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PRE-IRRADIATION ANALYSIS
SERVONIC PRESSURE TRANSDUCER MODEL 2121-01

MASTER

Report No. 8771:2375

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56

I ABSTRACT

Servonic Pressure Transducer, Model 2121-01, was determined to be a radiation-resistant instrument. When used in the NRX-A2 environment the transducer requires shock mounting which thermally isolates the instrument from a heat sink. Without provision for cooling, the assembly is limited to fields of 1.2×10^9 ergs/gram(C)-hr for full-duration, full-power runs. This is based on the exclusion of soft solder and on the premise that no component should exceed the upper temperature compensated limit (500°F). The transducers have proved reliable in ground test reactor irradiation tests at flux levels of 3.6×10^9 ergs/gram(C)-hr with cooling provided.

II DESCRIPTION

Servonic Pressure Transducer, Model 2121-01, is a potentiometric bourdon tube type pressure transducer. Model 2121-01 has a temperature range from 0 to 750 psia and Model 2121-02 has a range from 0 to 1000 psia. The compensated temperature range is -240 to +340°F. The total weight of the transducer is 5.5 ounces.

III SUMMARY

A. ANALYSIS OBJECTIVE

The purpose of this analysis was to determine if the instrument is compatible with the radiation environment of the NRX-A2, and to estimate the allowable dose rates from a gamma heating standpoint that can be tolerated.

B. CONCLUSIONS

Servonic pressure transducers have proved to be reliable in fields of 3.6×10^9 ergs/gram(C)-hr with cooling provided. For full-duration, full-power NRX-A2 runs, the transducer shock mount assembly should not be placed in fields greater than 1.2×10^9 ergs/gram(C)-hr without provision for cooling. This is based on the assumption that the transducer will be shock mounted and that no component should exceed 500°F. Effects of neutron degradation are considered negligible.

IV ANALYSIS

A. MATERIALS LIST

The original materials list furnished by the manufacturer (Reference 1) included 60% tin-40% lead solder with a melting point (mp) of 300-360°F and 94% tin - 6% antimony solder (mp - 450-500°F). After the results of gamma heating rates were obtained, Aerojet-General Corporation requested that the manufacturer change the bonding method. Servonic Instruments agreed to replace soldered joints with resistance welds. Except for solder, the materials list included those shown in Table I. Their compositions and properties have been added.

TABLE I

MATERIALS LIST OF SERVONIC 2121-01 PRESSURE TRANSDUCERS

<u>MATERIAL COMPONENT</u>	<u>COMPOSITION (%)</u>	<u>APPROXIMATE MP °F</u>	<u>SPECIFIC HEAT (BTU/lb-°F)</u>
Stainless Steel (Series 302, 303, 304L, 321, 400)	Handbook values	2800	0.12
Ni - Span C	42 Ni, 48.5 Fe, 5.8 Cr, .02 C, .4 Mn, others		0.105
Paliney #7 (J. M. Ney Co.)	35 Pd, 10 Pt, 30 Ag, 15 Cu, 10 Au	> 3000	0.057
Hard Brass		1700	0.09
Mallory Metal #1000	4 Cu, 6 Ni, 90 W	6100	0.039
Aluminum 2024 T4	Bal Al, 4.5 Cu, 1.5 Mg, 0.6 Mn	935-1180	0.23
Sigmund Cohn #479 Bare Wire	92 Pt, 8 W	> 3200	0.032
PSC Durock Formulation #17	Mixture of six metallic oxides	1200*	0.2
#24 AWG Durock insulated Cu Wire	Cu	1981	0.09
Sauereisen #1 Comp.	Unknown - Ceramic	- -	- -
Neyoro G (J. M. Ney Co.)	72 Au, 8.5 Pt, 4 Ag, 14.5 Cu	1945	0.041

The temperature coefficient of resistivity of the 92 Pt-8W resistance wire is 0.00024 ohms/ohm-°C in the temperature range -50 to +150°C.

The materials of construction are inorganic and are radiation-resistant from a damage standpoint.

* Softening point

B. GAMMA HEATING

It is necessary to mount the transducer in a shock absorbing device for use on NRX-A2 (Reference 2). Department 8771 instrumentation specialists selected shock mount Model K425, manufactured by Robinson Technical Products Company. The shock mount surrounds the transducer and inhibits heat dissipation, therefore, heat dissipation was considered negligible in the calculation of transducer component gamma heating rates. The heating rates and component temperatures were evaluated from the expression

$$C_p \Delta \dot{T} = \dot{Q}$$

where

$\dot{Q}$ = Gamma heating rate per unit weight

C_p = Specific heat of the material

$\Delta \dot{T}$ = Heating rate, °F/sec

Neyoro G will reach its melting point first; for a full-duration, full-power run the maximum field that it can withstand is 5×10^9 ergs/gram(C)-hr.

The radiation field limitations imposed by melting temperatures are usually superseded by the manufacturer's stated limits of temperature compensation. Transducers were tested in ovens at AGC and good response was obtained at 500°F oven temperatures. This is not a true simulation of gamma heating. However, if it is used to set the maximum temperature limitation of the transducer, the maximum radiation field should be 1.2×10^9 ergs/gram(C)-hr for a full-power, full-duration run. Cooling should be provided in radiation fields more intense than this value.

C. NEUTRON EFFECTS

The potentiometer output, expressed in volts, is a function of impressed voltage, and its operation is essentially independent of the absolute value of resistance of the wire if the impressed voltage is maintained constant. If neutron degradation is uniform in the potentiometer wire, its effect on the pressure readings will be negligible. Nevertheless, it may be of interest to note some observations on the change of potentiometer resistances.

The potentiometer resistances were measured in GTR Test No. 7 (Reference 4). The individual instruments showed decreases of 15, 11, 6 and 17% between pre-irradiation and post irradiation No. 1 values for an irradiation of 9.3×10^{16} n/cm². These resistance losses are higher than analytical values, or other experimental values, which have been reported for the change in resistivity.

Computations show that the flux of 9.3×10^{16} n/cm² would be expected to introduce 0.003% change in the resistivity of the wire. This is based on the expression:

$$\frac{(\Delta \rho / \Delta V) (N \sigma)}{\rho_0} = \text{Change in resistivity}$$

$$\Delta \rho / \Delta V = \text{Change of resistivity per vacancy created} = 4 \times 10^{-4}$$

$N \sigma$ = Vacancy creation rate

σ = Fast neutron cross-section of platinum ≈ 7 barns

N = ϕT = integrated fast neutron flux

ρ_0 = Resistivity of platinum = 9.825×10^{-6} ohm-cm at 32°F

The value of $(\Delta \rho / \Delta V)$ is an experimental value which is subject to uncertainty in the sense that it is applied here (Reference 3). The expression for the change of resistivity is based on the assumption that one vacancy is created per fast neutron captured. This expression predicts a 0.6% change for a flux of 2×10^{19} n/cm². A measured value of 0.7% decrease for this flux is reported in Reference 5. The details of measurement are not reported in enough detail to attempt an explanation of the differences.

D. RELATED TESTS

Four Servonic Model No. 2121-01-01 pressure transducers were irradiated in GTR in August 1963 (Reference 4), with average total doses and integrated fluxes ($E > 2.9$ Mev) as follows:

$$1.9 \times 10^{16} \text{ n/cm}^2 \text{ (} E > 2.9 \text{ Mev) or}$$

$$9.3 \times 10^{16} \text{ n/cm}^2 \text{ (} E > 0.1 \text{ Mev)}$$

$$2.2 \times 10^{11} \text{ ergs/gram(C)}$$

$$(177.96 \text{ MW - hr})$$

The pressure transducers were cooled by forced ambient air at 95-100°F. The temperatures of the inside of the transducers were maintained at 200°F in a gamma field of 3.6×10^9 ergs/gram(C)-hr. The transducers were not encased by a shock mount.

The pressure transducers were data cycled continuously every other four hours, and de-pressurized the other four. The data cycle consisted of measurements of the output at 0, 100, 300, 500, and 730 psig applied pressures. The output vs pressure characteristics of the Servonic devices were virtually unaffected throughout the test.

Insulation resistances were measured between a terminal and the case for each transducer with a Hewlett-Packard 425A microvolt ammeter and a 10-volt supply (Harrison 801). The behavior of all four transducers was practically the same. The pre-irradiation resistances of 300-400 Megohms decreased to 3-4 Megohms at a dose rate of 3.6×10^9 ergs/gram(C)-hr, and recovered to 1000-3000 Megohms in post-irradiation measurements. The conclusion (Reference 4) was that "the insulation resistance, though drastically reduced under transient conditions, should be sufficient for normal application."

V COMMENTS AND RECOMMENDATIONS

The subject transducer is a good design from a radiation standpoint. Its performance in GTR irradiation tests showed that it gave reliable output during and after irradiation.

Methods of cooling the transducers when mounted in shock absorbers should be investigated.

If a method of cooling is devised and the transducer is considered for placement in fields of NRX-A2 greater than 3.6×10^9 ergs/gram(C)-hr, tests similar to those at GTR should be performed in higher radiation fields to determine if the resistance remains adequate to give reliable data. The tests should combine vibration, radiation, and cooling with the transducer mounted in a shock absorber.

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