomolous readings for

insulation resistance of Component No. 6 either before or after the 8.62×10^{15} n/cm² exposure or at the exact time of failure. The post irradiation insulation resistance of Component No. 6 was 100 megohms being exceeded only by Component No. 5. This would infer that no leakage path to ground had developed which could account for the failure.

The initial resistance of Component No. 6 as shown in Figure 19 was 933.5 ohms while the final resistance was 937.2, an increase of 3.7 ohms. The average of the four Giannini units was 934.2 ohms initially and 942.0 ohms finally. Since Component No. 6 showed neither a gross increase nor decrease in resistance, the failure is not attributable to a failure of the potentiometer resistance.

Since neither insulation resistance breakdown nor potentiometer winding failure was evidenced, and since the readings at and after failure were erratic, it seems likely that the failure was caused either by contaminants on the winding or a lifted wiper. This may be verified if a post mortem examination can be performed. The failure is adjudged to be random.

The Statham transducer was a full 350 ohm bridge having a 4-terminal connector. From Figure 13 it can be seen that there was a general shift upwards in output of about 5 millivolts and this was evidenced at all stimuli during irradiation. From Figure 17 it can be seen that insulation resistance dropped from over 3000 megohms to 1.35 megohms. This represents a shunting effect of about 1.33 megohms. While insulation resistance loss is an important consideration in strain gage operation, the loss in this case is insufficient to cause the output shift which was experienced. This can be shown as follows:

The Statham electrical circuitry is shown below in Figure 20. The worst possible unbalance which could be caused by a 1.33 megohm leakage resistance would be its placement across 1 bridge leg as shown. Assuming that the bridge was balanced prior

Figure 20

Statham Transducer Circuitry

to the leakage resistance placement and solving for the unbalance after the placement, the effective parallel leg resistance is

$$\frac{(350)(1.33)10^6}{350 + 1.33 \cdot 10^6} = 349.908 \text{ ohms}$$

The unbalance would be

$$5.0 - \left(\frac{349.908}{350 + 349.908} \right) = .7 \cdot 10^{-3} \text{ V} = 0.7 \text{ millivolts}$$

Therefore, the +5 mv shift in output occurring during irradiation at all stimuli (see Figure 15) cannot be attributed to insulation resistance degradation alone.

Since the shutdowns during the reactor operation were accompanied by a drop in temperature, but were not accompanied by a drop in output (in fact, a rise), the shift of +5 mv cannot reasonably be attributed to the temperature rise.

Furthermore, since the increase in output of the Statham transducer was more or less constant at all stimuli, its cause is not attributable to a change in gage factor.

By this process of elimination, it is reasoned that the radiation environment resulted in a resistance change in one or more of the four bridge elements. Furthermore, this change was not uniform with respect to all four elements. It could have resulted from an actual resistance change or it could have resulted from a dimensional change which strained one or more strain elements.

V. CONCLUSIONS

4 tested The Giannini Model No. 461265J1 pressure transducer is a satisfactory instrument for use in radiation environments as described herein.

4 tested The Servonics pressure transducer No. 2121-0101 is a satisfactory instrument for use in radiation environments as described herein.

1 tested The Statham transducer, No. PA732TC-IM-350 maintained good linearity and sensitivity but suffered a +5 mv shift in output representing approximately 1/8 full scale. It is not considered satisfactory for use in the environments described herein.