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Recommended Practice

Guide for Specifications and Tests for Piezoelectric Acceleration Transducers for Aerospace Testing

ISA-RP37.2 — Guide for Specifications and Tests for Piezoelectric Acceleration Transducers for Aerospace Testing

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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-RP37.2.

This recommended practice 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. Toward 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.

CAUTION: The information presented within this ISA recommended practice is believed to be accurate and reflects the current state of knowledge within the field. The information is an interpretation and condensation of a larger volume of literature and experience, some of which is contradictory and speculative. Therefore, application of the information to particular situations requires the exercise of the independent professional judgment of the user. ISA is not responsible for any results from such use of the information and shall not be liable for any damages caused by such use.

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The development of this recommended practice was initiated as a result of a survey conducted in December 1960. A total of 240 questionnaires was sent out to transducer users and manufacturers in the aerospace field. In their replies, a strong majority indicated a need for standardization of specifications and tests of several types of commonly used aerospace test transducers with electrical output.

On the basis of these replies, a Project Sub-Committee 8A-RP37.2, Guide for Piezoelectric Acceleration Transducers for Aerospace Testing, was formed under the cognizance of Committee 8A-RP37, Transducers for Aerospace Testing, of the Aerospace Standards Group, and this recommended practice was developed.

The following individuals served as members of Subcommittee 8A-RP37.2:

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1 Scope

1.1 This recommended practice covers piezoelectric acceleration transducers, primarily those used in aerospace test instrumentation.

1.2 Terminology used in this document follows ISA-S37.1, *Nomenclature and Specification Terminology for Aerospace Test Transducers with Electrical Output*, except that additional terms considered applicable to piezoelectric vibration transducers are defined in 4.3.

2 Purpose

This recommended practice establishes the following for piezoelectric acceleration transducers:

2.1 Uniform minimum general specifications for design and performance characteristics.

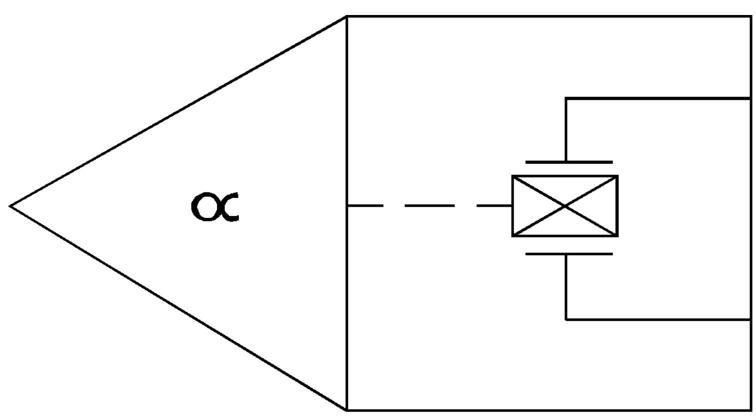
2.2 Uniform minimum acceptance and qualification test methods, including calibration.

2.3 Uniform presentation of minimum test data.

2.4 A drawing symbol for use in schematics.

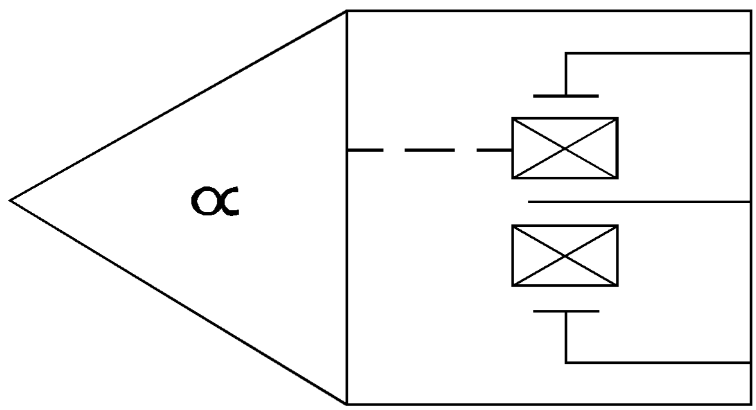
3 Drawing symbol

3.1 General

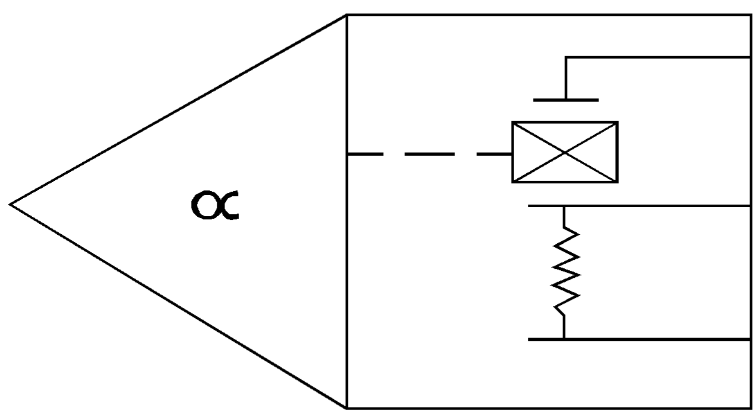


3.2 Self-checking accelerometers

3.2.1 Active



3.2.2 Passive



4 Characteristics

The first two paragraphs contain, in alphabetical order, the terms to be used in manufacturers' and users' specifications for piezoelectric acceleration transducers. Some terms not already defined in ISA-S37.1 (*Nomenclature and Specification Terminology for Aerospace Test Transducers with Electrical Output)* are marked with an asterisk (*) and are defined in 4.3.

In 4.1 and 4.2, each characteristic listed is checked (or numbered with reference to Sections 5 or 6) in one or several columns to indicate the characteristics which are included in manufacturers' literature or users' specifications as follows:

a) Basic — indicates characteristics which are normally specified for each transducer.

b) Supplemental — indicates additional characteristics which may be specified if desired.

The remaining three columns indicate the tests required to determine these characteristics.

a) Individual Acceptance Tests (IAT) — tests performed on each transducer.

   1) Within Stated Tolerances - these tests are of the "go - no go" type with respect to stated tolerances.

   2) Measured Value - these tests provide individual measured values of the characteristic.

b) Qualification tests — tests in addition to the IAT's performed on representative samples of each transducer design. All IAT's are, of course, performed during a formal qualification test program.

Some of the **basic** and **supplemental** characteristics are determined by the manufacturer's research and development and require no additional testing.

4.1 Design characteristics

	Basic	Supple-mental	Characteristics Determined During:		
			Individual Acceptance Tests		Qual. Tests
			Within Stated Tolerances	Measured Value	
Cable, (integral or non-integral) or Connector Type	x		5.1		
Cable, Standard, Supplied					
Type	x				
Length	x		5.3.2		
Capacitance at Room Temp.	x			5.3.2	
Temperature Range	x				6.2
Capacitance vs. Temp.		x			6.7
Noise	x		5.3.2		
Dimensions, Configuration and Markings*	x		5.1		
Grounded or Ungrounded*	x		x		
Housing Material(s)	x				
Insulation Resistance (minimum) at Maximum Rated Temperature					
Across Element	x				6.2.1
Element to Ground (if applicable)	x				6.2.1
Mounting Method (adhesive, stud, separate adaptors; state thread size, class, mounting torque, and temperature rating, if applicable.)	x				x
Temperature Range,					
Operating	x				6.2
Storage	x				
Transducer Capacitance with Stated Cable	x			5.3.3	
Transducer Seal	x		5.3.1		6.11
Transduction Element					
Material Type (proprietary name acceptable)	x				
Sensing Mode*	x				
Mechanical Isolation*		x			
Weight (state whether cable or other accessories are included)	x				x

*Defined in 4.3

4.2 Performance characteristics

	Basic	Supple-mental	Characteristics Determined During:		
			Individual Accep. Tests		Qual. Tests
			Within Stated Tolerances	Measured Value	
Acceleration Limit*	x				
Acceleration Range*	x				6.5.1
Amplification Factor at Resonant Frequency*		x			6.3.1
Amplitude Linearity					
Shock*	x				6.5.2
Vibration*	x				6.5.1
Partial Range		x	x		
Environmental Effects					
Acoustic Sensitivity*		x			6.9
Electromagnetic Response		x			6.10
Temperature Sensitivity Error*					
–65°F to 350°F (177°C) or	x				6.7
Above 350 °F.	x			5.4.1	
Below –65°F.	x			5.4.1	
Transient Temperature Error*		x			6.8
Other		x			6.12
Frequency, Resonant, Mounted; Nominal (and tolerance), or Minimum	x				6.3
Frequency Response*					
Maximum Range	x				6.4
Stated Partial Range	x			5.2.2	
Mounting Error		x			6.1
Polarity*	x		5.3.4		
Reference Sensitivity, Charge or Voltage, Nominal (and tolerance)*	x			5.2.1	
Sensitivity Stability	x				6.13
Strain Sensitivity		x			6.6
Transverse Sensitivity*					
At Stated Single Freq.	x			5.2.3	
Over Maximum Freq. Range		x			5.2.3

*Defined in 4.3

4.3 Additional terminology

(For terms not defined here, see ISA-S37.1.)

4.3.1 acceleration limit: the maximum vibration and shock acceleration which the transducer can accept in either direction along its sensitive axis without permanent damage, usually stated as ±____g's. The acceleration limits are usually much wider than the Acceleration Range and thereby represent a measure of the overload capability of the transducer.

4.3.2 acceleration range: the range of accelerations over which the transducer has the specified linearity.

4.3.3 acoustic sensitivity: the output of a transducer (not due to rigid body motions) in response to a specified acoustical environment. This is sometimes expressed as the acceleration in g rms sufficient to produce the same output as induced by a specified sound pressure level spectrum having an overall value of 140 db referred to 0.0002 dyne per sq. cm. rms.

4.3.4 amplification factor at resonant frequency: the ratio of the maximum sensitivity of a transducer (at its resonant frequency to its Reference Sensitivity).

> **NOTE —** "Amplification factor at resonant frequency" is sometimes referred to as "Q."

4.3.5 amplitude linearity, shock: closeness of sensitivity to reference sensitivity over a stated range of acceleration amplitudes, under shock conditions, usually specified as "within ±____percent for acceleration rise times longer than ____ microseconds."

4.3.6 amplitude linearity, vibration: closeness of sensitivity over a stated range of acceleration amplitudes, at a stated fixed frequency, usually specified as "within ±____percent."

4.3.7 electromagnetic field sensitivity: the maximum output of a transducer in response to a specified amplitude and frequency of magnetic field, usually expressed in gauss equivalent to a stated fraction of 1 g.

4.3.8 frequency response: the change with frequency of the sensitivity with respect to the reference sensitivity, for a sinusoidally varying acceleration applied to a transducer within a stated range of frequencies, usually specified as "within ±____ percent of the reference sensitivity from ____ to ____ cps." The applicable total capacitance and load resistance should be stated.

4.3.9 grounded or ungrounded: refers to the presence or absence of an electrical connection between the "low" side of the transducer element and the portion of the transducer intended to be in contact with the test structure. Method of ungrounding should be stated as "internally ungrounded" or "by means of separate stud."

4.3.10 markings: information shown on the transducer itself, will normally include Manufacturer, Model Number and Serial Number.

4.3.11 mechanical isolation of transduction element: internal construction of transducer which allows forces (particularly bending forces and external pressures) to be applied to the transducer case with negligible resulting forces on the transducer element.

4.3.12 polarity: the relationship between the transducer output and the direction of the applied acceleration; taken as "standard" when a positive charge or voltage appears on the "high" side of the transducer for an acceleration directed from the mounting surface into the body of the accelerometer.

4.3.13 reference sensitivity (charge or voltage): the ratio of the change in charge or voltage generated by a transducer to the change in value of the acceleration that is measured under a set of defined conditions (amplitude, frequency, temperature, total capacitance, amplifier input resistance, mounting torque). Deviations in sensitivity should be reported as deviations from the reference sensitivity.

4.3.14 sensing mode of transduction element: the method used to stress the transduction element such as compression, bending or shear.

4.3.15 sensitivity: the ratio of the change in transducer output to a change in the value of the acceleration.

NOTES

1. Where one sensitivity under defined conditions is the basis for determining deviations in performance, use "reference sensitivity."

2. Because the use of piezoelectric acceleration transducers for the measurement of both shock and vibration, the acceleration is required to be known in either g peak or g rms. A specified sensitivity in millivolts per g is to be understood as meaning "rms millivolts per rms g" or its equivalent "peak millivolts per peak g." The use of "mixed units" such as rms millivolts per peak is to be avoided. Note, however, that an output of 10 millivolts rms is also approximately 14.1 millivolts peak, and an acceleration of 1 g rms is approximately 1.41 g peak and, therefore,

$$10\frac{mv}{g} = 10\frac{mv\ rms}{g\ \ rms} = 10\frac{mv\ pk}{g\ \ pk} = 7.07\frac{mv\ rms}{g\ \ pk} = 14.1\frac{mv\ pk}{g\ rms}$$

4.3.16 shock: a substantial disturbance characterized by a rise and decay of acceleration from a constant value in a short period of time.

4.3.17 strain sensitivity: the sensitivity to strains applied to the base by bending, in the absence of any rigid body motion of the transducer. It is expressed as 10^{-6} times the equivalent acceleration level in g's for a strain in the plane of the base.

4.3.18 temperature range, operating: the interval of temperatures in which the transducer is intended to be used, specified by the limits of this interval.

4.3.19 temperature sensitivity error: the change in sensitivity of a transducer from its reference sensitivity as a result of changes in its ambient temperature over a specified operating temperature range.

NOTE — If changes in voltage sensitivity are specified, the total associated capacitance must be stated.

4.3.20 transient temperature error: the output of a transducer as a result of a specified transient temperature change within a specified operating temperature range.

NOTE — The associated capacitance and load resistance, as well as the time, after the applied transient, at which the amplitude peak occurs must be specified.

4.3.21 transverse sensitivity: the maximum sensitivity of a uniaxial transducer to a transverse acceleration, within a specified frequency range, usually expressed in percent of the reference sensitivity in the intended measuring direction.

5 Individual acceptance tests and calibration

Tests are listed in the order they are to be performed.

5.1 Visual inspection

Conduct a complete visual examination for conformance to stated configuration and markings. Determine weight, dimensions, thread size, and class utilizing standard inspection instruments. Check mating of accessory cable (if any) by attaching and removing the cable. Note any discrepancy.

5.2 Initial functional tests

5.2.1 Reference charge or voltage sensitivity

For most applications, it is recommended that the sensitivity of a transducer be determined by comparison with a standard calibrated transducer. This method is described in ANSI-S2.2-1959.

The frequency of the driving signal should be in the range of 40 to 100 cycles per second and should be monitored continuously by a properly calibrated electronic counter.

Charge sensitivity can be determined by multiplying the voltage sensitivity in volts per g by the total capacitance of the system in pico-farads, providing charge sensitivity in pico-coulombs per g.

A system consisting of a transducer, cable, and amplifier should be calibrated as a unit. The sensitivity will be that recorded at the output of the amplifier, in volts/g. Specifications should include transducer sensitivity with cable, capacitance, and amplifier gain.

If a standard transducer with calibration traceable to NBS is not available, a reasonably dependable sensitivity can be determined by methods described in ANSI-S2.2-1959. The chatter method, described in the Kissinger reference, see Annex A, is the simplest to use and is the most dependable for reasonable accuracy.

The temperature of the transducers should be measured and recorded.

NOTES

1. The standard transducer used should have a calibration traceable (see ISA-S37.1) to a calibration performed at the National Bureau of Standards within the normal calibration period of one year. The transducer used as a standard should be reserved for this purpose only; it should not be exposed to large values of shock, vibration or temperature extremes; and its calibration should be checked periodically by either of the referenced methods.

2. The surface on which each transducer is mounted and the part of the transducer base which touches that surface should be clean and flat, with a surface finish of 64 microinches or less. If oil or grease is used as a gasketing material, it should be clean, freshly applied to both surfaces just before the test, and completely removed immediately afterwards.

3. The signal used to excite the motion of the transducers should be as nearly sinusoidal as possible. The wave shape of the output signal of both transducers should be observed frequently throughout the test and no perceptible distortion should be allowed. Preferably, a distortion meter should be used, and the distortion kept below 3%.

4. Screw-attached transducers should be mounted with the torque recommended by the manufacturer, using a good grade torque wrench. A preliminary observation of the wave shape and amplitude on an oscilloscope should be made when the transducer is mounted with a torque about 10% less than recommended. Then the recommended torque should be applied. A calibration is not valid if a small increase in mounting torque changes the wave shape or amplitude of the output appreciably. Torque larger than recommended should never be used unless it is certain that no damage will result. The torque used should be reported with the results of the test.

5. The plate, on opposite sides of which the transducers are mounted, should be thick enough so that no appreciable flexure occurs and thin enough so that both pickups have the same motion.

6. The motion applied to the two transducers should be far enough above the noise level so that the system noise represents a minor error in the calibration. A signal-to-noise ratio of 40 db is desirable. Increasing the motion beyond this level is not desirable on most vibration test equipment because it increases the chance of distortion and non-axial motion. The acceleration level should be reported with the results of the test.

5.2.2 Frequency Response

Frequency response is determined by using the method described for reference sensitivity (5.2.1) at a number of frequencies over the range of interest. The frequency response of the standard in this range must be known.

For acceptance testing, ten frequencies should be chosen at which the output ratios are measured. If equally spaced on a logarithmic frequency scale, these frequency points should adequately determine the frequency response curve.

NOTES

1. The plate on which the two transducers are mounted should be made of a high-modulus material such as a machinable tungsten alloy.

2. If the signal from one transducer is applied to one set of plates of an oscilloscope, and the signal from the other transducer is applied to the other set of plates, rotation of the resulting Lissajous figure as the driving frequency is increased from very low to high frequencies indicates the onset of difference in the motion of the transducers. Distortion of the figure indicates bad motion or other cause for investigation. The test should be repeated with the transducer positions interchanged. A calibration is not valid if interchanging positions changes results by more than 3% (5% above 5,000 cps).

5.2.3 Transverse sensitivity

Mount the transducer in a suitable test arrangement such that the known vibratory motion in a plane perpendicular to the sensing axis is at least 100 times the motion in the direction of the sensing axis. The frequency and amplitude of the motion should be stated and should be within the rated frequency and amplitude ranges of the transducer. Rotate the mounted transducer about the sensing axis through 360 degrees to determine the transverse direction of maximum sensitivity.

Express the output at this maximum sensitivity as a percentage of the output which would be obtained if the known motion were applied in the direction of the sensing axis.

5.3 Tests and measurements

5.3.1 Transducer seal immersion test

Use water at room temperature in a transparent container such as a Pyrex® beaker. Heat the water to approximately 200°F. Remove detachable cables and connectors from the transducer. Immerse the transducer beneath the surface of the heated water. Any stream of air bubbles released from the transducer indicates leakage and constitutes failure. Dry the transducer without application of heat and measure the insulation resistance of the element. The minimum insulation resistance shall be met.

5.3.2 Coaxial cable

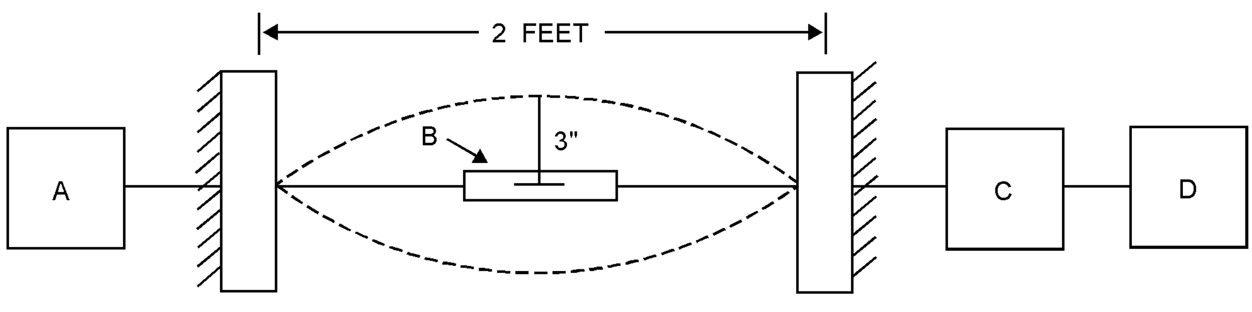
5.3.2.1 Length and capacitance

Measure the length of cable between the end faces of the connectors. It is acceptable, if within ±1/4 inch or ±2 percent of specified length, whichever is larger. For detachable cables, measure the capacitance with a capacitance bridge at 1000 cps and record.

5.3.2.2 Test for cable noise

The output noise of a standard length of cable (usually 3 or 4 feet) should be specified as "less than ____mv (peak to peak)" when tested with instrumentation shown in this paragraph. (This test is adapted from the Perls reference, see Annex A, but is somewhat more severe).

The instrumentation shall include a standard shielded capacitor (1000 pfd) connected across the cable; a weight equal to the weight of 40 feet of the test cable, in two half-cylindrical shapes that are clamped or taped to the outer jacket of the cable; a preamplifier or cathode follower with at least 10 megohms input impedance; and an oscilloscope or recorder with a capability of providing a full scale deflection from a 1 mv signal generated by the cable.



A - Shielded capacitor - 1000 pfd.
B - Cylindrical weight (2-1/2" length). Material - brass.
C - Cathode follower or preamplifier.
D - Oscilloscope or Recorder.

Connect the cable electrically as shown in the schematic. Clamp the cable between pieces of wood to the two anchor points, allowing a 3-inch sag in the center of the cable. Clamp weight (B) to cable at center of anchored span. Raise the cable by the weight to maximum height (3 inches above its neutral position) and drop. Monitor output noise of the cable on the oscilloscope. Repeat test 3 times. Record the maximum value in mv peak to peak.

5.3.3 Transducer capacitance

Measure capacitance of transducer with cable attached by means of a capacitance bridge at 1000 cps; measure capacitance of transducer cable at 1000 cps. Subtract cable capacitance from total capacitance to obtain transducer capacitance. Temperature should be 70°F to 85°F.

5.3.4 Polarity (use either the transient method or the comparison method.)

5.3.4.1 Transient method

Check (with a battery or other DC voltage source) the transducer preamplifier and oscilloscope readout to determine the direction of scope deflection for a positive voltage input to the preamplifier.

Connect the transducer to the preamplifier and apply a transient acceleration to the transducer. The initial voltage output from the transducer should be positive for:

a) Uniaxial transducers with force applied against the base of the transducer

b) Triaxial transducers with force applied in the direction of arrows shown on the transducer for the axes involved

5.3.4.2 Comparison method

Compare the test accelerometer with a standard accelerometer on an electrodynamic vibration exciter operating at a frequency below 1000 cps.

Use a phase meter or oscilloscope to indicate the phase angle between the standard and test accelerometers. Select the preamplifiers used on both the standard and test accelerometers so that their phase shifts between input and output are the same. The test accelerometer should have approximately zero phase shift.

> **NOTE —** Back-to-back mounting results in opposite motions being applied to the two accelerometers at any instant.

5.4 Final functional tests

5.4.1 Temperature sensitivity error at maximum or minimum rated temperature

Determine transducer capacitance at room temperature (C_{trt}).

Mount the transducer on a calibration exciter in a temperature chamber. Determine the voltage output E_{rt} at room temperature at a frequency below 1000 cps with a known external capacitance C_{ext}. Maintain the vibration amplitude and frequency constant throughout the entire test. Stabilize the transducer at the rated temperature for 15 minutes. Measure the following:

a) Voltage output E_{mt} at rated temperature with the known external capacitance C_{ext}.

b) Transducer capacitance at rated temperature (C_{tmt}).

c) Transducer resistance at rated temperature.

CAUTIONS and NOTES

1. The standard which is used to establish the vibration amplitude must be known to be suitable under all test conditions.

2. Measure capacitances at 1000 cps with a capacitance bridge, without motion applied to the transducer.

3. Measure resistance with a megohmmeter. Test voltage should be 50 vdc unless otherwise specified.

4. Allowance may have to be made for changes in cable resistance and/or cable capacitance throughout the transducer temperature range.

5. Monitor the output waveform of the transducer with an oscilloscope to insure that it appears sinusoidal.

6. Do not leave the transducer in an open circuit condition while the temperature is being changed; it should be shorted or connected to a preamplifier.

Repeat the room temperature tests as above at the conclusion of the final functional tests.

If applicable, compute the percentage change in transducer voltage sensitivity at rated temperature compared with room temperature.

If applicable, compute the percentage change in transducer charge sensitivity at rated temperature compared with room temperature:

$$100\left[\frac{(C_{tmt}+C_{ext})E_{mt}-(C_{trt}+C_{ext})E_{rt}}{(C_{trt}+C_{ext})E_{rt}}\right]$$

Low resistance or excessive sensitivity change with temperature may constitute failure. Nonrepeatability of room temperature output before and after the test may constitute failure.

5.4.2 Reference voltage or charge sensitivity

Repeat 5.2.1

5.4.3 Frequency response

Repeat 5.2.2

5.4.4 Transverse sensitivity

Repeat 5.2.3

6 Qualification tests

Tests which are performed on representative transducers in addition to the Individual Acceptance Tests.

6.1 Effectiveness of mounting technique

6.1.1 With thread-mounted transducers, determine the sensitivity at a frequency between 40 and 100 cps for various thread torques in the region of the recommended mounting torque. This determines the care which must be used in installing the transducer. Do not exceed a maximum torque rating, if such a rating exists.

6.1.2 With electrically insulated mounting studs, apply the rated maximum mounting torque to the stud several times; reject if there is visible evidence of mechanical damage. Use the tested mounting stud if possible when conducting the final frequency response test. (See 5.4.3).

6.2 Temperature range

6.2.1 Resistance and Capacitance at Maximum Rated Temperature (delete if rated higher than 350°F as measured in 5.4.1).

Insert transducer with cable attached into an oven with the temperature sensing thermocouple in contact with or adjacent to the base of the transducer. Short the open end of the cable. Increase oven temperature and stabilize at the maximum rated temperature for 15 minutes. Remove short and measure the resistance of the transducer-cable combination using a 50 volt megohmmeter. Measure the capacitance at 1000 cps with a capacitance bridge. Again short the open end of the cable and return to room temperature. If the resistance is not acceptable, re-run the test with the cable alone to determine whether the cause of low resistance is within the transducer or the cable assembly.

In the same way measure the insulation resistance from both sides of the element to ground for ungrounded transducers.

> **NOTE —** All connectors should be wiped with clean alcohol and a dry cloth before the test.

6.2.2 Soak Test

Soak the transducer and associated cable for one hour each at the minimum and maximum rated temperatures (the transducer should be shorted during the test). Measure the reference sensitivity before and after the test, in accordance with 5.2.1. Reject if the apparent change in reference sensitivity exceeds an allowable limit.

6.3 Mounted resonant frequency

The frequency response of a piezoelectric accelerometer depends on the value of the (lowest) resonant frequency of the instrument when mounted on the structure to be tested. It is shown in the Schloss and the Lederer references (see Annex A) that this frequency is not only a function of the mass of the structure, but also of the compliance at the contact between structure and accelerometer. It does not appear possible to specify a test which will determine this frequency for all installations of a given transducer. It is therefore suggested that a test be specified which will give an indication of transducer resonant frequency under a set of standard, reproducible conditions, with the understanding that the resonant frequency in actual use will in all probability be appreciably different (generally lower, by a factor depending on the mass and compliance of the test structure).

The resonant frequency is to be determined with the transducer mounted on a small plate or anvil made of a high modulus material such as a machinable tungsten alloy. (Normally acceptable dimensions for damped natural frequencies below 50,000 cps approximate a one-inch cube. In general, the mass of the plate or anvil should be approximately ten times the active mass of the transducers.) Determine the resonant frequency by the Sinusoidal Method or the damped natural frequency by the Shock Method. State method used. [Impedance methods are applicable only to certain accelerometer designs, and it is shown in the Lederer and Clements references (see Annex A) that they do not reliably establish the lowest mounted resonant frequency]. Use the Sinusoidal Method, if it is known that the resonant frequency of the vibration exciter is above that of the accelerometer; otherwise use the Shock Method. It may not be practical to obtain good results from the Shock Method when the accelerometer has additional resonances near its resonant frequency. (See ISA-S37.1 for definitions. In practice, for transducers with low damping, the resonant, damped natural, and undamped natural frequencies are essentially the same.)

6.3.1 Sinusoidal method

Measure the accelerometer output using the comparison method throughout the frequency range including and above the resonant frequency of the accelerometer. The resonant frequency is the frequency of maximum sensitivity. The phase angle relative to the standard accelerometer changes by almost 180 degrees in the range of frequencies near the resonant frequency of the accelerometer.

The standard accelerometer should be built into the exciter. The resonant frequency of the exciter is determined by measuring the transfer impedance between the driver coil current and the standard accelerometer output. Use a dummy mass load to simulate a transducer during the transfer impedance test. Use the exciter only throughout the range up to 95 percent of its resonant frequency.

> **NOTE —** The low-frequency rigid-body rise in amplitude and change in phase may be ignored.

The resonant frequency of the exciter may also be determined with an accelerometer whose damped natural frequency has been determined by the Shock Method and found to be above the exciter resonant frequency.

6.3.2 Shock method

The damped natural frequency should be determined by mechanical excitation by a short transient impact whose pulse duration is about three times the natural period of the accelerometer. The damped natural frequency is established by the frequency of the ringing which occurs on the transducer output; the ringing should be presented on a photograph of an oscilloscope trace or on a memory oscilloscope.

6.4 Frequency response, maximum range (see 5.2.1 and 5.2.2.)

Special care and/or special techniques may be required in the frequency range of 1 to 20 cps and at frequencies exceeding 2000 cps.

6.5 Amplitude linearity

The Vibration Linearity or Shock Linearity methods may be used. It is necessary to use the Shock Linearity Method, if the acceleration range exceeds the attainable acceleration on resonant beams or rods. Calibration efforts in linearity tests often exceed 2%. In these cases, it should be stated that the test indicated no deviations from linearity greater than the calibration errors.

6.5.1 Vibration linearity

Amplitude linearity is performed using the comparison method with a standard accelerometer. Transversely resonant beams may be used at frequencies up to 1000 cps and longitudinally resonant rods up to 10,000 cps to obtain the desired acceleration. The beams and rods are attached rigidly to the exciter and tuned to their fundamental free-free resonant transverse and longitudinal modes, respectively. When using the resonant rod, care is taken to mount both the standard and test accelerometers in close proximity on the same end and at a location far from the node point. The ratio of the two outputs is measured throughout the range of applied accelerations as determined from the standard accelerometer.

The standard accelerometer must be calibrated over the applied acceleration range by the Shock Linearity method, 6.5.2, or by the Reference Voltage or Charge Sensitivity method, 5.2.1, or by one of the absolute calibration methods listed in ANSI-S2.2-1959.

6.5.2 Shock linearity

Use a ballistic impact or comparison technique similar to that outlined in ANSI-S2.2-1959, Sections 4.6 and 5, respectively. Measure and record the basic sensitivity before and after the shock linearity tests.

6.6 Strain sensitivity

The technique used to measure strain sensitivity of an accelerometer meets the requirement of ANSI- Z24.21-1957 reference, paragraph 3.1.3.7. The accelerometer is mounted on a simple cantilever beam. The radius of curvature at the point where the accelerometer is mounted is 1000 inches when the measurements are taken.

A steel beam is held as a cantilever in a vice bolted to a concrete floor. The beam is 3.0" wide by 0.5" thick and 60" long. (The free length is approximately 57 inches.) The natural frequency is very close to 5 cps. Four strain gages are bonded to the beam adjacent to the accelerometer mounting hole (two each, top and bottom, about 1.5" from the edge of the clamp.) A two-channel recorder is used to record the output of both the strain gage bridge and the accelerometer under test.

The system is excited by manually deflecting the free end of the beam and allowing it to vibrate freely. The output of the accelerometer is taken from the oscillograph record at a point where the strain in the surface of the beam is 250×10^{-6} inch per inch. (This is equivalent to a radius of curvature of 1000 inches.) The strain sensitivity, in g's, for a strain of 10^{-6} inch per inch is found by dividing the above accelerometer output by 250 times the accelerometer sensitivity in millivolts per g.

6.7 Temperature sensitivity error

To determine the temperature response at each temperature of interest, follow procedures given in 5.4.1 but do not repeat room temperature test.

6.8 Transient temperature error

Mount the transducer on a one-inch cube of aluminum. Adjust the external capacitance to be approximately equal to the capacitance of the specified cable (or use the actual cable). Connect the transducer to a DC amplifier whose input resistance is approximately 10^8 ohms. Immerse the transducer in water whose temperature is approximately 50°F above room temperature. Measure and record the maximum quasi-DC voltage which is generated by the transducer and the time from the start of the transient at which this maximum voltage is reached. If the voltage reverses within the first two seconds and reaches a peak in the opposite polarity, record the amplitude and the time of the peak also. Convert these voltages to equivalent g's based upon the transducer reference voltage sensitivity with the specified cable.

6.9 Acoustic sensitivity

Place the acceleration transducer in a reverberant acoustical test chamber. The transducer shall be mounted or suspended with a system whose undamped natural frequency is 25 cps or less. Subject the transducer to a specified sound pressure level spectrum covering the frequency range from 75 cps to 9600 cps. Either a swept sinusoid or a random acoustic input may be employed. Measure the rms electrical output of the acceleration transducer (using a suitable preamplifier) and convert to equivalent rms g's based upon the reference sensitivity of the transducer and corrected for external capacitance, preamplifier gain, etc. Report the maximum transducer output in equivalent rms g's; the frequency of this maximum output, if evident; and the specified sound pressure level spectrum.

> **NOTE —** The acoustic sensitivity of piezoelectric accelerometers is negligible in almost all applications except possibly where vibration is to be measured on vibration-isolated components which are subjected to high-intensity airborne noise. Even in these cases,

the sound pressure reaching the transducer generally causes vibratory accelerations of the structure to which the accelerometer is attached of sufficient magnitude to make negligible any output due to pressure changes alone. Tests for acoustic sensitivity, including the one suggested here, tend to be conservative in that they yield an electrical output which is too large because it includes signals due to rigid-body motions of the accelerometer.

6.10 Electromagnetic response

Mount the transducer on a 10 to 15 lb. plate of nonmagnetic material such as lead. Place the mounted transducer in a known 60 or 400 cps magnetic field so that the sensitive axis of the transducer points toward the source of electromagnetic energy and the plate is away from the source. Rotate the transducer and plate about the sensitive axis of the transducer recording the maximum transducer electrical output. Record as equivalent g per gauss based on reference sensitivity corresponding to the external capacity used in the electromagnetic test. Specify test frequency or frequencies.

NOTE — Induced mechanical vibrations and electrical ground loops must be eliminated from the test set up.

6.11 Transducer seal immersion test (Use on all moisture sealed or hermetically sealed transducers).

De-aerate several inches of water at 70°F in a closed transparent container by reducing the absolute pressure to about 2 psi. Return the pressure to normal and immediately immerse the transducer beneath the surface. Reduce the absolute pressure to about 2 psi. Air leakage from the transducer constitutes failure. Let the pressure return to normal atmospheric with the transducer still submerged. Dry the transducer without the application of heat and measure the insulation resistance of the element. The minimum insulation resistance shall be met.

6.12 Other environmental effects

Special tests, as dictated by the user's needs, may include, but are not limited to:

- Altitude
- Explosion
- Fungus
- Humidity
- Nuclear Radiation
- Radio Interference
- Salt Fog
- Sand and Dust

6.13 Sensitivity stability

Measure the Reference Sensitivity of three transducers as in 5.2.1. Then perform the following:

a) Soak each transducer at maximum rated temperature for one hour. Return to room temperature by allowing to cool for 24 hours. Measure and record new reference sensitivity for each.

b) Impact each transducer three times in succession at maximum rated acceleration. Measure and record the new reference sensitivity of each 24 hours later.

c) Soak each transducer at minimum rated temperature for one hour. Return to room temperature by allowing to warm for 24 hours. Measure and record new reference sensitivity for each.

For each transducer, note the maximum percentage change from the original reference sensitivity anywhere during the above tests, and calculate the arithmetical average of these for the three transducers. This is a measure of the average Sensitivity Stability of the transducer.

NOTE — The manufacturer may have data on stability sensitivity of any transducer design based on long term measurements. These measurements are compiled over years' time by periodic (monthly) reference sensitivity measurements on transducers not otherwise in use.

Model No.		**Part No.**
Manufacturer	**INDIVIDUAL ACCEPTANCE TESTS & CALIBRATIONS FOR PIEZOELECTRIC ACCELERATION TRANSDUCERS**	**Serial No.**
		Transducer Element
		Case Material

1. VISUAL (5.1): Dimensions ❑ Weight ❑ Finish ❑ Markings ❑ Cable ❑ Receptacle ❑
2. ELECTRICAL: Transducer Capacitance (5.3.3)______pf; Cable Capacitance (5.3.2)______pf
   Cable Length (5.3.2)______ft.; Cable Noise (5.3.2) less than _______mv
3. TRANSDUCER SEAL (5.3.1):
4. POLARITY (5.3.5):
5. MAXIMUM TRANSVERSE SENSITIVITY (5.2.3):______%
6. REFERENCE CHARGE OR VOLTAGE SENSITIVITY (5.2.1): ______ at ______ cps at ______ °F

Frequency Response (5.2.2)__________% max				**Temperature Sensitivity Error (5.4.1) at __________ cps, ________ g.**					
Frequency cps	Amplitude g's	Output mv or pc*	Sensitivity		Reference Temp. °F	T_1 °F	T_2 °F	T_3 °F	T_4 °F
				Resistance	meg ohm				
				Transducer Capacitance	pf				
				Cable Capacitance	pf				
				System Capacitance	pf				
				Output	mv				
				% Change					

BY______________________DATE_________________APPROVED_____________________

NOTE—Numbers in parentheses refer to sections in ISA-RP37.2.

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*pc stands for pico-coloumbs

Model No.	QUALIFICATION TESTS FOR PIEZOELECTRIC ACCELERATION TRANSDUCERS	Part No.
Manufacturer		Serial No.
		Transducer Element
		Case Material

REFERENCE SENSITIVITY ___________ at __________ cps at __________°F.

Transducer capacitance __________ pf; Cable capacitance __________ pf

6.1 Mounting technique

Preamplifier Model _________ Gain _________ Cable capacitance ________ pf

Transducer:

	Torque	**Sensitivity at ____ cps**
Maximum		
Rated		
75% Rated		
50% Rated		

Stud: Maximum Torque Rating ________________ Evidence of Damage _____________

6.2 Temperature range

Resistance at top rated temperature of ____ °F across element ____meg Ω; to ground ____ meg Ω.

Capacitance at top rated temperature across element _____ pf.

Transducer: Reference Sensitivity at _______cps.
Reference Sensitivity after maximum temperature of _____°F: ______
Reference Sensitivity after minimum temperature of _____°F: ______

Stud: Evidence of damage due to maximum and minimum temperature ______
Cable: Evidence of damage due to maximum and minimum temperature ______

6.3 Mounted resonant frequency

__________ Kc Measured by _____________ Method with/without mounting stud

6.4 Frequency response

See Individual Acceptance Test (5.2.2)

NOTE — Bold numbers and numbers in parentheses refer to sections in ISA-RP37.2.

6.5 Amplitude linearity

Preamplifier Model ________________ Gain _________________

Cable Capacitance __________________ pf

VIBRATION				SHOCK			
Amplitude	**Signal**	**Sensitivity**	**Deviation from Ref. Sens.**	**Amplitude**	**Signal**	**Sensitivity**	**Deviation from Ref. Sens.**

6.6 Strain sensitivity

____g x 10^{-6} for a strain in the plane of the base.

6.7 Temperature sensitivity error

See Individual Acceptance Test (5.4.1)

6.8 Transient temperature error

DC Amplifier Model #______ Input Resistance _______ ohms
Ambient Temperature of Aluminum Block _____°F; Water Temperature ____°F
Cable capacitance ______ pf; Amplifier Gain ________
Maximum DC voltage generated: __________ volts and __________g/°F

6.9 Acoustic sensitivity

Preamplifier Model # ________ Gain ________ Cable Capacitance________ pf

Frequency Band	SPL	mv (rms)	Equivalent g

6.10 Electromagnetic response

Preamplifier Model ________ Gain ________ Cable Capacitance __________ pf

Mounting Material _________ Weight __________

Magnetic field level __________gauss at _________ cps

Transducer output __________ mv _____________ g/gauss

6.11 Transducer seal

Water Temperature ________ °F

Pressure ________ psia

Air Leakage?

Insulation Resistance across Element _______ meg Ω; to ground _______ meg Ω

6.12 Other environmental effects

Give details of tests and results of measurements.

6.13 Sensitivity stability

Stability Tests:

a) Soak Temperature: _____°F; Time: _____ hr; Cooling time: _____hrs.

b) Impact Acceleration: _____ g applied _____ times.

c) Soak Temperature: _____°F; time: _____ hr; warming time: _____ hrs.

Reference Sensitivity measured at ______ cps, ______ °F.

REFERENCE SENSITIVITY IN MV/G

Serial No.	Before Tests	After (1)	24 hrs. after (2)	After (3)

	Serial No.	Before Tests	After (1)	24 hrs. after (2)	After (3)
TRANSDUCER CAPACITANCE (pf)					
CABLE CAPACITANCE (pf)					

BY______________________DATE_________________APPROVED______________________

NOTE—Test numbers and numbers in parentheses refer to procedures in ISA-RP37.2.

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