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REPORT NO. RN-S-0236
TO
AEC-NASA SPACE NUCLEAR PROPULSION OFFICE
FINAL TEST REPORT FOR RADIATION EFFECTS TESTS
ON
INSTRUMENTATION CABLES 23/R601 AND 23/R701

NERVA PROGRAM

JULY 1965

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FINAL TEST REPORT FOR RADIATION EFFECTS TESTS
ON
INSTRUMENTATION CABLES 23/R601 AND 23/R701

ROCKET ENGINE OPERATIONS - NUCLEAR

NERVA PROGRAM

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ABSTRACT

Two radiation effects tests on instrumentation cables were conducted at the Ground Test Reactor at General Dynamics/Fort Worth in 1964. In the first test, 23/A601, four ten-foot sections of four-conductor, shielded, Rockbestos Model 0235A cable were irradiated to an integrated exposure of 1.23×10^{17} neutrons/cm² ($E > 0.9$ Mev) and 4.7×10^{10} ergs/gm(C) gamma radiation. Insulation resistance measurements at ambient temperatures were taken throughout the test. With the exception of an initial decrease in resistance caused by moisture absorption, no significant reductions in insulation resistance were noted.

The second test, 23/R701, was a combined radiation and temperature test with vibration after the termination of irradiation. Fifteen cables and cable connector assemblies from various sources were irradiated to integrated exposures of 4.33×10^{16} neutrons/cm² ($E > 0.9$ Mev) and 1.44×10^{11} ergs/gm(C) gamma radiation. The cable assembly temperature was cycled from -320°F to +450°F every few hours throughout the test. Measurements of insulation resistance, capacitance, and connector contact resistance, were taken at ambient as well as the high and low temperatures. No change in connector contact-resistance or cable capacitance that could be correlated with radiation was noted. Most of the insulation resistances decreased with accumulated doses and then showed a marked recovery in post-radiation measurements. The vibration test had no apparent effects on the insulation resistance or cable capacitance. However, it caused severe physical damage to many of the cable assemblies and cable tie-downs.

W. D. Stinnett
Program Manager
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I. TEST OF CABLE 23/R601

A. PURPOSE

The purpose of this test was to determine the effects of nuclear radiation on the insulation resistance of a Rockbestos Model 0235A, four-conductor, shielded cable. A secondary objective was to determine the temperatures that would result from gamma irradiation.

B. METHOD

Four ten-foot sections of cable were mounted on an expanded aluminum screen in a configuration as shown in Figure 1. Copper-constantan thermocouples were mounted on both the shield and the insulation surface of each section of cable.

The following insulation resistance measurements were made during each data cycle throughout the test:

Cable 1	Single conductor to shield
Cable 2	Single conductor to single conductor
Cable 3	Single conductor to three single conductors
Cable 4	4 Conductors to shield

In all cases, the insulation resistance measurements were made by applying a 50 volt d.c. potential and measuring the current in the circuit with an RCA Model WV-84C ultra-sensitive microammeter. The test circuit is shown in Figure 2.

C. SUMMARY AND RECOMMENDATIONS

The Rockbestos Model 0235A cable maintained insulation resistances that would be satisfactory for most instrumentation applications while in a radiation environment. The radiation exposure rates were less than they would be on a NERVA engine, however, the total dose on a 20-minute NERVA run would be less than at the Ground Test Reactor.

Figure 1
Irradiation Test Mounting Configuration

Figure 2
Shielded Cable Test Circuit

A method of preventing test cables from absorbing moisture during tests should be found and applied in future tests.

D. TECHNICAL DISCUSSION

The results of the insulation resistance measurements are shown in Table I. There was a large decrease in insulation resistance between the laboratory data cycle and the pre-irradiation data cycle. The only explanation for the large reduction is that the cables were stored for several days in an area of high humidity after the measurements has been made in the laboratory. The cable is normally moisture resistant, however, the ends of the cable were not sealed for this test.

Data measurements were taken at reactor power of 10 kw, 100 kw, 1 MW, and 3 MW. As the reactor power increased to 3 MW, the data show a dose rate effect evidenced by the corresponding decrease in insulation resistance. As the 3 MW irradiation continued the temperature of the cables quickly rose to approximately 120°F and stabilized. (The temperature data for each section of cable are shown in Figures 3 through 6.) The insulation resistance of the cable increased and remained high throughout the test. The improvement probably was a result of the moisture being baked out of the cable insulation.

There are large fluctuations in the insulation resistance measurements throughout the 3 MW irradiation portion of the test. The fluctuations are random and attributed to the extreme sensitivity of the meter rather than radiation. The post-irradiation measurements, shown in Table I, show no change in insulation resistance.

NOTE: A resistance measurement fluctuation of 100 megohms corresponds to a current measurement fluctuation of only 0.5 micro amperes.

The radiation exposures of the cables are given below:

Cable	Integrated Neutron Flux (n/cm ²) E > 0.9 Mev	Gamma Dose ergs/gm (C)
1	1.23×10^{17}	4.7×10^{10}
2	1.45×10^{17}	4.4×10^{10}
3	3.42×10^{16}	1.0×10^{11}
4	3.42×10^{16}	6.8×10^{10}

Data Run	Mw-Min	Switch Position								
		1	2	3	4	5	6	7	8	9
Laboratory		62500	62500	62500	62500	71500	50000	62500	62500	62500
Preirr		227	625	625	312	500	625	166	500	556
10 kw		143	715	500	128	286	455	123	357	417
100 kw		151	46.5	357	109	217	385	117.5	263	250
1 Mw		50	147	45.5	16.7	27.8	807	20	41.7	55.5
3 Mw	260	15.6	135	33.3	18.5	25	9.62	27.8	62.5	7.35
3 Mw	690	100	1670	1670	1250	2170	3330	2940	4170	2940
3 Mw	1410	10000	5000	1000	12500	6250	100000	41700	167000	50000
3 Mw	2130	6250	12500	6250	6250	5000	33300	20000	20800	16700
3 Mw	2850	5000	5000	16700	25000	12500	14300	12500	12500	12500
3 Mw	3520	4170	4170	31200	50000	50000	33300	25000	7820	2500
3 Mw	4290	1190	1190	1670	22270	2500	1670	1670	1250	1520
3 Mw	5010	1670	2000	3330	12500	1670	2780	2500	2500	2500
3 Mw	5730	5000	5000	12500	1670	2000	2000	1920	1920	1790
3 Mw	6450	5000	4170	10000	10000	5000	2780	5000	4160	5000
3 Mw	7120	4170	2780	5000	50000	10000	50000	2780	2500	6250
3 Mw	7890	2170	2370	4550	12500	6250	19200	2000	1850	2780
3 Mw	8610	3570	4170	11100	2000	1670	1430	1320	1670	2500
Postirr 1		1430	1790	2500	2500	4550	1780	100	2500	500
Postirr 2		4170	3520	4170	4550	5000	6250	5550	5550	1250
Postirr 3		1670	3520	4550	5000	5000	1110	1110	1670	2080
Postirr 4		5000	5000	10000	3330	8350	1250	10000	10000	12500

Figure 3
Shielded Cable 1: Temperature-vs-Radiation Exposure

Figure 4
Shielded Cable 2: Temperature-vs-Radiation Exposure

Figure 5
Shielded Cable 3: Temperature-vs-Radiation Exposure

Figure 6
Shielded Cable 4: Temperature-vs-Radiation Exposure

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II. TEST OF CABLE 23/R791

A. PURPOSE

The purpose of this test was to determine the effect of combined temperature and nuclear radiation environments on the insulation resistance, capacitance, and contact resistance of NERVA candidate cables and cable assemblies. The integrity of the cables and tie-downs after being subjected to the extreme environments was also to be examined by vibration tests after the irradiation.

B. METHOD

Fifteen assemblies were mounted on aluminum plates using the same procedures for cable installation as those used on NPX-A2 and A3. The assemblies included cables from five manufacturers, Aeroresearch, Temptron, Boston Insulated Wire, Physical Sciences, and Rockbestos Wire and Cable. The connectors were all from Statham with the exception of the one in the Physical Sciences Cable assembly. In addition to cables terminated with connectors, several were sealed with Aero-Seal and welded stainless steel cups.

Data concerning the insulation resistance, cable capacitance, and connector contact resistance was recorded at high, low, and ambient temperature throughout the test. The same measurements were repeated after the vibration tests.

C. SUMMARY AND RECOMMENDATIONS

All of the test items with the exception of the Boston Insulated Wire Cable assembly are satisfactory for electrical functions in an environment equivalent to the Ground Test Reactor at General Dynamics/Fort Worth. In the NERVA environment, further decreases in insulation resistance are to be expected because of the higher radiation dose rates. The cables were exposed to a greater total dose in the Ground Test Reactor than they would be in a 20-minute NERVA engine run. Cable tie-downs, while satisfactory for the flexible cables like Physical Sciences, Rockbestos, and Boston Insulated Wire, are not suitable for the 0.250-in. diameter cables. The installation procedure for the larger sheathed cables should be improved, either by changing the tie-down material, weld schedule, or number of tie-downs per foot.

The cable-to-connector termination procedure used for the cable assemblies in this test is not satisfactory for sheathed cables - and is marginal in the case of the flexible cables. It is recommended that a tig-weld process be developed and tested if further use of stainless steel, sheathed cables is planned.

Post-irradiation tests performed at Aerojet-General, Sacramento, indicate that properly applied Aero seal is a satisfactory radiation resistant moisture seal for sheathed cables.

D. TECHNICAL DISCUSSION

1. Test Method

a. Test Assembly

The test assembly consisted of two, quarter-inch aluminum plates mounted parallel with four studs and steel spacers (Aerojet Drawing 096995). The candidate cables and cable assemblies were mounted on the surfaces of the plates facing each other. The number, termination, and identification of the cables is given in Table II. A photograph of the opened assembly is shown in Figure 7. The letters on the photograph refer to the cable identification given in Table II.

The cables were mounted on the surface of the aluminum plates by looping a stainless steel braid material (#24-2-36-SS shielding) around the cable and spot welding on each side as shown in Figure 8. The connectors were affixed to the aluminum plate by two machined pieces of aluminum that were subsequently bolted in place.

Finally the test assembly was placed in a rectangular nitrogen dewar. The dewar was alternately filled with LN_2 and hot GN_2 which cycled the test assembly temperature between $-320^{\circ}F$ and $+450^{\circ}F$. Each thermal cycle took several hours.

TABLE II
Cables And Connectors (Test
No. 23/R701)

Code	Mfg.	Cable Identification P/N	Termination
C	Aeroresearch	125-4M-F(CU)24	Welded stainless-steel cap
M	Aeroresearch	125-4M-F(CU)24	Glass
L	Aeroresearch	125-4M-F(CU)24	Connector BP-60066-10-4S
A	Aeroresearch	125-4M-F(CU)24	Connector BP-60066-10-4S
B	Temptron	347-125(4)24GA-CU	Welded stainless-steel cap
K	Temptron	347-125(4)24GA-CU	Glass
N	Temptron	347-250(6)24GA-CU	Welded stainless-steel cap
J	Temptron	347-250(6)24GA-CU	Glass
G	Temptron	347-250(6)24GA-CU	Connector BP-60066-10-6S
F	Temptron	347-250(6)24GA-CU	Connector BP-60066-10-6S
O	Temptron	347-250(6)24GA-CU	Connector BP-60066-10-6S
E	Boston Ins. Wire	M4614-S-004	Connector BP-60066-8-4S
H	Physical Sciences	C-39038	Connector
D	Rockbestos	0235A	Connector BP-60066-8-4S
I	Rockbestos	0235A	Connector BP-60066-8-4S

Figure 7
Cable and Connector Test Assembly

Figure 8
Resistance Measurement Circuits
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b. Resistance Measurements

The circuits used for all of the conductor-to-conductor and conductor-to-shield insulation resistance measurements are shown in Figure 8. The operation of the circuit is such that a 50 volt d-c potential is applied between the conductors or the conductor and shield. The current flowing through the insulation was then measured by a RCA Ultrasensitive Model WV-84C micrometer.

The 20-foot section of test cable was connected to the instruments in the control room by 120-foot lengths of single conductor shielded cable. The insulation resistance measurement of the test cable was separated from errors introduced by leakage through the 120-foot cable insulation resistance by means of a guarded circuit. As shown in Figure 8, the shield of the 120-foot cable was raised to the same potential as the conductor. Thus, no current flowed between them, hence, the current flowing in the measurement circuit was a direct measure of the insulation resistance of the test cable alone.

Approximately five feet of the 20-foot test cables were mounted on the test assembly. The remainder of the test cable was routed away from the reactor and spliced to facility cables which were 120 feet long. The splice was potted with a 50 percent mixture of epon and versimide. The control room terminations of the facility cable were sockets in a Teflon patch panel which made it possible to patch in resistance and capacitance measuring circuits. The cable layout is shown schematically in Figures 8, 9, and 10.

c. Capacitance Measurements

Conductor-to-conductor and conductor-to-shield capacitance measurements were made with a Rhode and Schwartz Model KARU51C capacitance meter. Measurements were made by matching the capacitance meter to the conductors and shields for each measurement. The circuit used for these measurements is shown in Figure 9. It should be noted that the measurements from this circuit actually give the value of the desired conductor-to-conductor, or conductor-to-shield capacitance, plus the capacitance of the 120-foot single conductor cables. The values shown in Table III include the 120-foot cable capacitance.

Figure 9
Capacitance Measurement Circuits

Figure 10
Connector Contact Resistance Measurement Circuit

TABLE III
CABLE CAPACITANCE
($\mu\mu\text{f}$)

*Neutron Flux N/sq. cm. ($E > 0.9$ Mev)
**Gamma Dose ergs/gm (c)

Cable Ident.	Pre-irrad.	Reactor Power			*1.73(14)	*4.81(15)	*1.55(16)	*2.62(16)	*3.67(16)	*4.33(16)	Post-irrad.	Before Vib.	After Vib.
		10 kw	100 kw	1 Mw	**5.76 (8)	**1.6 (10)	**5.17(10)	**8.72(10)	**1.22(11)	**1.44(11)			
C-cond to cond	3900	3820	3810	3810	3840	3900	3820	3920	3940	3780	3820	4120	4170
-cond to shld	8000	7980	8000	8010	8310	8150	7970	8320	8390	8380	8360	8820	8670
M-cond to cond	3850	3880	3900	3880	3870	3900	3820	3870	3940	3860	3860	4100	4120
-cond to shld	6100	6180	6180	6180	6510	6250	6170	6520	6490	6580	6460	6920	6740
L-cond to cond	3900	3910	3880	3850	3880	3950	3820	3920	3940	3880	3860	4130	4145
-cond to shld	7400	7500	7500	7510	7860	7750	7420	7820	7940	7830	7860	8340	8170
B-cond to cond	3900	3880	3780	3790	3790	3900	3770	3820	3840	3760	3810	4010	4095
-cond to shld	8000	8030	8000	8030	8310	8350	8020	8420	8440	8430	8360	8980	8670
K-cond to cond	1700	1730	1700	1720	1700	1830	1690	1720	1740	1680	1710	1980	1945
-cond to shld	3900	3980	3970	3960	4300	4150	3950	4320	4340	4280	4280	4720	4550
D-cond to cond	2425	2420	2410	2410	2440	2480	2370	2420	2390	2380	2360	2640	2645
-cond to shld	5650	***	***	***	***	5950	5590	4820	5990	5080	5980	6320	3170
N-cond to cond	1600	1580	1580	1600	1670	1650	1580	1670	1650	1680	1710	1770	1870
-cond to cond	2800	2860	***	***	***	***	2970	2870	2900	2830	2860	3100	3170
-cond to shld	6250	6330	6280	6350	6700	6450	6370	6670	6750	6680	6660	7220	6990
J-cond to cond	2750	2760	2760	2760	2710	2800	2770	2720	3290	2680	2710	2920	2995
-cond to cond	2400	2460	***	***	***	***	2420	2470	2990	2460	2440	2640	2720
-cond to shld	6300	6380	6370	6410	6760	6500	6370	6720	6800	6730	6760	7240	7020
G-cond to cond	2500	2510	2500	2510	2500	2500	2470	2520	2500	2480	2480	2720	2770
-cond to cond	2800	2810	***	***	***	***	2870	2820	2850	2830	2810	3030	3145
-cond to shld	6600	6680	6660	6680	6960	6850	6970	7020	7000	7080	7060	7620	7370
F-cond to cond	2750	2800	2770	2790	2790	2800	2820	2820	2850	2780	2840	3020	3070
-cond to cond	3000	3020	***	***	***	***	3070	3020	3050	3030	2980	3270	3320
-cond to shld	6500	6610	6520	6580	6900	6800	6520	6970	7000	6830	6910	7470	7250
H-cond to cond	1900	1950	1950	1950	1960	1850	1920	1970	2050	1930	1960	2160	2120
-cond to cond	1875	1970	***	***	***	***	1880	1900	1900	1880	1810	2030	2140
-cond to shld	2500	2520	2510	2520	2600	2600	2520	2570	2600	2580	2560	2840	2640
E-cond to cond	2050	2080	2080	2080	2060	2150	2020	2070	2100	2080	2060	2270	2290
-cond to shld	4700	4740	4750	4770	5100	4750	4720	5070	5100	5080	5160	5630	5250
I-cond to cond	2325	2370	2380	2380	2390	2450	2370	2350	2330	2380	2360	2620	2610
-cond to shld	6100	6180	6190	6160	6540	6400	6170	6470	6500	6380	3360	7100	3430

***No data taken

Table IV
Connector Pin Contact Resistances
(ohms)

Data Cycle	Temp (°F)	Connector A		Connector O	
		A to B	C to D	A to B	C to D
Preirradiation	+ 50	1.190	1.220	1.490	1.470
Preirradiation	+310	1.330	1.390	1.700	1.720
10 kw	+ 57	1.212	1.248	1.539	1.506
100 kw	+ 62	1.231	1.253	1.523	1.496
1 Mw	+ 83	1.240	1.279	1.562	1.533
1.68 (14) n/cm ²	+ 70	1.210	1.260	1.530	1.500
7.32 (14) n/cm ²	+ 70	1.243	1.278	1.560	1.536
1.18 (15) n/cm ²	+410	1.228	1.261	1.543	1.531
4.2 (15) n/cm ²	-320	1.066	1.066	1.222	1.192
4.73 (15) n/cm ²	+ 99	1.305	1.355	1.657	1.607
6.00 (15) n/cm ²	+ 90	1.295	1.326	1.671	1.627
7.56 (15) n/cm ²	+145	1.317	1.344	1.668	1.620
8.62 (15) n/cm ²	+ 75	1.281	1.295	1.581	1.558
9.92 (15) n/cm ²	+ 81	1.260	1.286	1.578	1.539
1.30 (16) n/cm ²	+450	Open	1.490	1.892	1.859
1.39 (16) n/cm ²	-320	1.089	1.065	1.225	1.195
1.51 (16) n/cm ²	+190	1.306	1.322	1.653	1.628
1.64 (16) n/cm ²	+165	1.396	1.373	1.723	1.684
1.78 (16) n/cm ²	+ 83	1.250	1.248	1.558	1.508
1.90 (16) n/cm ²	+ 80	1.268	1.280	1.565	1.534
2.01 (16) n/cm ²	+ 77	1.265	1.268	1.570	1.529
2.17 (16) n/cm ²	+235	1.316	1.315	1.666	1.633
2.30 (16) n/cm ²	-320	1.070	1.064	1.218	1.180
2.34 (16) n/cm ²	+ 95	1.254	1.264	1.575	1.538
2.47 (16) n/cm ²	+450	Open	1.455	1.869	1.836
2.55 (16) n/cm ²	+ 80	1.286	1.270	1.589	1.537
2.68 (16) n/cm ²	+ 90	1.295	1.278	1.574	1.555
2.81 (16) n/cm ²	+ 85	1.302	1.288	1.585	1.546
2.93 (16) n/cm ²	+ 88	1.296	1.580	1.277	1.536
3.06 (16) n/cm ²	+ 84	1.290	1.284	1.569	1.534
3.19 (16) n/cm ²	+ 87	1.259	1.262	1.540	1.509
3.32 (16) n/cm ²	-320	1.082	1.067	1.219	1.182
3.41 (16) n/cm ²	+ 89	1.274	1.264	1.558	1.522
3.50 (16) n/cm ²	+453	Open	1.445	1.865	1.831
3.58 (16) n/cm ²	+112	Open	Open	1.617	1.564
3.71 (16) n/cm ²	+107	1.320	1.299	1.593	1.568
3.86 (16) n/cm ²	+108	1.308	1.306	1.588	1.552
3.99 (16) n/cm ²	+ 85	1.290	1.281	1.569	1.531
4.08 (16) n/cm ²	+ 92	1.290	1.280	1.584	1.535
4.13 (16) n/cm ²	-320	1.070	1.040	1.212	1.172
4.22 (16) n/cm ²	+ 83	1.280	1.258	1.553	1.514
4.32 (16) n/cm ²	+450	Open	1.435	1.863	1.839
Postirradiation	+415	Open	1.436	1.858	1.817
Postirradiation	+ 96	1.285	1.236	1.551	1.530
Postirradiation	-320	1.074	1.058	1.213	1.173
Postirradiation	+ 90	1.297	1.247	1.531	1.506
Before vibration	+ 75	1.363	1.256	1.566	1.532
After vibration	+ 72	Open*	Open*	Open*	Open*

*Cables broke during vibration test

TABLE V
CABLE INSULATION RESISTANCE

*Neutron Flux N/sq. cm. ($E > 0.9$ Mev)
**Gamma Dose ergs/gm (c)

Cable Ident.	Pre-irrad.	Reactor Power			*1.73(14)	*4.81(15)	*1.55(16)	*2.62(16)	*3.67(16)	*4.33(16)	Post-irrad.	Before Vib.	After Vib.
		10 kw	100 kw	1 Mw	**5.76 (8)	**1.6 (10)	**5.17(10)	**8.72(10)	**1.22(11)	**1.44(11)			
C-cond to cond	500+	278	500+	357	192	227	500	500+	500+	500+	500+	500+	500+
-cond to shld	500+	500+	500+	500+	500	313	500+	500+	500+	500+	500+	500+	500+
M-cond to cond	500+	455	500+	417	125	125	143	500+	200	9.3	500+	500+	500+
-cond to shld	500+	500+	500+	500+	6.6	9.1	6.4	3.1	3.3	5.1	500+	500+	500+
L-cond to cond	385	185	500+	500K	93	78	131	500+	200	500+	207	86	500+
-cond to shld	500+	500+	500+	278	1.7	1.9	500+	500+	500+	500+	500+	500+	500+
B-cond to cond	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
-cond to shld	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
K-cond to cond	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
-cond to shld	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
D-cond to cond	500+	500+	500+	500+	122	113	100	125	120	6.9	500+	294	500+
-cond to shld	500+	500+	500+	500+	3.3	3.9	3.1	2.2	2.4	2.7	500+	500+	500+
N-cond to cond	500+	500+	500+	500+	500+	500+	500	500	500+	455	500+	500+	500+
-cond to cond	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
-cond to shld	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+	500+
J-cond to cond	500+	500+	500+	500+	250	333	217	227	31	109	500+	500+	500+
-cond to cond	500+	500+	500+	500+	250	208	250	357	500+	62	500+	500+	500+
-cond to shld	500+	500+	500+	500+	91	100	68	500+	58	57	500+	500+	500+
G-cond to cond	500+	500+	500+	500+	135	125	109	500+	128	6.4	500+	250	500+
-cond to cond	500+	500+	500+	500+	131	116	109	139	128	6.2	500+	250	500+
-cond to shld	500+	500+	500+	500+	2.4	2.5	2.1	1.4	1.6	1.9	500+	455	500+
F-cond to cond	500+	500+	500+	500+	135	125	106	135	128	6.0	500+	455	500+
-cond to cond	500+	500+	500+	500+	131	116	106	135	128	6.5	500+	500	500+
-cond to shld	500+	500+	500+	500+	2.4	2.5	2.1	1.6	1.6	1.8	500+	500+	500+
H-cond to cond	500+	500+	500+	500+	185	167	119	172	167	25	500+	500+	500+
-cond to cond	500+	500+	500+	500+	131	119	86	59	116	8.5	500+	415	500+
-cond to shld	500+	500+	500+	500+	56	500	7.7	2.8	25	4.2	500+	500+	500+
E-cond to cond	250	167	500+	70	70	79.5K	96	122	114	960K	345K	192	500+
-cond to shld	385	156	500+	106	2.8	29.9K	1.8	1.4	1.4	500K	227K	200	500+
I-cond to cond	500+	500+	500+	500	119	144	96	119	116	6.3	500+	312	500+
-cond to shld	500+	500+	500+	500	2.5	294K	2.5	1.8	1.8	2.4	500+	500+	500+

d. Contact Resistance

The pin-to-socket resistance of two of the connectors was measured by use of the circuit shown in Figure 10. The actual circuit used included the resistance of the test cable conductors with the contact resistance. The values shown in Table IV include the resistance of the test cable which is 1.03 ohms.

2. Test Results

a. Insulation Resistance

The results of the measurements of conductor-to-conductor and conductor-to-shield insulation resistance are given in Table V. It is apparent that most of the cable insulation resistances were somewhat sensitive to accumulated doses of radiation. While there was no detectable degradation of the resistance of the Temptron 347-125(4)24GA-CU cables (B and K), it may have been because they had extremely high resistances to begin with, and they did not degrade below 500 megohms.

The post-irradiation data show a marked recovery for all cables except the Boston Insulated Wire and Cable assembly, the resistance of which remained below one megohm. An insulation resistance of one megohm would not bother a thermocouple circuit; however, for most other instrumentation circuits, it would be considered unsatisfactory. Aerojet cable specification 90052 requires a resistance of 100 megohms.

b. Capacitance

The results of the cable capacitance measurements are shown in Table III. The cable capacitances were virtually unaffected by radiation. While the data show fluctuations in all of the cable capacitances, the fluctuations are random and do not indicate any trend for either increasing or decreasing with accumulated dose. It should be noted that since the measurements included the full 140-ft cable capacitance, it would take a large change in test cable capacitance to show a small change in the data. Conclusions regarding cable capacitance should therefore be limited to the fact that there were no large changes.

c. Contact Resistance

The results of the pin to socket contact resistance measurements are given in Table IV. It is apparent that there was no noticeable change in contact resistance caused by radiation. There are some fluctuations in the resistance values; however, they are attributed to the sensitivity of the test equipment and to the effects of temperature on the copper conductors.

The test circuit of the AeroResearch 125-4M-F(cu)24, (Cable A) opened during several of the high temperature heat cycles. There were three possible places in the circuit that could have been opening; the solder connections on the pin-to-pin jumpers located on the open end of the test connector, the pin-to-socket contact itself, and at the test cable-to-connector termination. After the cable assembly was returned to Aerojet, the cable assembly was removed from the test assembly and tests were conducted in an attempt to pinpoint the cause of the open readings. The solder connections on the pin-to-pin jumpers were found to be intact. The test cable-to-pin termination on pin B of the connector was found open and was the probable cause of the open circuit.

d. Vibration Test

Five weeks after the irradiation, a vibration test was conducted. The test fixture was disassembled and each plate individually vibrated along each axis at 32-g rms random frequency. Upon completion of the vibration tests, measurements of insulation resistance, capacitance, and contact resistance were repeated. There was no apparent effect on the cable capacitance measurements. The connectors used for contact resistance measurements were severed from the cables during the vibration, as shown in Figure 11, consequently the circuits measured open. Several of the assemblies showed an increase in insulation resistance. It should be noted, however, that most of the connectors were severed and all of the potting material had been shaken out of the potting boot.

A closeup of post vibration damage to the assemblies is shown in Figure 12.

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Figure 11
Post Irradiation Vibration Test Setup

Figure 12
Closeup of Post Irradiation Vibration Test Damage