ISA-S37.5-1982 (R1995)

Approved September 29, 1995

Standard

Specifications and Tests for Strain Gage Linear Acceleration Transducers

ISA-S37.5 — Specifications and Tests for Strain Gage Linear Acceleration Transducers

ISBN 0-87664-379-9

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Preface

This preface, as well as all footnotes and annexes, is included for informational purposes and is not part of ISA-S37.5.

This standard has been prepared as a part of the service of ISA, the international society for measurement and control, toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive; P.O. Box 12277; Research Triangle Park, NC 27709; Telephone: (919) 549-8411; Fax: (919) 549-8288; E-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards, recommended practices, and technical reports. The Department is further aware of the benefits to USA users of ISA Standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Towards this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std. 268-1992, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

It is the policy of ISA to encourage and welcome the participation of all concerned individuals and interests in the development of ISA standards, recommended practices, and technical reports. Participation in the ISA standards-making process by an individual in no way constitutes endorsement by the employer of that individual, of ISA, or of any of the standards, recommended practices, and technical reports that ISA develops.

This standard is intended as a guide for technical personnel at user facilities as well as by manufacturers' technical and sales personnel whose duties include specifying, calibrating, testing or showing performance characteristics of strain-gage linear accelerometers. By basing users' specifications as well as technical advertising and reference literature on this standard, or by referencing portions thereof, as applicable, a clear understanding of the users' needs or of the transducers' performance capabilities, and of the methods used for evaluating or proving performance, will be provided. Adhering to the specification outline, terminology and procedures shown will not only result in simple, but also complete specifications; it will also reduce design time, procurement lead time, and labor, as well as material costs. Of major importance will be the reduction of qualification tests resulting from use of a commonly accepted test procedure and uniform data presentation.

The development of this Standard was initiated as the result of a survey conducted in December 1960. A total of 240 questionnaires was sent out to transducer users and manufacturers. A strong majority indicated in their replies a need for transducer standardization. As strain-gage acceleration transducers were one of the types shown to be most in need of standardization, a Subcommittee, 8A-RP37.5, was formed under the former Survey Committee on Transducers for Aerospace Testing, 8A-RP37. Subcommittee 8A-RP37.5 became Standards Committee SP37.5 when the scope of the committee's work was broadened to include the applications of these transducer types by all industries and sciences. To provide a coordinated document, this committee was composed of representatives from government, user, and manufacturer categories. This Standard was then processed over several mail-review and revision cycles until a consensus of reviewers was reached, and it was published as ISA Standard in 1971. It was approved as ANSI Standard MC 6.3-1975 in October 1975.

The assistance of those who aided in the preparation of this document by answering questionnaires, offering suggestions, and in other ways, is gratefully acknowledged.

The following individuals served as members of the 1975 SP37.5 committee:

NAME	COMPANY
L. L. Lathrop, Chairman (1965-71)	Sandia Laboratories
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J. S. Hilten, Chairman (1971-)	National Bureau of Standards
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The following individuals served on the ISA Committee SP37, who reaffirmed ISA-S37.5 in 1995:

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C. Williams	Eastman Kodak Company
G. Wood	Graeme Wood Consulting
M. Zielinski	Fisher-Rosemount

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1 Scope

1.1 This Standard covers uni-directional and bi-directional strain-gage linear acceleration transducers.

1.2 Included among the specific types of strain-gage linear acceleration transducers for which this Standard is applicable, are the following:

Bonded, unbonded, deposited metallic, or semiconductor strain gages.

1.3 Terminology used is defined in either ISA-S37.1, *Electrical Transducer Nomenclature and Terminology* or in 4.3, Additional Terminology, of this Standard. An asterisk appears after those terms defined in ISA-S37.1; a double asterisk appears after those terms defined in this Standard.

2 Purpose

This Standard establishes the following for strain-gage linear acceleration transducers:

a) Uniform minimum specifications for design and performance characteristics

b) Uniform acceptance and qualification test methods, including calibration techniques

c) Uniform presentation of minimum test data

d) A drawing symbol for use in electrical schematics (see Note in Section 3)

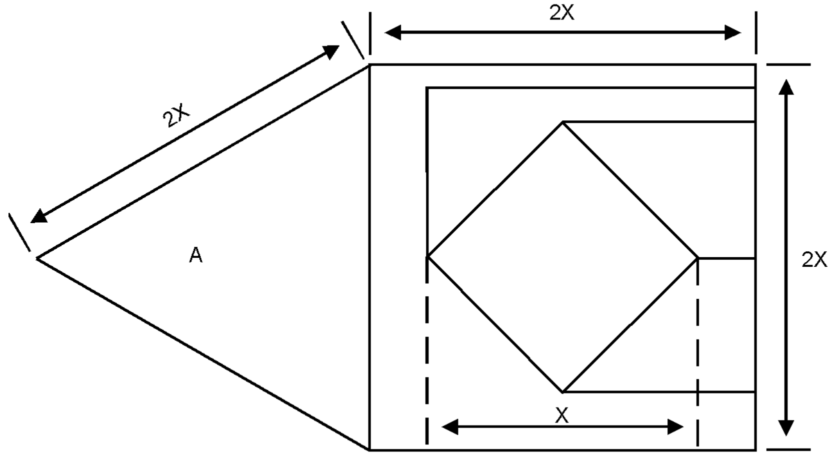
3 Uniform drawings and symbols

3.1 Drawing symbol

The electrical diagram symbol for a linear strain-gage acceleration transducer is a square of dimensions 2x by 2x, with an added equilateral triangle, the base of which is the left side of the square. The triangle symbolizes the sensing element. The letter "a" in the triangle designates linear (rectilinear) acceleration.

NOTE — Angular acceleration is designed by the Greek letter alpha (α).

The strain gage bridge is symbolized by a small square, with diagonals x by x, centered in the large square. The diagonals of the small square are drawn perpendicular to the sides of the large square. Lines from each apex of the small square projected to the right side of the large square represent the electrical leads.



NOTE — This symbol is not ANSI approved at this time. It has been submitted to the ANSI Y32 Committee on Graphic Symbols for their consideration and approval.

3.2 Outline drawings

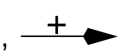
Orthogrographic projection outline drawings, with tolerances should include the following information:

a) The outline dimensions

b) The location and size of the mounting holes

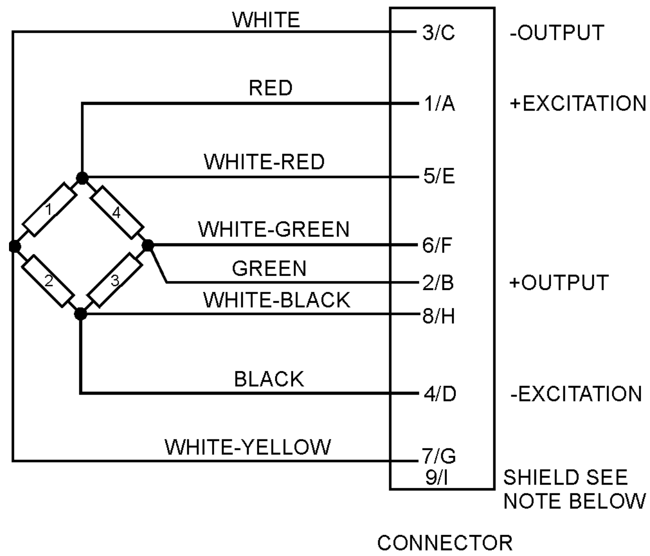
c) The identification and location of the electrical connections; where a commercial connector is used, it and the mating connector should be identified

d) The location of the center of the seismic mass (using the following symbol, )

e) The direction and polarity of the sensitive axis (using the following symbol,  , to indicate the direction in which the case must be accelerated to produce a positive electrical output) (see 4.1.1.3, Identification, and 4.1.3.6, Polarity of Electrical Output).

3.3 Electrical connections

Whether the electrical termination is by means of a connector or a cable, the pin designations or wire color code shall conform to the following transducer wiring standard promulgated by the Western Regional Strain Gage Committee, as approved September 18, 1957, and revised May 6, 1960.



NOTES

1. The bridge elements shall be arranged so that functions producing positive electrical output will cause increasing resistance in arms 1 and 3 of the bridge.

2. For shielded transducers, pins 5, 7, and 9 shall be shield terminals for 4, 6, and 8 wire systems respectively.

4 Specification characteristics

4.1 Design characteristics

4.1.1 Basic mechanical design characteristics

4.1.1.1 Dimensions

Drawings giving dimensions (as well as other information) shall be provided as described in 3.2, Outline Drawings. Dimensions shall be given in millimeters (inches).

4.1.1.2 Mass

The mass of the transducer shall be given in grams (ounces).

4.1.1.3 Identification

The following characteristics shall be permanently inscribed on the outside of the transducer case or on a suitable nameplate permanently attached to the case:

a) Nomenclature of the transducer per ISA-S37.1, Electrical Transducer Nomenclature and Terminology (see 3, Nomenclature).

b) Name of the manufacturer

c) Model or part number

d) Serial number

e) Range

f) Excitation

g) Identification of electrical connections

h) Direction and polarity of the sensitive axis (see 3.2, Outline Drawings)

i) (Optional) Customer specification or part number

j) (Optional) Temperature range

k) (Optional) Input and output impedance

l) (Optional) Approximate sensitivity

m) (Optional) Marking "delicate instrument"

4.1.1.4 Temperature range

The following temperature ranges shall be listed in °Fahrenheit or °Celsius

a) The operating or compensated temperature range*

b) The usable temperature (if the accelerometer can be used beyond the compensated temperature range)

c) The maximum (minimum) ambient temperature range* (storage temperature range)

4.1.2 Supplemental mechanical design characteristics

Listing of the following mechanical design characteristics is optional.

4.1.2.1 Type of strain gage

For example: metallic or semiconductor; bonded, unbonded, or diffused.

4.1.2.2 Location of strain gage

For example: strain gages attached to the cantilevers supporting the seismic mass; strain gages attached between the seismic mass and the transducer case. Indicate method of attachment.

4.1.2.3 Number of active strain gage elements

For example: two-arm bridge; four-arm bridge.

4.1.2.4 Damping

Specify type of damping (pneumatic, magnetic, or fluid); also, if fluid damping is used, specify type and characteristics of fluid.

4.1.2.5 Movement of the seismic mass with acceleration

Approximate displacement in millimeters (inches) of the seismic mass due to full scale acceleration.

4.1.2.6 Mechanical stops

The location of the stops relative to the range of the transducer.

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*Defined in ISA-S37.1

4.1.3 Basic electrical design characteristics

These characteristics are applicable at 24 ± 3°C (75 ± 5°F).

4.1.3.1 Excitation*

Expressed as ____ volts (milliamperes) dc; or ____ volts (milliamperes) ac rms at ____ Hz.

4.1.3.2 Maximum excitation*

Expressed as ____ volts (milliamperes) dc; or ____ volts (milliamperes) ac rms at ____ Hz.

4.1.3.3 Input impedance*

Expressed as ____ ±____ ohms at ____ ± ____ Hz; or ____ ± ____ ohms (dc).

4.1.3.4 Output impedance*

Expressed as ____ ± ____ ohms at ____ ± ____Hz; or____ ± ____ ohms (dc).

4.1.3.5 Electrical connections

Electrical connections shall be made as described in 3.3, Electrical Connections.

4.1.3.6 Polarity of electrical output

A positive output is produced by applying a positive acceleration to the case of the accelerometer. (See 3.2, Outline Drawings(5), and 3.3, Electrical Connections.)

4.1.3.7 Insulation resistance*

Expressed as ____ megohms, minimum, at ____ volts dc between all terminals in parallel and the transducer case.

4.1.3.8 Shunt calibration resistor**

(Optional) Expressed as ___ ohms for___ % of full scale output.

NOTE — The circuit arrangement shall be defined.

4.1.3.9 Interference

The design characteristics incorporated in the accelerometer construction to minimize any radio frequency interference or electromagnetic interference signals being induced into the transducer or generated by the transducer by either conduction or radiation shall be described.

4.1.3.10 Load impedance*

Performance characteristics values apply only for load impedance values of ____ ohms, minimum or ____ ± ____ ohms.

4.2 Performance characteristics

The pertinent performance characteristics of strain gage accelerometers should be tabulated in the order shown. Unless otherwise specified they apply at 24 ± 3°C (75 ± 5°F); Relative Humidity, 90% maximum; Barometric Pressure, 73 ± 7 cm Hg (29 ± 3 inches Hg).

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*Defined in ISA-S37.1
**Defined in 4.3, Additional Terminology

4.2.1 Range*

Expressed as ± ____g or ____ g to ____ g.

NOTE — The standard g shall be considered to be 9.806650 meters/s^2 (32.17405 ft/s^2. The SI unit of acceleration is the meter per second squared (m/s^2).

4.2.2 Acceleration overload*

Expressed as ± ____ g or____ g to ____ g (see 4.2.1, Range).

4.2.3 End points*

Expressed as ____ ± ____mV and ____ ± ____mV at ____ volts (milliamperes) excitation.

4.2.4 Full-scale output*

Expressed as ____ ± ____ mV per volt (milliampere) excitation; or ____ ± ____mV at ____ volts (milliamperes) excitation.

NOTE — At the specified load impedance.

4.2.5 Zero-measurand output*

Expressed as ____ ± ____ mV per volt (milliampere) excitation; or ____ ± ____ mV at ____volts (milliamperes) excitation.

NOTE — At the specified load impedance.

4.2.6 Linearity*

Expressed as ____ linearity within ± ____% of full scale output.

NOTE — The type of linearity specified shall be one of the straight line types defined in ISA-S37.1; namely, end point, independent, least squares, terminal, or theoretical slope.

4.2.7 Hysteresis*

Expressed as ____% of full scale output. Alternately 4.2.6 and 4.2.7 may be combined as 4.2.8.

4.2.8 Hysteresis and linearity*

Expressed as combined hysteresis and linearity within ± ____ % of full scale output.

NOTE — The type of linearity shall be stated (see 4.2.6, Linearity).

4.2.9 Repeatability*

Expressed as within ____% of full scale.

4.2.10 Stability*

Expressed as within ____% of full scale output over a period of ____ (hours, days, months). Alternately 4.2.6, 4.2.7, 4.2.9, and 4.2.10 may be combined as 4.2.11.

4.2.11 Static error band*

Expressed as ± ____% of full scale output as referred to ____ line.

NOTE — See ISA-S37.1 for listing of reference lines. The calibration cycle(s) used to establish this reference line shall be clearly identified. A least squares or end point line is preferred.

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*Defined in ISA-S37.1

4.2.12 Warmup period*

Expressed as ____minutes for subsequent sensitivity shift and zero shift not to exceed ____% of full scale output, or for the static error band not to be exceeded.

4.2.13 Output regulations*

Expressed as sensitivity shift of ± ____% for a change in bridge excitation of ±10%; zero balance (mV/V) variation of ± ____% full scale for a change in bridge excitation of ± 10%.

4.2.14 Frequency response*

Expressed as output within ± ____% of the output obtained in a static calibration or at a stated reference frequency over a frequency range from ____ Hz to ____ Hz at a temperature of ± ____ °C(°F).

4.2.15 Natural frequency and damping ratio (alternate)*

The natural frequency and damping ratio shall be expressed as ____ ± ____ Hz and ____ ± ____ of critical damping respectively when the instrument temperature is ____ ± ____ °C(°F).

NOTE — At f_n a phase shift of 90 degrees will be observed between the input acceleration and the output signal.

4.2.16 Phase shift**

Expressed as phase shift linear within ± ____ degrees from zero Hz to ____ Hz.

4.2.17 Temperature error*

Expressed as temperature from ____ °C(°F) to ____ °C(°F) which will not cause a sensitivity shift of more than ____% or zero shift of more than ____% of full scale output. Alternately the following may be specified (4.2.18 and 4.2.19):

4.2.18 Thermal sensitivity shift for static acceleration*

Expressed as ____ % per ____ °C(°F) temperature change over a temperature range from ____ °C(°F) to ____ °C(°F).

4.2.19 Thermal zero shift for static acceleration*

Expressed as ____% of full scale output ____ °C(°F) temperature change over the temperature range from ____ °C(°F) to ____ °C(°F). Alternately sections 4.2.17, 4.2.18, and 4.2.19 may be specified by:

4.2.20 Temperature error band for static acceleration*

Expressed as output values are within ± ____% of full scale output from the straight line or curve establishing the static error band, over temperature range from ____ °C(°F) to ____ °C(°F).

4.2.21 Temperature gradient error for static acceleration*

Expressed as less than ± ____% of full scale output while subjected to a step function temperature change from ____ °C(°F) to ____ °C(°F), lasting for ____ minutes and applied to ____ (specify particular part of the transducer).

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*Defined in ISA-S37.1

**Defined in 4.3, Additional Terminology

4.2.22 Proof transverse acceleration (static)**

Expressed as, shall withstand transverse static accelerations of ____ g.

4.2.23 Proof transverse acceleration (vibrational)**

Expressed as, shall withstand transverse vibrational acceleration of ____ g over a frequency range of ____to ____ Hz.

4.2.24 Transverse sensitivity (static)*

Expressed as a maximum of ____% of the accelerometer sensitivity for a transverse acceleration of ____ g.

4.2.25 Transverse sensitivity (compound, static)

(Optional) Expressed as a maximum of ____% of the accelerometer sensitivity for a transverse acceleration component of ____ g and a sensitive axis acceleration component of____ g.

4.2.26 Transverse sensitivity (vibrational)

Expressed as a maximum of ____% of the accelerometer sensitivity for a transverse vibrational acceleration of ____ g and covering a frequency range of ____Hz to ____Hz.

4.2.27 Transverse sensitivity (compound, vibrational)

(Optional) Expressed as a maximum of ____% of the accelerometer sensitivity for a transverse acceleration component of ____ g and a sensitive axis acceleration component of____ g and covering a frequency range of ____Hz to ____Hz.

4.2.28 Alignment of the sensitive axis

Expressed as within ± ____ degrees as referenced to the mounting surface.

4.2.29 Damping integrity**

(Optional) Expressed as no error in the predicted output greater than ____% of full scale output (or Response Ratio) due to changes in accelerometer attitude (position relative to the field of gravity).

4.2.30 Storage life

Expressed as ____ months (years) without changing performance characteristics beyond specified tolerances.

NOTE — Environmental storage conditions shall be described in detail.

4.2.31 Life, cycling*

Expressed as _____ full range cycles over which the transducer shall operate without change in characteristics beyond their specified tolerances.

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*Defined in ISA-S37.1
**Defined in 4.3, Additional Terminology

4.2.32 Other conditions

Other pertinent conditions which shall not change transducer performance beyond specified limits should be listed. Examples are:

Humidity	High Level Acoustic Excitation
Salt Atmosphere	Explosive Atmosphere
Nuclear Radiation	Magnetic Fields
Shock	Sand and Dust
Over Range	Total Immersion (and in what medium)
Fungus Resistance	Solar (or other) Heat Radiation
Ambient Pressure (Altitude)	

4.3 Additional terminology

4.3.1 phase shift: The phase angle by which the output of a transducer lags a sinusoidal varying measurand.

NOTE — Expressed as a fraction of a cycle of the frequency, usually in degrees, or radians.

4.3.2 shunt calibration resistor: A shunt resistor which, when placed across specified points of the electrical circuit of the transducer, will electrically simulate a specified percentage of the full scale output of the transducer at room conditions.

4.3.3 damping integrity: The ability of the accelerometer to produce a predicted output, with no transients, during or after changes in the attitude of the transducer, due to bubbles, contamination, etc.

4.3.4 proof transverse acceleration (static): The maximum transverse static acceleration that can be applied without causing permanent degradation in performance beyond specified tolerance.

4.3.5 proof transverse acceleration (vibrational): The maximum transverse dynamic acceleration(s) over a specified frequency range(s) that can be applied without causing permanent degradation in performance beyond specified tolerances.

4.4 Tabulated characteristics versus test requirements

This table is intended for use as a quick reference for design and performance characteristics and test of their proper verification as contained in this standard.

Characteristic	Paragraph	Basic Design Characteristics	Optional Design Charateristics	Verified During	
				Acceptance Test	Qualification Test
Dimensions	4.1.1.1	x		5.2.1	
Weight	4.1.1.2	x		No Test	
Identification	4.1.1.3	x		5.2.1	
Temperature Range	4.1.1.4	x		No Test	
Type of Strain Gage	4.1.2.1		x	No Test	
Location of Strain Gage	4.1.2.2		x	No Test	
Number of Active Strain Gage Elements	4.1.2.3		x	No Test	
Damping Fluid	4.1.2.4		x	No Test	
Movement of the Seismic Mass with Acceleration	4.1.2.5		x	No Test	
Mechanical Stops	4.1.2.6		x	No Test	
Excitation	4.1.3.1	x		No Test	
Maximum Excitation	4.1.3.2	x		No Test	
Input Impedance	4.1.3.3	x		5.2.2	
Output Impedance	4.1.3.4	x		5.2.2	
Electrical Connection	4.1.3.5	x		5.2.1	
Polarity of Electrical Output	4.1.3.6	x		5.2.4, 5.2.5	
Insulation Resistance	4.1.3.7	x		5.2.3	
Shunt Calibration Resistor	4.1.3.8		x	No Test	
Interference	4.1.3.9	x		No Test	
Load Impedance	4.1.3.10	x		No Test	
Range	4.2.1	x		5.2.4, 5.2.5	
Acceleration Overload	4.2.2	x			6.16
End Points	4.2.3	x		5.2.4, 5.2.5	
Full Scale Output	4.2.4	x		5.2.4, 5.2.5	
Zero Measurand	4.2.5	x		5.2.4, 5.2.5	
Linearity	4.2.6	x		5.2.4, 5.2.5	
Hysteresis	4.2.7	x		5.2.4, 5.2.5	
Hysteresis and Linearity	4.2.8	x		5.2.4, 5.2.5	
Repeatability	4.2.9	x		5.2.4, 5.2.5	
Stability	4.2.10	x		5.2.4, 5.2.5	6.17
Static Error Band	4.2.11	x		5.2.4, 5.2.5	
Warmup Period	4.2.12	x			6.2
Output Regulation	4.2.13	x			6.3
Frequency Response	4.2.14	x			6.4
Natural Frequency and Damping Ratio (alt.)	4.2.15	x			6.4
Phase Shift	4.2.16	x			6.4
Temperature Error	4.2.17	x			6.5
Thermal Sensitivity Shift	4.2.18	x			6.5
Thermal Zero Shift	4.2.19	x			6.5
Temperature Error Band	4.2.20	x			6.5
Temperature Gradient Error	4.2.21	x			6.7
Proof Transverse Acceleraton (Static)	4.2.22	x			6.8
Proof Transverse Acceleration (Vibrational)	4.2.23	x			6.9
Transverse Sensitivity (Static)	4.2.24	x			6.10
Transverse Sensitivity (Compund Static) (Optional)	4.2.25		x		6.11
Transverse Sensitivity (Vibrational)	4.2.26	x			6.12
Transverse Sensitivity (Compound Vibrational)	4.2.27		x		6.13
Alignment of the Sensitive Axis	4.2.28	x			6.14
Damping Integrity	4.2.29		x		6.15
Storage Life	4.2.30	x			6.19
Life Cycling	4.2.31	x			6.18
Other Conditions	4.2.32	x		No Test	6.20

5 Individual acceptance tests and calibrations

5.1 Basic equipment necessary to perform individual acceptance tests and calibrations of strain gage linear accelerometers

The basic equipment for acceptance tests and calibration consists of a source of acceleration, a monitored source of electrical excitation and a device which measures the electrical output of the transducer. The cumulative errors and uncertainties of the measuring system comprising these components should be less than 1/10, where feasible, of the permissible tolerance of the transducer performance characteristic under evaluation. The traceability to the national standards for this measuring system should be well known.

5.1.1 Source of acceleration

The range of the instrument supplying or monitoring the calibration acceleration should be selected to provide the necessary accuracy to 125% of the full scale range of the transducer. The source of calibration signal may be either continuously variable over the range of the instrument or provided in discrete steps. The steps must be programmed in such a manner that the transition from one value of acceleration to the next value of acceleration is accomplished without overshoot. Typical accelerometer calibrating devices are as follows.

5.1.1.1 Earth's field static calibrator

Range 0 g to ± 1 g.
Accuracy*

5.1.1.2 Centrifuge static calibrator

Typical Range, 0.1 g to 1000 g.
Accuracy*

5.1.1.3 Electromagnetic shaker calibrator

Typical Range, up to 100 g (except as limited by displacement, velocity, and table weight), 5 Hz to 10,000 Hz, 1.3 cm (0.5 inch) double amplitude.

Accuracy*

5.1.2 Stable source of excitation

Commonly used sources are primary and secondary batteries, such as dry cells, and storage batteries or line-powered, electronically regulated power supplies.

5.1.3 Read-out instrument

Examples of suitable devices are as follows.

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*Conservative, obtainable accuracies of the applied calibration acceleration are shown below; they are taken for illustrative purposes from the NBS Miscellaneous Publication #250, 1965, entitled "Calibration and Test Services." Static calibration in the earth's field, error no greater than 0.001 g. Static calibration on a centrifuge, error no greater than 0.2% of the applied acceleration. Dynamic calibration on an electromagnetic shaker, error no greater than 1% of the applied acceleration.

5.1.3.1 Manually balanced potentiometer

Typical range: 0 to 11 mV, ± (0.008% ± 0.5 μV) limit of error; 0 to 111 mV, ± (0.006% ± 1 μV) limit of error; 0 to 1.111 V ± (0.004% ± 10 μV) limit of error; 0 to 11.110 V, ± (0.006% ± 100 μV) limit of error.

5.1.3.2 Self balancing potentiometer

Typical Range, 0 to 6 mV, limit of error ± 0.3%; 0 to 100 mV, limit of error ± 0.3%

5.1.3.3 Digital electronic voltmeter

Typical ranges, ± 10 mV ± 0.01% of the reading and ± 0.01% full scale; ± 100 mV or ± 1000 mV, ± 0.02% of the reading and ± 0.002% full scale.

NOTE — The input impedance of the readout instrument should be as high as possible and shall be in compliance with the load impedance specified for the transducer.

5.2 Calibration and test procedures

Results obtained during the calibration and test procedures should be reported on data sheets similar to the sample data sheet, Figure 1. These procedures shall be performed at 24 ± 3°C (75 ± 5°F) unless otherwise indicated.

5.2.1 Visual inspection

The transducer shall be inspected visually for mechanical defects, poor finish, improper dimensions and improper identification markings. The electrical connector shall also be inspected.

5.2.2 Impedance measurement

A Wheatstone bridge (or other type bridge) shall be used to measure the input and output impedances of the instrument. See 4.1.3.3 and 4.1.3.4.

5.2.3 Insulation resistance

Measure the insulation resistance between all transduction element terminals (or leads) connected in parallel and the case (and ground pin) of the transducer with a megohmmeter or similar acceptable device, using a potential of 50 volts dc, unless otherwise specified.

5.2.4 Earth's field static calibration

The transducer shall be attached to an earth's field static calibrator. The excitation source and readout instrument shall be connected to the transducer and turned on. Adequate warmup time for the test equipment and instrument shall be allowed before tests are conducted.

NOTE — The earth's field calibration may be waived if the range of the instrument is so high that the ± 1 g calibration will not yield useful information. Two or more calibration cycles shall be run consecutively. If the range of the instrument is greater than ± 1 g the calibration cycle shall consist of at least the ± 1 g, 0 g, and –1 g points; if the range of the instruments is ± 1 g or less, the calibration cycle shall consist of a minimum of nine equally spaced data points. This calibration cycle shall include both ascending and descending directions, and, in the case of bi-directional accelerometers, both positive and negative accelerations. For example, a ±1 g instrument would be tested at the following points: 1 g, 0.5 g, 0 g, –0.5 g, –1 g, –0.5 g, 0 g, 0.5 g, and 1 g. (See Lederer and Hilten reference.)

or's Part No. ____________ User's Part No. ____________ Serial No. ____________

Range ____________ g Excitation Voltage ____________ volts

Visual Inspection:

Mechanical ☐ Finish ☐ Dimensions ☐ Identification ☐ Electrical Connectors ☐

Input Impedance: ____________ ohms

Output Impedance: ____________ ohms

Insulation Resistance: ____________ megohms at ____________ volts dc

and 5.2.5 Static Calibration:

Temperature ____________ °C(°F) Acceleration Source ____________ Radius ____________ mm (in.)

				Run #1							Run #2				Max Error	
				+ Accel		- Accel					+ Accel		- Accel		+	-
	rps	Accel g	Theo. Output	E_omV	Dev	E_omV	Dev	rps	Accel g	Theo. Output	E_omV	Dev	E_omV	Dev		
FIELD		+1							+1							
		0							0							
		–1							–1							
CENTRIFUGE																

End Points: ________ and ________ mV (1); ________ and ________ mV (2)

Full Scale Output: ________ mV (1); ________ mV (2)

Zero Measurand Output: ________ mV (1); ________ mV (2)

Linearity: ± ______ % FSO (maximum)

Hysteresis: ______ % FSO (maximum)

Repeatability: ______ % FSO

Static Error Band: + ______ % and – ______ % FSO

Above referred to: ____________ reference line or curve

Allowed

Figure 1 — Acceptance test and calibration record, strain gage accelerometer

5.2.5 Static calibration on the centrifuge

5.2.5.1 Incremental

The transducer shall then be attached to a centrifuge; the excitation source and readout instrument shall be connected to the transducer and turned on. Adequate warmup time for the test equipment and instrument shall be allowed before tests are conducted.

NOTE — The centrifuge calibration may be waived if the range of the instrument is ± 1 g or less.

Two or more complete calibration cycles shall be run on the instrument in the centrifuge. A complete calibration shall include both ascending and descending directions and in the case of bi-directional accelerometers, both positive and negative accelerations. It will include a minimum of nine equally spaced points. For example, a ± 4 g instrument would be tested at the following points: 0 g, 2 g, 4 g, 2 g, 0 g, (and then reversing the instrument on the centrifuge) –2 g, –4 g, –2 g, and 0 g. The interruption of the calibration for reversing the instrument on the centrifuge should require a minimum of time.

5.2.5.2 Continuous comparison (alternate)

The transducer under test is mounted on the centrifuge, as is a high precision reference accelerometer having a well established low error. Both instruments are carefully positioned so as to sense the same value of acceleration. The electrical outputs of both instruments are added in opposition, using attenuation where necessary, so that the net signal represents the deviation of the test accelerometer from that of the reference accelerometer. This signal is fed into the y-axis circuit of an x-y recorder and the full output of the reference accelerometer is fed into the x-axis circuit of the recorder.

By increasing the applied acceleration from zero to full scale and then decreasing it to zero again, a complete plot of test accelerometer response deviation versus applied acceleration is obtained. For bi-directional accelerometers, the test instrument must be tested with reversed mounting position.

The rate of application of acceleration may affect the shape of the plotted characteristic; the rate should not exceed the time response capabilities of reference accelerometer, test accelerometer, or recorder.

This method may also be used in conjunction with the earth's field static calibration. This technique is rapid as well as valuable for uncovering the presence of such defects as air bubbles, foreign particles, obstructions, etc., but its validity relies entirely on the complete knowledge of the performance characteristics of the reference accelerometer and its continued stability (see Finley reference).

5.2.6 (Optional) dynamic calibration

The transducer shall be mounted on the moving table of an electromagnetic or similar shaker. The excitation source and readout instrument shall be connected to the transducer and turned on. Provision shall be made for determining the phase of the acceleration input (an electronic phase meter may be used). Adequate warmup time for the test equipment and instrument shall be allowed before tests are conducted. A minimum of ten frequency points, approximately equally spaced, shall be selected covering a frequency range extending to a frequency 1 1/2 times the estimated natural frequency of the instrument. The transducer shall then be calibrated at each of the above frequencies at an acceleration level close to but not in excess of the maximum range of the instrument (care must be taken when approaching the natural frequency of high g instruments). Calibration data for the phase shift of the transducer can be taken at the same time. See Figure 3.

NOTES

1. The low frequency amplitude capability of the shaker may require some of the initial points in the ten point frequency response curve described above to be taken at a reduced input.

2. Also see 4.3.3.

5.2.7 (Optional) temperature effects

The transducer shall be calibrated in the earth's field or on the centrifuge at a minimum of three different temperatures [including 24 ± 3°C (75 ± 5°F)] covering the operating temperature range of the instrument. These calibrations shall be carried out as described in 5.2.4 or 5.2.5 except that only one calibration cycle shall be run. Care shall be taken to stabilize the instrument temperature at each selected calibration temperature. See Figure 3.

6 Qualification tests

Qualification tests shall be summarized using a test form similar to that in Section 9. The sequence of the tests must be conducted in a logical order. For example, a shock acceleration may permanently distort the seismic mass suspension changing the initial alignment so the alignment test may need to be performed before and after the shock acceleration tests.

Qualification tests are to be performed on a number of representative samples to measure a transducer's performance characteristics against the values of the specification. These particular characteristics are, in general, those which are a function of basic transducer design and are not expected to vary significantly from unit to unit. However, as particular application requirements dictate, it may be deemed prudent to include certain of these tests in the acceptance tests.

6.1 Initial performance tests

The tests of Section 5 shall be conducted to establish a reference performance; in addition, a calibration cycle shall be performed between and after the individual qualification tests and the results compared to the reference performance and the specifications.

6.2 Warmup period

The zero balance shall be measured repeatedly over a period of at least one hour starting with the application of excitation voltage.

In a separate test the sensitivity shall be determined repeatedly over a period of at least one hour starting with the application of excitation voltage using either the earth's field or the centrifuge as an acceleration source.

Report No. ______________ Test Facility ______________ Date Tests Started ______________

Vendor ______________ Vendor Part No. ______________ Date Tests Started ______________

Range ______________ P.O. No. ______________ Test Type ______________

Serial No. ______________

Part No. ______________

SUMMARY OF RESULTS

Test	Tested to Proc. No. Test Waived by	S37.5 Para. No.	Check if Acceptable	Check Type of Failure: Error	Check Type of Failure: Electr.	Check Type of Failure: Mechan.	Check Type of Failure: See comments	Error / Error Band: +%FSO	Error / Error Band: –%FSO
1. Visual Inspection		5.2.1							
2. Impedance Measurement		5.2.2							
3. Insulation Resistance		5.2.3							
4. Static Calibration (1 g)		5.2.4							
5. Static Calibraion (>1 g)		5.2.5							
6. Dynamic Calibration (Optional)		5.2.6							
7. Temperature Effects (Optional)		5.2.7							
8. Warmup Period		6.2							
9. Output Regulation		6.3							
10. Dynamic Characteristics		6.4							
11. Steady State Temperature Effects		6.5							
12. Dynamic Characterisitcs (High and Low Temp.)		6.6							
13. Transient Thermal Effects		6.7							
14. Proof Transverse Acceleration (Static)		6.8							
15. Proof Transverse Acceleration (Vibrational)		6.9							
16. Transverse Sensitivity (Static)		6.10							
17. Transvers Sensitivity (Compound, Static)		6.11							
18. Transvers Sensitivity (Vibrational)		6.12							
19. Transvers Sensitivity (Compound, Vibrational)		6.13							
20. Alignment		6.14							
21. Damping Integrity		6.15							
22. Acceleration Overload		6.16							
23. Stability		6.17							
24. Life Test		6.18							
25. Storage Life Test		6.19							

Figure 2 — Qualification test summary strain gage accelerometer

NOTES

1. It is desirable to determine the warmup characteristics of the zero balance separately from the sensitivity as this permits the series of zero measurements to be made without disturbing the accelerometer.

2. In all tests, the equipment will have been previously warmed up.

6.3 Output regulation

Perform one static calibration cycle at 90%, 100%, and 110% of the rated excitation. Compare the values of full scale output, zero balance, linearity, and hysteresis to those of the specifications and of the initial acceptance tests.

NOTE — The 110% test above shall not be performed if it exceeds the maximum allowable excitation.

6.4 Dynamic characteristics

The transducer shall be attached to a shaker. The excitation source and readout instrument shall be connected to the transducer and turned on. Provision shall be made for determining the phase of the accelerometer output with reference to the acceleration input. An electronic phase meter may be used. Adequate warmup time for the test equipment and instrument shall be allowed before tests are conducted. Frequency points shall be selected covering a frequency range extending to a frequency 1 1/2 times the estimated natural frequency of the transducer. These calibration points shall include at least the following (frequencies are listed as a percentage of the natural frequency): 5, 10 (these points to tie in with the static calibration), 20, 30, 40, 50, 60 (these points to cover the maximum flat region), 70, 80, 90, 100, 125, 150% (these points to establish damping and natural frequency). Calibrations shall be made at a minimum of two values of amplitude (typically 50% of full scale and 100% of full scale). The transducer phase shift shall be determined at enough of the above listed frequencies to determine the phase linearity of the instrument and the point of 90 degree phase shift.

NOTES

1. Depending on the range of the instrument, the capability of the shaker may not permit calibration of some of the values cited above.

2. The frequency response of the transducer is commonly very temperature dependent. See 6.6.

3. See 6.15.

6.5 Steady state temperature effects

A minimum of six calibrations utilizing the earth's field or centrifuge shall be performed on the transducer (as described in 5.2.4 or 5.2.5 except that only one calibration cycle shall be run). This series of calibrations shall begin and end with a calibration at 24 ± 3°C (75 ± 5°F) the remaining four, or more calibrations shall cover the operating temperature range of the accelerometer. Care should be taken to assure that the transducer is at a stabilized temperature.

6.6 Dynamic characteristics (high and low temperature)

The transducer shall be calibrated as described in 5.2.6 and at the maximum and minimum temperatures of interest. Care should be taken that the transducer is fully stabilized at each test temperature.

6.7 Transient thermal effects

6.7.1 Zero

With the transducer mounted to provide a zero g input, the transducer shall be brought rapidly to a selected high or low temperature. The temperature and accelerometer output shall be continually recorded during this transient. Heating or cooling can be accomplished by conduction through the base, by directing heated or cooled air on the instrument, by placing the instrument into a temperature controlled test chamber, or by other means.

6.7.2 Sensitivity

The test of 6.7.1 shall be repeated except that the earth's field or the centrifuge shall be used as an acceleration source.

6.8 Proof transverse acceleration (static)

The specified maximum static transverse acceleration is applied in each of two orthogonal transverse axes.

6.9 Proof transverse acceleration (vibrational)

The specified maximum transverse vibrational acceleration is imposed in each of two orthogonal transverse axes over the specified frequency range.

6.10 Transverse sensitivity (static)

Mount the accelerometer with its sensitive axis perpendicular to the centrifuge table. Apply the specified transverse static acceleration; keeping the location of the center of gravity of the seismic mass constant, rotate the accelerometer about its sensitive axis and take data for enough additional points to determine an approximate maximum accelerometer transverse response. Repeat the above tests with the sensitive axis parallel to the centrifuge table and perpendicular to the acceleration that will be applied by the centrifuge.

NOTE — For these tests, the sensitive axis is considered to be perpendicular (or parallel) to the accelerometer mounting surface.

6.11 (Optional) transverse sensitivity (compound static)

Mount the accelerometer on the centrifuge table with the sensitive axis of the accelerometer parallel to the centrifuge table and at a known angle with that table radius that intersects the center of gravity of the seismic mass. Apply the specified transverse static acceleration; keeping the location of the center of gravity of the seismic mass constant, rotate the accelerometer about its sensitivity axis and take data for enough additional points to determine an approximate maximum accelerometer transverse response.

NOTE — The transverse response is determined by subtracting the computed output resulting from the sensitive axis acceleration component from the total accelerometer output. For these tests, the sensitive axis is considered to be perpendicular (or parallel) to the accelerometer mounting surface.

6.12 Transverse sensitivity (vibrational)

Mount the accelerometer with its sensitive axis perpendicular to the shaker motion. Apply the specified transverse vibrational acceleration over the specified frequency range; rotate the accelerometer about its sensitive axis; and take enough additional points to determine the approximate maximum accelerometer transverse response.

NOTES

1. For these tests, the sensitive axis is considered to be perpendicular (or parallel) to the accelerometer mounting surface.

2. The suspension design of some shakers creates a transverse component; care should be taken to mount the accelerometer so that its sensitive axis is perpendicular to this motion.

3. For a method of improved accuracy, see Finley reference.

6.13 (Optional) transverse sensitivity (compound, vibrational)

Mount the accelerometer with its sensitivity axis at a known angle to the motion that will be applied by the shaker. Apply the specified vibrational acceleration over the specified frequency range; rotate the accelerometer about its sensitive axis; and take additional points to determine the approximate maximum accelerometer response.

NOTES

1. For these tests, the sensitive axis is considered to be perpendicular (or parallel) to the accelerometer mounting surface. The suspension design of some shakers creates a transverse component; care should be taken to mount the accelerometer so that its sensitive axis is perpendicular to this motion. The transverse response is determined by subtracting the computed output resulting from the sensitive axis acceleration component from the total accelerometer output.

2. For a method of improved accuracy, see Hilten reference.

6.14 Alignment

The accelerometer shall be mounted with its sensitive axis (as defined by the case and its mounting surface) perpendicular to the direction of applied acceleration. The accelerometer is then turned about its sensitive axis until the points of maximum output deviations are found. These will be two points 180 degrees apart so that one-half the difference between these points represents the value of output caused by the misalignment for the acceleration applied. From this data, the magnitude and direction of the maximum misalignment can be determined.

NOTE — The source of acceleration can be the field of gravity or a centrifuge depending on the range of the accelerometer.

6.15 Damping integrity

Record the dynamic response of the accelerometer at a frequency approximately of 0.7 the natural frequency. Now quickly invert the accelerometer relative to the field of gravity on the vibration calibrator and, without delay, record the response at the same frequency. A significant change in response may indicate the presence of a gas bubble or foreign matter. Alternatively perform a calibration cycle on a centrifuge or in the field of gravity, then quickly invert the accelerometer and repeat the calibration.

NOTES

1. If the gas bubble problem is accentuated by the addition of an external vacuum environment, it is an indication of a defective case seal.

2. Vacuum and/or temperature, combined with high vibration amplitudes that are within the accelerometers normal measuring range may permit cavitation and a change in frequency response even though no appreciable amount of gas is present in the damping fluid. Although liquids are incompressible at the pressures involved, sealing

diaphragms, expansion chambers, and the damping chamber walls sometimes allow for an increase in volume permitting cavitation.

6.16 Acceleration overload

The specified overload acceleration is applied in the directions and magnitudes specified; the performance during overload is monitored. Where the overload recovery time is required to be short, this time is best measured with an oscilloscope after application of a shock acceleration overload. A post overload calibration cycle is performed and compared to the specifications and the initial acceptance tests.

6.17 Stability

Calibrations shall be performed at suitable intervals of time to determine the ability of the accelerometer to reproduce the initial calibrations at room temperature. Of particular interest will be the repeatability of full scale output; additional characteristics of interest will be zero balance, linearity, hysteresis, and frequency response.

6.18 Life test

After applying a specified number of full range excursions of measurand, at least one complete calibration cycle shall be performed to establish a minimum value of cycling life.

6.19 Storage life test

After storing the transducer under specified conditions for a specified period of time, one complete calibration cycle shall be performed to establish minimum storage life.

6.20 Effects of other environments

Expose the transducer to other specified environmental conditions followed in each case by one complete calibration cycle to test ability of the transducer to perform satisfactorily after such exposure.

Figure 3

5.2.6 DYNAMIC CALIBRATION

Acceleration Input = ____________________________g (CONSTANT)

	Frequency Hz	**Output mV**	**Phase Angle Degrees (Lag)**

Temperature __________________________°C(°F)
Natural Frequency________________________Hz
Damping Ratio ______________________Of Critical

5.2.7 TEMPERATURE EFFECTS

Low Temperature Full Scale Output Temperature __________°C (°F)
Zero ____mV
+ FS + ____mV
– FS – ____mV
Room Temperature Full Scale Output Temperature __________°C (°F)
Zero ____mV
+ FS + ____mV
– FS – ____mV
Upper Temperature Full Scale Output Temperature __________°C (°F)
Zero ____mV
+ FS + ____mV
– FS – ____mV

Annex A — References

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI S2.2-1959 (Revised 1971)	Methods for the Calibration of Shock and Vibration Pickups
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67 Alexander Drive
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Research Triangle Park, NC 27707 Tel. (919) 990-9220

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ISBN: 0-87664-379-9