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NON-NUCLEAR EVALUATION
OF THE WIANCKO DEVELOPMENTAL ACCELEROMETER TYPE AX-44

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ABSTRACT

This report describes a series of tests which were conducted during the non-nuclear evaluation of the Wiancko developmental variable reluctance type accelerometer. The accelerometers were purchased as a system which included Wiancko electronics. As a system, the purchase specification was not met with respect to frequency response and temperature sensitivity. When used with Crescent-East electronics, good high temperature performance was obtained. The accelerometers are to be retained for use with this electronics system.

NON-NUCLEAR EVALUATION OF THE WIANCKO DEVELOPMENTAL ACCELEROMETER TYPE AX-44

1.0 INTRODUCTION

The object of this report is to describe the non-nuclear evaluation of the developmental type Wiancko AX-44 accelerometer. Two of these units were ordered in December 1963 and it was intended that Wiancko would be provided with performance feedback to be utilized in the design of deliverable hardware. As it turned out, delivery of the developmental units was delayed several times and orders were placed for the NRX-A3 deliverable hardware before the developmental units were fabricated. Delivery of the developmental units was not made until August 1964. Several design changes are being incorporated in the deliverable hardware as a result of the performance feedback now in effect. An improved variable reluctance accelerometer is expected to follow. Delivery time of the deliverable hardware is uncertain, however.

Inside the NRX pressure vessel, operation of the developmental AX-44 accelerometer is expected to be marginal, mainly because of internal heating. In certain applications outside the vessel, however, the unit is expected to operate satisfactorily and it is presently planned to install the two units on the NRX-A3 forward flange. This application will test the device in reduced level radiation and probably yield valid diagnostic data.

2.0 SYSTEM DESCRIPTIONS

2.1 Purchase Specification

The accelerometers and associated electronics were purchased as systems under WANL specification, "Specification for Accelerometers for Testing in Radiation and Cryogenic Environments" with modifications listed in Wiancko proposals B-8148 and B-8084. The most significant of the performance requirements are summarized below:

Range:	± 20 g's peak	
Frequency Response:	5 to 2000 cps. Output deviation from the 100 cps, 20 g output will be as follows for the various temperature range:	
	Frequency Response at	15-1000 cps 15-2000 cps
	-65 to + 200°F	$\pm 3\%$ $\pm 5\%$
	-320 to + 300°F	$\pm 5\%$ $\pm 8\%$
	-423 to + 700°F (Predicted)	$\pm 8\%$ $\pm 13\%$
Thermal Sensitivity Shift:	Not to exceed + 2% of the full range at 78°F from -65°F to + 200°F, by $\pm 4\%$ from -320 to + 300°F, and $\pm 10\%$ from -423°F to + 700°F. The -423°F values are predicted only, as Wiancko does not have test facilities for use at this temperature.	
Damping:	Helium gas. Damping factor of 0.5 at + 75°F and predicted 0.1 of critical damping at -423°F.	
Residual Unbalance:	$\pm 2\%$ F R at 75°F.	
Transverse Sensitivity:	.02 g/g to 200 cps.	
Ambient Pressure:	0 to 1000 psia.	
Radiation Resistance:	To 10^{19} nvt.	

2.2 Accelerometer

2.2.1 Mechanical Details

The Wiancko developmental type AX-44 accelerometer is a variable reluctance transducer requiring AC excitation and signal demodulation. Figure 1 is a 5/1 scale cutaway sketch of the sensing element. A single-degree-of-freedom mechanical system is provided by the mass loaded diaphragm configuration. The magnetic circuit of each coil is through its associated mu-metal pad which is welded to the mass. The instantaneous reluctances of the two magnetic circuits are related to the position of the mass which, in turn, is related to the input acceleration of the transducer frame. The Ni-Span C diaphragm is .004 inches thick and full scale displacement of the mass is 60 microinches. The coil bracket material is also Ni-Span C. Englehard CA9R and Sauereisen number 1 are used as bonding agents where required. The unit is filled with helium at one atmosphere pressure. The natural resonant frequency of the device is 4.4 kcs. Figure 2 is a photograph of the accelerometer which shows a section of the integral MgO insulated sheathed leads. The case material is 347 stainless steel. The total weight of the accelerometer is 154.25 grams.

2.2.2 Electrical Details

Referring again to Figure 1, the two coils consist of 340 turns each of AWG No. 41 ceramic insulated nickel-clad copper wire wound in the Ferroxcube ferrite cup cores. The coils are connected in series internally and three wires are brought out. Internally, the leads are insulated by ceramic beads. The input impedance of the transducer, which is the end-to-end coil impedance with demodulator connected, was measured at 10 kcs, 5 volts rms carrier level. The measured data are shown by Table I

PART	MATERIAL	QUANTITY	TOTAL WGT.(gms)
1. Diaphragm	Ni-Span C No. ANS5225	1	10.55
2. Spring	Ni-Span C No. AMS5225	2	1.00
3. Clamp	Ni-Span C No. AMS5225	2	3.70
4. Coil & Bracket	Ni-Span C No. AMS5225	2	13.00
5. Sleeve	Ceramic Beads Over AWG No. 26	3	
6. Ferroxcube	Ferrite	2	
7. Coils	Ceramic Insulated Nickel-Plated Wire		1.10 *
8. Mu Metal Pads		2	
9. Terminals	No. 347 Stainless Steel	3	

* Wire and cores

FIGURE 1
SENSING ELEMENT AX-44 ACCELEROMETER

FIGURE 2
DEVELOPMENTAL ACCELEROMETER WIANCKO TYPE AX-44
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TABLE I
Measured End-To-End Coil Impedance
Wiancko Developmental AX-44 Accelerometer
 (10 kcs - 5 volts, rms)

<u>Temperature ($^{\circ}$F)</u>	<u>Resistance (Ohms)</u>	<u>Impedance (Ohms)</u>
600	92.2	1380 /86.2 $^{\circ}$
500	84.8	1370 /86.5 $^{\circ}$
350	70.5	1300 /86.9 $^{\circ}$
75	46.7	1180 /87.7 $^{\circ}$
-320	9.7	720 /89.2 $^{\circ}$

The electrical resonant frequency of the transducer plus 160 inches of integral cable is 67.5 kcs.

In operation the coils form two arms of a bridge which is completed in the associated electronics. Unbalance in the coils, due to displacement of the mass is detected and amplified in the electronics.

2.2.2 Thermal Characteristics

A calculation of internal temperatures was performed by the WANL Radiation Effects Group. Three watts per gram gamma heating rate and 150 $^{\circ}$ F case temperature were assumed. Several of the calculated temperatures are indicated by Figure 3 which is a sketch of the model used for the calculations. The calculated temperature rise from device hot spot to case was 616 $^{\circ}$ F. The above boundry conditions correspond to PBR full power operation. The transducer will overheat in the Plum Brook reactor at full power.

FIGURE 3
INTERNAL TEMPERATURES
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2.3 Electronics

2.3.1 Wiancko, Type 56102

The Wiancko electronics package, type 56102 which was tailored for use with the AX-44 accelerometer, consists of a power supply, carrier generator, demodulator, and amplifier. The carrier frequency is set to approximately 15 kcs and no provision is made for external synchronization of the oscillator. The output impedance of the carrier generator is 1140 ohms; the demodulator input impedance is approximately 300 ohms. The amplifier rated output is 0-5 volts at 1500 ohms. About 12 millivolts of ripple voltage is present at the output.

Present plans are that the Crescent rather than Wiancko electronics will be used with the AX-44 accelerometer. The Wiancko electronics were tested, however, to determine performance characteristics of the system.

2.3.2 Crescent East, Type 9111

The Crescent East demodulator, types 9111 is a universal demodulator designed for use with variable reluctance and LVDT transducers. It is specified for NRX-A3 use. The package consists of a power supply, demodulator, and amplifier. The system requires carrier excitation at 5 to 10 volts rms through a frequency range of 3 to 10 kcs. The carrier is at approximately the impedance of the external generator. The demodulator input impedance is about 10 K ohms; the amplifier output is at 1000 ohms. The DC output level is adjustable from 0 to 10 volts. Approximately 3% noise is present in the output when connected to the Wiancko accelerometer. Since the Crescent system will be used in future NRX tests, it is planned now to use the AX-44 accelerometer with this carrier-demodulator system rather than the Wiancko electronics. Consequently, the AX-44 accelerometer-Crescent demodulator combination was used in most of the following tests.

3.0 PERFORMANCE TESTS

The Ling, 150 pounds force, Type RP-1/2 E-A280-3 vibration system was utilized in all vibration tests. Figure 4 shows a test specimen mounted on the shaker table of this system.

3.1 Wiancko Electronics

The Wiancko type 56102 electronics was utilized in all tests described in paragraphs 3.1.1 through 3.1.3 of this report.

3.1.1 Frequency Response

Measured frequency response data at three static temperatures are plotted in Graph 1. The data were normalized to the 100 cps output at 75°F. Temperature induced sensitivity shifts are therefore also indicated by this graph. At static temperatures within the -320°F to +500°F temperature range, the system is flat with respect to frequency to slightly over 500 cps and useable to about 1 kcs.

3.1.2 Linearity

Linearity data of the Wiancko accelerometer-Wiancko electronics system at 100 cps vibration are plotted in Graph 2. In this graph measured outputs were normalized with respect to the 75°F output. The vibration frequency was held constant at 100 cps and the accelerometer temperature was stabilized prior to data runs. System linearity, at static temperature, is excellent.

3.1.3 Temperature Shock

The unit was vibrated at 10 g's peak at 500 cps, at 75°F then suddenly immersed in LN₂ at (-)321°F. The vibration level and frequency were held constant. Relative sensitivity was measured as a function of time by a Visicorder plot.

FIGURE 4
WIANCKO DEVELOPMENTAL AX-44
ACCELEROMETER MOUNTED ON TEST SHAKER TABLE
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GRAPH 1
 FREQUENCY RESPONSE AT 10 g's
 WIANCKO ACCELEROMETER DEVELOPMENTAL AX-44
 WIANCKO ELECTRONICS

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The trace was scaled and the data were plotted in Graph 3. A thermocouple was implanted about 1/16 inch inside the case. The temperature at this point decreased to $(-)235^{\circ}\text{F}$ in 2.5 seconds and stabilized at $(-)320^{\circ}\text{F}$ in 50 seconds. A large temperature differential thus existed across the transducer hot spot and outside case during the first few minutes of the test. The long temperature time constant, shown by the graph, indicates that the integrated thermal resistance of the transducer, within the test temperature range, is relatively high.

3.2 Crescent-East Electronics

The Crescent-East type 9111 or 9112 demodulator-amplifiers were used in all tests discussed in paragraphs 3.2.1 through 3.2.6 of this report. The above-mentioned demodulator types are identical electrically except for the number of signal channels and were therefore used interchangeably, according to availability, during the following tests.

Although the AX-44 accelerometer was designed for 15 kcs, 12 volts rms excitation, tests were conducted to determine operational characteristics at reduced level 5 and 10 kcs excitations so as to comply with the Crescent capability and NRDS data system requirements. The tests indicated 10 kcs, 5 volts rms excitation to be optimum with respect to frequency and level. The excitation was set to these values during the following transducer tests.

3.2.1 Frequency Response

Frequency response data from the AX-44 accelerometer, Crescent demodulator system are plotted to different scales on Graphs 4 and 5. The response of serial number 70331 is shown by Graph 4; the response of 70332 is shown by Graph 5.

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In the graphs system outputs are normalized with respect to the 75°F, 100 cps, output. It was found that the sensitivity of SN 70331 could be changed by as much as 70 per cent by lightly tapping the case or by sweeping the vibration through the natural resonant frequency of the transducer while the transducer was undergoing temperature change. This unit was returned to the factory for diagnosis and rework. This effect was not observed in SN 70332. This unit, and the response curves shown by Graph 5, are therefore considered normal for the accelerometer type. The curves of Graph 4 are those of a defective unit and should be so considered.

Referring to Graph 5, the 75°F response peaks at 136 per cent at about 480 cps. The test fixture was evaluated carefully and no resonances were observed within the frequency bands discussed in this report. The peak in response results from the combined accelerometer-demodulator filter characteristic. This peak in response limits the system to a useful upper frequency of about 200 cps unless additional signal filtering is employed. The system output is down about 30 per cent at (-)320°F; performance at elevated temperatures, within the frequency limitations of the system, is exceptionally good.

3.2.2 Linearity

Accelerometer SN 70332 was vibrated at constant 100 cps. The vibration level was increased in steps to full scale then decreased in corresponding decrements. Linearity data are shown by Graph 6. In the graph all outputs are normalized with respect to the 75°F outputs. The accelerometer was soaked at temperature for 20 minutes prior to each data run.

3.2.3 Hysteresis

The measured g levels were approached first from the increasing then from the decreasing directions. The change in output was less than the resolution of the instrumentation.

3.2.4 Transverse Response

The transducer was accelerated in a direction perpendicular to the sensitive axis at 20 g 's peak and at room temperature. The transverse sensitivity was 0.23 % F R at 100 cps and 1.15 % F R at 25 cps.

3.2.5 Acoustic Noise

Acoustic noise sensitivity was measured at the Westinghouse Research and Development Center Acoustic Laboratory. The rms noise level was 140 db (Constant percentage bandwidth, 80 cps to 10 kcps). The demodulator was isolated from the noise field. The system response was not detectable in the 13 mv residual electrical noise. This precludes a quantitative analysis of noise sensitivity but a worst case, or upper limit, estimation can be based on the experiment. The acoustic noise voltage was more than 20 db below the electrical noise or it would have been detectable. The induced acoustic noise voltage was therefore less than 1.3 mv. Assume that it was 1.3 mv and that a linear scale up is legal. At 170 db SPL the worst case acoustic response would be 41 mv or 0.8 g 's.

3.2.6 Temperature Shock

The test unit was vibrated at 10 g 's peak at 100 cps at 75°F. It was then suddenly immersed in LN₂ at (-)320°F. The vibration level and frequency were held constant. A thermocouple was implanted in the case approximately 1/16 inch deep. The temperature at this point decreased to (-)235°F in 2.5 seconds. It stabilized at

(-320°F in 50 seconds. The measured accelerometer response is shown by Graph 8. In this graph percent output with respect to room temperature output is shown as a function of time.

4.0 DISCUSSIONS

4.1 Compliance to Purchase Specification

Neither of the Wiancko Electronics - AX-44 accelerometer systems meets the performance requirements of the purchase requisition with respect to frequency response and thermal sensitivity shift. The defective unit has been returned to Wiancko for repair. Performance of the repaired unit will be reported later. It is presently assumed that the performance of this unit, after repair, will be similar to that of the good unit.

Use of the accelerometers with the Crescent electronics will relieve Wiancko of the responsibility for meeting the purchase specification requirements. However, as will be discussed later, it is advisable to accept the units for use with Crescent electronics.

4.2 Application in Nuclear Environment

This type accelerometer has not yet been tested in radiation but it has been requested that the two units be tested on the NRX-A3 pressure vessel forward flange. Thermocouples will be implanted in the transducer cases. In this location a rough calculation indicates that the internal temperature rise will be less than 50°F. More precise heat transfer calculations will be made. This experiment is expected to test the variable reluctance principle and the materials used in radiation, provide

correlation between calculated and measured temperature rises in the device, and to provide diagnostic data. For these reasons it is expedient to accept the accelerometers for use with the Crescent electronics.

Inside the pressure vessel, at required acceleration measurement locations, a scale up of the previously mentioned computer calculation indicates a temperature rise in the transducer on the order of 800°F. It is felt that marginal performance, at best, would be obtained in these locations.

4.3 Temperature Shock Tests

During the first few minutes of the temperature shock test a large temperature gradient was generated between the accelerometer hot spot and outside case. Operation in a cold gas with radiation heating present was thus simulated. Referring to Figure 8, no spurious outputs occurred during the test but rather, gradual changes in sensitivity took place as internal temperature differentials decreased. Since the circuit configuration is relatively insensitive to corresponding changes in the two coils and the g loading was held constant, the changing output is attributed to changing displacement of the mass. During the first minute of the test the diaphragm frame was shrinking faster than the diaphragm and the displacement of the mass increased; during the subsequent part of the test the equivalent stiffness of the diaphragm increased and the displacement of the mass decreased. The process was complete in ten minutes.

5.0 CONCLUSIONS

The following conclusions result from evaluation of the AX-44 system.

1. The accelerometers should be used with the Crescent 9111 electronics with excitation set to 5 volts rms, 10 kcs. The useful frequency range of this combination can be extended from 200 to about 500 cps by appropriate signal filtering if this is required.
2. Performance of the system does not conform to the requirements of the purchase specification. It is recommended that the systems be accepted, however, and that the accelerometers be evaluated on the NRX-A3 forward flange.
3. The developmental accelerometer will indicate frequency properly in the NRX-A3 test and the probability that indicated acceleration data will be valid is good. The implanted thermocouples will provide a check of calculated temperatures.
4. The manufacturer has been assisted in the design of deliverable hardware through performance feedback from the developmental unit and through materials and design consultations. The problems of in-vessel operation, while not yet all solved, have been better defined. A greatly improved variable reluctance transducer is expected to result from work on the developmental model.