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LIQUID ROCKET PLANT **MASTER**

PIEZOELECTRIC AND STRAIN GAGE-TYPE
ACCELEROMETERS

ELECTRICAL IRRADIATION TEST
NO. 23/L001

Volume 1

Final Test Report No. 1.9.5-2E

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FINAL TEST REPORT NO. 1.9.5-2E

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VOLUME I

ELECTRICAL IRRADIATION TEST

MASTER

NO. 23/LOOL

PIEZOELECTRIC AND STRAIN GAGE-TYPE

ACCELEROMETERS

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I. ABSTRACT

Four Endevco, six Clevite, and one Kistler piezoelectric and six Statham strain gage-type accelerometers were tested on the Ground Test Reactor (GTR) for 100 hours during the period 24 through 29 October 1963. Accelerometers were vibrated using shaker tables driven by air motors with unbalanced flywheels. Neutron and gamma integrated doses were measured during the test. Accelerometer outputs were recorded at intervals throughout the test. The accelerometers were not significantly affected by radiation during this test.

II. INTRODUCTION

This is one of a series of tests to determine the effects of nuclear radiation on diagnostic instrumentation components being evaluated for use on the NERVA engine. This test was performed at the Nuclear Aerospace Research Facility (NARF) of General Dynamics/Fort Worth on the Ground Test Reactor (GTR).

Test items covered by this report are strain gage type and crystal type accelerometers. The irradiation test duration was 100 hours at a reactor power level of 3 megawatts.

III. EXPERIMENT IDENTIFICATION

A.	Test Plan Reference Number	23/L001
B.	Sponsor	LRP
C.	Testing Facility	GTR
D.	Test Date	24 through 29 Oct. 1963
E.	Concurrent Test	23/L501

IV. PURPOSE OF THE EXPERIMENT

To evaluate the effects of nuclear radiation on accelerometers as a part of the evaluation program to select accelerometers for use on the NRX and NERVA engine tests.

V. TEST DESCRIPTION

The test fixture used in this test contained two major assemblies (Figure A-1). One was a shake table assembly for testing accelerometers and the other was a pressure manifold and oven assembly for testing pressure transducers. This test report describes only the accelerometer test. Accelerometers were mounted on the shake tables as shown in Figures A-1, 2 and 3 and were vibrated in the vertical plane.

The shake tables were vibrated using unbalanced flywheels driven by air motors. The motors and flywheels were adjusted to produce minimum vibrations in the horizontal plane. The tables were also restrained in the horizontal plane by spring loaded guide pistons at each corner. The air motors were driven by shop air and controlled from the control room. Details of the fixture are given in Reference No. 1, and Appendix D.

Two fixtures were used in the test. One was installed on the west face of the GTR and the other was located outside of the nuclear environment.

Twenty accelerometers were used on the test. Three were used as reference transducers on the non-irradiated fixture and the other seventeen were tested in the nuclear environment on the irradiated test fixture. The accelerometers are listed in Table B-1.

Statham strain gage-type accelerometers were excited with 5vdc+1mV by Harrison Laboratories 801c power supplies. Their outputs were amplified by Model 2200 Dana amplifiers. Outputs of the Endevco, Clevite, and Kistler accelerometers were amplified using Endevco, Model 2710 charge amplifiers.

The amplified outputs of all accelerometers were recorded on a CEC Model 4-119 recording oscillograph, and Non-Linear Systems M-24 digital volt-ohmmeter. Input voltages to the digital volt-ohmmeter were filtered to reject shake table noise. Shake table frequencies were recorded using a Hewlett-Packard Model 524, CR counter.

Input and output resistance measurements were taken on bridge-type accelerometers using the Non-Linear Systems M-24 digital volt-ohmmeter.

Copper-Constantan thermocouples were used to measure temperature of some of the accelerometers tested.

VI. TEST PROCEDURE

A description of the detailed test procedure employed is given in AGC Report 8200-2A, Reference No. 1. This procedure includes data handling requirements, receiving inspection, pre-irradiation checkout, test fixture installation, pre-irradiation test, irradiation test and post-irradiation test procedure.

The irradiation test procedure was changed prior to the start of testing as follows:

- A. The test duration was changed from 50 to 100 hours to obtain an integrated dose better simulating that of the NRX-A tests.
- B. Data cycles are as follows:
 - 1. One data cycle at 10 KW power level.
 - 2. One data cycle at 100 KW power level.
 - 3. One data cycle at 1 MW power level.
 - 4. One data cycle per hour at 3 MW power level for first eight hours.
 - 5. One data cycle every four hours thereafter, except (a) after thirty-two hours increase insulated compartment temperature to 175°F and record three pressure data cycles, (b) after forty hours increase insulated compartment temperature to 275°F and record three pressure data cycles, and (c) after forty-eight hours, increase insulated compartment temperature to 375°F and record three pressure data cycles. Reduce the insulated

compartment temperature to ambient temperature after the third 375°F data cycle. Repeat (a), (b) and (c) after 82, 90 and 98 hours respectively.

6. One data cycle per hour for the first hour hours after the reactor is shut down.

VII. NUCLEAR MEASUREMENTS

Four dosimeter packets were located adjacent to the front and back edges of the accelerometer shake table. A detailed description of the nuclear measurements is given in Reference No. 2.

VIII. TEST RESULTS

Sample oscillograph traces of the accelerometers are given in Figure C-1.

Pre- and post-irradiation sensitivities are listed in Table B-3 for the piezoelectric accelerometers. Pre- and post-irradiation input and output resistance values are shown in Table B-4.

The reference shaker table became inoperative approximately eight hours after the start of irradiation testing. Shaker motors were replaced on this table and normal operation of the reference table was resumed. Five data cycles were all that was lost during this period.

The irradiated shaker table became inoperative near the end of irradiation testing. The last data cycle and those scheduled immediately after the irradiation test could not be taken. After the fixture was returned to the checkout area, the shaker motors were lubricated and became operable. Post-irradiation data cycles were then run.

Radiation dosimetry results are given in Table B-2.

IX. DISCUSSION OF TEST RESULTS

Test results indicate there were no significant effects to piezoelectric accelerometers from radiation. Oscillograph records indicate that

the piezoelectric accelerometers have an output wave form similar to the strain gage type. The increased amount of noise is because of the higher response of the piezoelectric types.

Pre- and post-irradiation test calibrations on the Clevite accelerometers indicate that the non-irradiated units had sensitivity shifts nearly the same as those that were irradiated (See Table B-3). The average change in sensitivity of Endevco accelerometers was slightly less than that of Clevites.

Two Statham Model A-515 accelerometers were inoperative before the start of the test. One had an open bridge and the cause of failure has not been determined for the other. Two other Statham accelerometers were reported operating intermittently in Reference 2. Accelerometer A9-1 appeared to be highly damped during pre-irradiation vibration cycling and at the start of irradiation testing, but appeared normal soon after start of irradiation testing and remained normal for the duration of testing. Accelerometer A3-1 shared a power supply with a pressure transducer. The malfunction may have been an operational switching error. Table B-4 compares Statham accelerometer pre-irradiation input and output resistance values with those taken near the end of the irradiation test. The differences in resistance readings were slight and could have been caused by cable resistance between the control room and the transducers.

Figure C-1 shows samples of oscillograms of accelerometer traces during pre-irradiation, irradiation and post-irradiation testing. Accelerometer outputs were recorded on the oscillograph to show only gross effects and were not intended for measuring qualitative data. The complex wave form is caused by clashing of the gear teeth on the air motors and not by electrical noise.

Air motors on both the reference and irradiated shaker tables become inoperative during the test. Motors were replaced on the reference table and only five data cycles were lost. The motors could not be replaced on the irradiated table and the last data cycle during test along with those just after test could not be taken. After the fixture was removed to the checkout area, the air motors were lubricated and became operative. Post-test data were then obtained.

X. CONCLUSIONS AND RECOMMENDATIONS

A. It is concluded that:

1. Piezoelectric accelerometers were not significantly affected by radiation during this test.

2. Data acquisition methods used, lack of known stimulus (g level frequency), and complex output waveform precluded any qualitative analysis.

B. It is recommended that:

1. Additional accelerometer tests be performed using a known input stimulus such as an electrically driven shaker table and the data be recorded using an analog magnetic tape recorder.

2. Test specifications and procedures be more specific about pre- and post-calibrations of test transducers.

3. More consideration be given to test measurement requirements to see that they are adequate and complete. An example of this is when testing strain gage-type transducers; input, output and insulation resistances should be measured before, during, and after each test.

4. Instrumentation equipment lists should be prepared listing measurement channels (interconnecting cables, patching, etc), power supply, amplifier and recorder channels. In case of an indicated malfunction on any particular test instrument, all components of that channel could be checked to verify the test instrument was the cause of the malfunction.

XI.

APPENDICES

- A. PHOTOGRAPHS
- B. TABLES
- C. TEST DATA
- D. DRAWINGS
- E. REFERENCES

APPENDIX A

PHOTOGRAPHS

<u>FIGURE</u>	<u>TITLE</u>
A-1	Electrical Components Test Fixture for 23/L501 and 23/L001.
A-2	Accelerometers Mounted on Shake Table
A-3	Accelerometer Locations on Shake Table

Figure A-1. Electrical Components Test Fixture for 23/L501 and 23/L001

Figure A-2. Accelerometers Mounted on Shake Table

Figure A-3. Accelerometer Locations on Shake Table

APPENDIX B

FIGURE

TITLE

B-1	List of Accelerometers Tested Listed By Manufacturer, Model, Serial Number and Test Designation.
B-2	Dosimetry Results for Accelerometers
B-3	Sensitivity Comparison for Piezoelectric Accelerometers.
B-4	Input and Output Resistance Measurements for Statham Accelerometers.

TABLE B-1
LIST OF ACCELEROMETERS TESTED

<u>DESIGNATION</u>	<u>MANUFACTURER</u>	<u>MODEL</u>	<u>SERIAL NO.</u>
A1-1	Endevco	2245M6	GA01
A6-1			GA02
A13-1			GA03
A18-1			GA04
A2-1	Clevite	25D21X	5200
A5-1			5205
A8-1			5196
A11-1			5197
A14-1			5181
A17-1			5212
A2-2			5190
A5-2			5188
A3-1	Statham	A515	4
A4-1			5
A9-1			1
A10-1			3
A15-1			7
A16-1			11
A3-2			8
A7-1	Kistler	808K4	1507

TABLE B-2
DOŠIMETRY RESULTS FOR ACCELEROMETERS

<u>SHAKE-TABLE LOCATION*</u>	<u>GAMMA DOSE ergs/gm(C)</u>	<u>INTEGRATED NEUTRON FLUX (n/cm²)</u>	
		<u>E 2.9 Mev</u>	<u>E 0.48 ev</u>
Front - Left	7.53×10^{10}	17.1×10^{15}	11.0×10^{14}
Back - Left	5.78×10^{10}	8.56×10^{15}	8.38×10^{14}
Front - Right	9.20×10^{10}	15.4×10^{15}	11.7×10^{14}
Back - Right	3.24×10^{10}	5.68×10^{15}	10.9×10^{14}

* As Viewed From Reactor Closet.

TABLE B-3

SENSITIVITY COMPARISON FOR PIEZOELECTRIC ACCELEROMETERS

ACCELEROMETER	FREQUENCY CPS	PRE-IRRADIATION	POST IRRADIATION	PERCENT CHANGE
		OPEN CIRCUIT	OPEN CIRCUIT	
		$\frac{mv}{g} \quad (rms)$	$\frac{mv}{g} \quad (rms)$	
IRRADIATED ACCELEROMETERS				
Clevite	100	28.15	28.2	+ 0.18
A5-1	1000	28.19	25.4	- 9.89
Clevite	100	27.75	30.2	+ 8.82
A11-1	1000	27.75	25.8	- 7.02
Clevite	100	27.45	29.2	+ 6.37
A2-1	1000	27.45	25.8	- 6.01
Clevite	100	27.13	27.0	- 0.47
A8-1	1000	27.13	25.5	- 6.01
Clevite	100	27.17	29.0	+ 6.73
A14-1	1000	27.17	26.3	- 3.20
Clevite	100	27.69	27.1	- 2.13
A17-1	1000	27.69	26.7	-3.57
Endevco	50	6.88	6.79	- 1.31
A1-1	400	6.95		
	450		7.09	
Endevco	50	8.52	8.25	- 3.17
A6-1	400	8.35		
	450		8.46	
Endevco	50	7.99	8.09	+ 1.25
A13-1	400	8.15		
	450		8.09	
Endevco	50	9.16	8.90	- 2.84
A18-1	400	9.35		
	450		9.31	
Kistler	100		1.21	
A7-1	1000		1.17	

TABLE B-3 (CONT'D)

ACCELEROMETER	FREQUENCY CPS	PRE-IRRADIATION		POST IRRADIATION		PERCENT CHANGE
		OPEN CIRCUIT		OPEN CIRCUIT		
		<u>mv</u>	<u>(rms)</u>	<u>mv</u>	<u>(rms)</u>	
		<u>g</u>	<u>(rms)</u>	<u>g</u>	<u>(rms)</u>	

NON-IRRADIATED ACCELEROMETERS

Clevite	100	27.15		28.3		+ 4.24
A2-2	1000	27.15		26.6		= 2.02
Clevite	100	27.06		28.9		+ 6.79
A5-2	1000	27.06		26.1		= 3.55

TABLE B-4

INPUT AND OUTPUT RESISTANCE MEASUREMENTS
FOR STATHAM ACCELEROMETERS

ACCELEROMETER		BRIDGE RESISTANCE IN DHMS			
DESIGNATION	SERIAL NO.	INPUT PINS ATOD		OUTPUT PINS BTOC	
		PRE-TEST	10,200 MW-MIN	PRE-TEST	10,200 MW-MIN
A3-1	4	364	370.3	346	350.6
A4-1	5	362	368.0	346	350.4
A9-1	1	424	427.9	350	354.0
A10-1	3	362	366.1	352	355.7
A15-1	7	362	700.1	342	699.5
A16-1	11	362	365.9	344	347.6

APPENDIX C

FIGURE

TITLE

C-1

Sample Oscillograph records showing
accelerometer output data.

Figure C-1. Sample Oscillograph Records Showing Accelerometer Output Data

APPENDIX D

DRAWINGS

- D-1 AGC Dwg. 248537 Pallet, Electrical - Irradiation Test No. 1
- D-2 AGC Dwg. 248560 Schematic Diagram Electrical - Irradiation Test No. 1
- D-3 Electrical Block Diagram of Pressure Transducer and Accelerometer Test Setup.

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Figure D-3. Electrical Block Diagram of Pressure Transducer and Accelerometer Test Setup

REFERENCES

1. Final Test Procedure 1.9.5-2, Electrical Irradiation Test No. 501.
Aerojet-General Corporation Report 8200-2A.
2. NERVA Components Irradiation Program Volume 8: GTR Test 10.
General Dynamics - Fort Worth Report FZK-170-8.