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TITLE: CALIBRATION SPECIFICATION FOR ACCELEROMETERS

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CALIBRATION SPECIFICATION FOR ACCELEROMETERS

1.0 SCOPE

This specification outlines the Westinghouse Astronuclear Laboratory (WANL) requirements for the calibration of all accelerometers used for reactor instrumentation.

2.0 PERFORMANCE OF TESTS

- 2.1 All calibrations will be performed by the Standards Laboratory and/or Sensor Application Engineering, per the requirements of this specification. The sequence of testing in accordance with this specification shall be performed first at room temperature. Any additional testing at various environmental conditions shall be determined by the cognizant Sensor Application Engineer, at the time of testing, per the particular transducer application.
- 2.2 The original data taken shall be kept by Sensor Application Engineering as a permanent record for the accelerometer. The data sheets shall be dated, signed by the technician and forwarded to the Sensor Application Engineer responsible for calibrations. The WANL Quality Control inspector will review and verify that the test conforms with the requirements of this specification.
- 2.3 Sensor Application Engineering shall be responsible for correlation of data and furnishing the calibration information in useable form for field and data reduction use.
- 2.4 No deletions, changes or omission of tests covered by this specification

shall be made without written approval of Sensor Application Engineering with the cognizance of Quality Engineering.

- 2.5 Additional tests or repetition of tests will be coordinated through Sensor Application Engineering.
- 2.6 The accelerometer will be acceptance tested and meet the requirements of the Quality Control inspection procedure before being calibrated.

3.0 REFERENCE DOCUMENTS

The following documents per their latest revisions are a reference for this specification. In any conflict between this specification and those documents paragraph 2.4 shall apply.

WANL-E-675453-A	Accelerometers, Variable Reluctance Type
WANL-E-675454	Transducer-Acceleration Linear Electro-Mechanical Servo Type
WANL-E-675397	Piezoelectric Accelerometers, Cold-Flow Test

4.0 TEST EQUIPMENT REQUIREMENTS

The following is a minimum list of test equipment needed to perform these tests. Additional and/or equivalent test equipment can be substituted if necessary.

Megohmmeter	test range, 50V DC to 500V DC
Impedance Bridge (RLC) (John Fluke)	
Charge Amplifier, Model 566 (Kistler, Inc.)	

Visicorder Oscillograph
(Minneapolis-Honeywell)

Power Supply, Model M-6.6-6.0
(Technipower, Inc.)

Cathode Follower, Type F460

Crescent-East Demodulator

Shaker Table and associated equipment

Power Supply, 28V DC	± 2 volts at 2MA
(Gulton Industries, Type LA64207)	

AC Excitation Source	voltage stability better than 0.1%
	frequency stability better than 1.0%

5.0 TEST REQUIREMENTS

- 5.1 Whenever possible the accelerometer should be calibrated through the same type of leads, demodulators, amplifiers, etc., that they will experience during reactor test. As in the case of variable reluctance transducers, the calibration should be performed with the same demodulator it will be used with throughout the test program.
- 5.2 For calibration of accelerometers, the following definitions apply.
 - 5.2.1 Calibration step - each voltage measurement recorded at a given input of acceleration for a given frequency.
 - 5.2.2 Calibration cycle - one operating range excursion of the accelerometer in the increasing and decreasing direction, consisting of all the calibration steps. The operating range shall be the assigned operational G-level for which the accelerometer will

be used in a particular application, as specified by the applicable drawing.

6.0 PRE-CALIBRATION MEASUREMENT

- 6.1 Record all applicable information, i.e. manufacturer, serial number, WANL part number, type of transducer, frequency range, acceleration range, etc. on the individually assigned WANL calibration data report form (see attachment).
- 6.2 Measure and record the input and output impedance of each accelerometer at each environmental condition. Record on the data sheet as $R + jX_L$. For piezoelectric type, measure and record output capacitance.
- 6.3 Using a 50 volt megohmmeter, measure and record the insulation resistance between all leads or terminals in parallel and the transducer case at each environmental condition.

7.0 CALIBRATION PROCEDURE

- 7.1 If applicable, install accelerometer in its associated mounting bracket.
- 7.2 Attach accelerometer to shaker test table with axis of accelerometer under test in line with axis of shaker table.
- 7.3 Electrically connect accelerometer to test system per attached block diagram, Fig. I, II or III.
- 7.4 Energize the test system, then set up the excitation voltage(s), where applicable, for the particular accelerometer being test. Allow approximately thirty (30) minutes warm-up, then reset any critical voltages.

- 7.4.1 For variable reluctance type, setup the demodulator by peaking the phase and adjusting zero and/or operating range output(s).
 - 7.4.2 For piezoelectric type, adjust the associated amplifiers and readout equipment for operating range output.
 - 7.4.3 For strain gage type, adjust associated excitation and readout equipment for zero and operating range output.
- 7.5 Perform first calibration run. First calibration run for all accelerometers shall always be performed at room temperature. An additional room temperature calibration run, as determined by the cognizant Sensor Application Engineer, may be required after an exceptionally severe environmental test has been performed.
- 7.5.1 With the accelerometer vibrating at 50% of its operating range, vary the frequency over the applicable frequency range. The G-level and frequency range shall be determined by the particular transducer application (i.e. specification control drawing, equipment specification and measurement list requirements). Measure this frequency response on a strip chart recorder.
 - 7.5.2 With the accelerometer vibrating at 100 cps, measure and record the output voltage at each step of each cycle. Each cycle of a calibration run for a particular accelerometer shall begin at 0% acceleration and increase to 100% of the operating range and return to 0%. Use 20% steps between 0% and 100% of the operating range.

8.0 POST-CALIBRATION CALCULATIONS

- 8.1 To determine the frequency response, calculate and record at room temperature the per cent of output voltage variation over a given input frequency range, at a given G-level. The G-level and frequency range shall be determined by the particular transducer application (i.e. specification control drawing, equipment specification and measurement list requirements).

$$\text{Frequency response, \%} = \left| \frac{E_R - E_M}{E_R} \right| \times 100$$

where; E_R = the voltage output measured at 100 cps.

$E_R - E_M$ = the maximum voltage output difference measured above or below the E_R over the frequency range.

- 8.2 Calculate and record, for each run, the error resulting from the effects to linearity and hysteresis. These errors shall be that percentage of variations of full range output taken from a straight line drawn through the calibration points over the full calibration range.

NOTE: To calculate linearity and hysteresis:

- (a) Determine the average output at each step for each run.
- (b) Subtract algebraically, when applicable, the average outputs resulting from 0% and 100% inputs. This resultant is the operating range sensitivity.
- (c) Determine the linear change in output by dividing full range output by the number of increasing even calibration

step. This determines the straight line between the 0% and 100% operating range output.

- (d) Determine the worst case of linearity and hysteresis from the straight line between 0% and 100% full range output. This can be one of two cases: (1) all points lie on one side of the straight line, and (2) the points lie on both sides of the straight line. The maximum voltage difference between the straight line and the hysteresis curve (1), or the maximum voltage difference between the increasing and decreasing hysteresis curve (2), is the worst case of linearity and hysteresis. This maximum voltage difference is designated as L.

(e) Linearity and hysteresis, $\%OR = \frac{L}{2(S)} \times 100$

where; OR = operating range in volts as determined at 8.2(b).

S = sensitivity at a particular environmental calibration run.

- 8.3 To determine the transverse response, calculate and record from the calibration curve, established at 7.5.2, the output in G's resulting from vibration of the accelerometer in the transverse direction.

$$\text{Transverse response} = \frac{\text{output G's}}{\text{input G's}}$$

- 8.4 To determine residual unbalance, calculate and record for each run the average output observed at zero acceleration.

8.4.1 Residual unbalance, $\%OR = \frac{RU}{OR} \times 100$

where; RU = residual unbalance in volts.

OR = operating range in volts as determined at 8.2(b).

- 8.5 To determine the thermal zero shift, calculate the average of the output voltages recorded at 0% input at each calibration temperature.

$$8.5.1 \quad \text{Thermal zero shift, \%OR/}^{\circ}\text{F} = \frac{V_{RT} - V_T}{OR(T_{RT} - T_T)} \times 100$$

where; OR = operating range in volts as determined at 8.2. (b).

V_{RT} = residual unbalance at room temperature.

V_T = residual unbalance at test temperature.

T_{RT} = room temperature.

T_T = test temperature.

- 8.6 To determine the thermal sensitivity shift, calculate the sensitivity at each calibration temperature.

$$8.6.1 \quad \text{Thermal sensitivity shift, \%}^{\circ}\text{F} = \frac{S_{RT} - S_T}{S_{RT}(T_{RT} - T_T)} \times 100$$

where; S_{RT} = sensitivity at room temperature.

S_T = sensitivity at test temperature.

T_{RT} = room temperature.

T_T = test temperature.

- 8.7 Calculate and record the sensitivity for each run. Sensitivity is the average output voltage change observed resulting from one hundred per cent (100%) change of input acceleration. (Subtract algebraically the average outputs for 0% and 100% inputs.)
- 8.8 To determine the repeatability, calculate and record, in % operating range the maximum deviation from the average value of the three continuous full excursions under identical conditions, i.e., for each run establish the maximum output voltage difference between cycles at each calibration step.

8.8.1 Repeatability, $\%OR = \frac{M}{2S} \times 100$

where; OR = operating range in volts as determined at 8.2(b).

M = maximum output voltage difference between
cycles at a calibration step for the given run.

S = sensitivity.

CALIBRATION DATA REPORT-TRANSDUCER, TYPE _____

WESTINGHOUSE FORM 59447

SHEET 2

NO. _____

MANUFACTURER _____

WANL E-SPEC NO. _____

MANUFACTURER SERIAL NO. _____

MANUFACTURER MODEL NO. _____

DATE _____

WANL PART NO. _____

A. INDICATE TYPE AND ACCURACY OF PHYSICAL TEST STIMULUS

HEISE GAGE ☐

PNEUMATIC DEAD WEIGHT TESTER ☐

(SPECIFY) OTHER _____

SERIAL NUMBER _____ ACCURACY _____ %

B. INDICATE TYPE AND ACCURACY OF TRANSDUCER OUTPUT READOUT INSTRUMENTATION

TYPE _____ SERIAL NUMBER _____ ACCURACY _____ %

C. INDICATE TYPE AND ACCURACY OF TRANSDUCER EXCITATION SOURCE

TYPE _____ SERIAL NUMBER _____ ACCURACY _____ %

D. INDICATE PRESSURE TRANSDUCER TYPE AND HOOK-UP

FIG. 1 ☐

STRAIN GAGE

FIG. 2 ☐

VARIABLE RELUCTANCE

FIG. 3 ☐

LVDT

FIG. 4 ☐

OTHER _____

E. INDICATE STRAIN GAGE TYPE AND HOOK-UP

FIG. 1 ☐

FULL BRIDGE

FIG. 2 ☐

HALF BRIDGE

FIG. 3 ☐

QUARTER BRIDGE

* NOTE: INDICATE WHICH IS ACTIVE AND DUMMY AND POLARITY OF EACH LEAD.

F. INDICATE ACCELEROMETER TYPE AND HOOK-UP

FIG. 1 ☐

PIEZOELECTRIC

FIG. 2 ☐

ELECTRO-MECHANICAL

G. DISPLACEMENT (LVDT) HOOK-UP

H. NOTES

SAMPLE COPY

WESTINGHOUSE FORM 59446

NO.

CALIBRATION DATA

SAMPLE COPY

NOTE: MEASUREMENTS MADE WITH _____ AMPLIFIER, WITH GAIN OF _____ AND _____ INPUT IMPEDANCE, LENGTH OF TEST CABLE _____ FEET.

CALIBRATION TEST STANDARD	CALIBRATION FACTOR
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REMARKS:

STANDARDS ACCEPTANCE

DATE _____

QUALITY CONTROL ACCEPTANCE

DATE _____

FIG. I
VARIABLE RELUCTANCE TYPE

FIG. II
ELECTRO-MECHANICAL AND STRAIN GAGE TYPE

FIG. III
PIEZOELECTRIC TYPE