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Methods for the calibration of vibration and shock transducers —

Part 16: Calibration by Earth's gravitation

Méthodes pour l'étalonnage des transducteurs de vibrations et de chocs —

Partie 16: Étalonnage par gravitation tellurique

[Revision of first edition (ISO 5347-5:1993)]

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16063-16 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

ISO 16063 consists of the following parts, under the general title *Methods for the calibration of vibration and shock transducers*:

- *Part 1: Basic concepts*
- *Part 11: Primary vibration calibration by laser interferometry*
- *Part 12: Primary vibration calibration by the reciprocity method*
- *Part 13: Primary shock calibration using laser interferometry*
- *Part 15: Primary angular vibration calibration by laser interferometry*
- *Part 21: Vibration calibration by comparison to a reference transducer*
- *Part 22: Shock calibration by comparison to a reference transducer*
- *Part 31: Testing of transverse vibration sensitivity*
- *Part 41: Calibration of laser vibrometers*

The following parts are under preparation:

- *Part 32: Resonance testing – Testing the frequency and the phase response of accelerometers by means of its excitation*
- *Part 42: Calibration of seismometers with high accuracy using acceleration of gravity*

Methods for the calibration of vibration and shock transducers — Part 16: Calibration by Earth's gravitation

1 Scope

ISO 16063 comprises of a series of documents dealing with methods for the calibration of vibration and shock transducers.

This part of ISO 16063 specifies the instrumentation and procedure to be used for performing primary calibration of accelerometers using Earth's gravitation. It is applicable to rectilinear accelerometers with DC (zero hertz frequency) response, such as straingauge-, piezoresistive-, variable capacitance- and servo accelerometer types.

This part of ISO 16063 is applicable to the calibration of the magnitude of the sensitivity, referenced to the acceleration due to the local gravitation at 0 Hz.

With the use of appropriate calibration equipment, this part of ISO 16063 can be applied to the calibration of the magnitude of the sensitivity, referenced to fractional parts of the acceleration due to the local gravitation at 0 Hz. The specification of the instrumentation used, contains requirements on environmental conditions as well as specific requirements for the apparatus to be used.

NOTE This part of ISO 16063 is applicable to reference standard accelerometers and working standard accelerometers.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Mechanical vibration, shock and conditioning monitoring – Vocabulary*

ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers – Part 1: Basic concepts*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*[1)]

ISO/IEC Guide 99, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

1) ISO/IEC Guide 98-3 is a reissue of the Guide to the expression of uncertainty in measurement (GUM) with necessary correction only to the printed 1995 version.

3 Uncertainty of measurement

All users of this part of ISO 16063 are expected to make an uncertainty budget according to Annex A in order for them to document their uncertainty of measurement (UoM) estimation. A calibration arrangement example is given in order to help set up systems that fulfil different uncertainty requirements.

When the local value of acceleration due to gravitation (g_l) is known and used, an UoM of 0,1 % can be obtained.

When the local value of acceleration due to gravitation (g_l) is not known and the standard acceleration due to gravitation (g_n) is used (ignoring the influence of latitude and altitude), an UoM of 0,5 % can be obtained. This estimation is assuming a value for the acceleration due to earth's gravitation of 9,8665 m/s^2 ± 0,026 m/s^2.

The aforementioned uncertainty limits are applicable for devices with a maximum transverse sensitivity of 5 %.

A more detailed description of the uncertainty components is given in Annex A.

NOTE The uncertainty of measurement is expressed as the expanded measurement uncertainty in accordance with ISO 16063-1 (referred to in short as uncertainty).

4 Requirements for apparatus and other conditions

4.1 General

This clause gives recommended specifications for the apparatus necessary to fulfil the scope of Clause 1 and to obtain the uncertainties of Clause 3, if the recommended specifications listed below are met for each item.

It is mandatory to document the expanded uncertainty using the methods of Annex A.

4.2 Environmental conditions

The calibration shall be carried out under the ambient conditions.

a) Room temperature: (23 ± 3) °C.

b) Relative humidity: 75 % RH max.

Care shall be taken that external vibration and noise do not affect the quality of the measurements.

4.3 Mounting platform

The mounting platform shall be arranged so that it is possible to rotate and align the geometric axis of sensitivity of the accelerometer from 0° to 180° relative to the direction of the gravitational acceleration vector.

At the measurement positions, the platform angle in all directions shall be within ± 0,1° relative to the vertical plane.

For performing measurements at positions that equal fractions of local gravity (mounting angle > 0° and < 180 °) the preferred orientation angles as per Table 1 shall be used:

Table 1 — Preferred orientation angles

Orientation angle (θ)	Magnitude of acceleration due to local gravity
± 30° (180 ± 30)°	0,866 0·g
± 45° (180 ± 45)°	0,707 1·g
± 60° (180 ± 60)°	0,500 0·g

$$a_\theta = g \cdot \cos(\theta) \quad (1)$$

where

a_θ is the magnitude of acceleration due to local gravity with the accelerometer mounted at a known angle, in metres per second squared.

θ is the accelerometer mounted angle, in degrees.

g is the magnitude for the acceleration due to local gravitation, in metres per second squared.

4.4 Accelerometer output measuring instrumentation

A voltage measuring instrument, measuring the output from the accelerometer having the following characteristics shall be used:

a) Frequency range: 0 Hz (DC voltage).

b) Maximum uncertainty: 0,05 % of reading.

4.5 Earth's gravitation

The positive and negative magnitudes for the acceleration due to local gravity, expressed in metres per second squared (m/s^2), shall be used.

The value of the local magnitude of acceleration due to gravity g_l can be determined by measurement with absolute or relative gravimeters [14] or by use of geodetic formulae [13], or survey.

$$g_l = 9{,}7803184\left(1 + 0{,}0053024\sin^2(\phi) - 0{,}0000059\sin^2(2\phi)\right) - 0{,}000003086H \quad (2)$$

where

- $g_{(l)}$ is the magnitude for the acceleration due to gravitation at the given latitude and elevation, in metres per second squared
- $\varnothing$ is the given latitude in radians
- H is the given altitude in metres above sea level.

Using (2), g_l can be determined with an uncertainty of 0,01 %.

If the magnitude for the acceleration due to local gravity is not known, then the standard acceleration due to gravity, g_n, shall be used.

g_n = 9,80665 m/s^2.

5 Method

5.1 General

As the acceleration due to gravitation varies with location and altitude (typical, values of acceleration due to local gravity at the locations of metrology institutes are within the range of 9,78 m/s^2 to 9,83 m/s^2), the local value with four significant digits shall be used.

5.2 Test procedure for 0° and 180°

Set the geometric axis of sensitivity of the accelerometer to 0° with the gravitational acceleration vector and record the accelerometer output voltage, u_0. Rotate the mounting platform so as to position the geometric axis of sensitivity of the accelerometer to 180° relative to the gravitational acceleration vector. Record the accelerometer output voltage, u_{180}.

Calculate the accelerometer sensitivity, S_g, in volts per metre per second squared (V/(m/s^2) using the following formula:

$$S_g = \frac{u_0 - u_{180}}{2 \cdot g} \qquad (3)$$

where

- u_0 is the value for accelerometer output at the first extremity of rotation (0°).
- u_{180} is the value for accelerometer output at the second extremity of rotation (180°).
- g is the magnitude for the acceleration due to gravitation that is applied in laboratory (g_n or g_l), in metres per second squared.

5.3 Test procedure for fractions of gravitation

Set the geometric axis of sensitivity of the accelerometer to ± n° relative to the vertical plane and record the accelerometer output voltages, $u_{\pm n}$. Rotate the mounting platform so as to position the geometric axis of sensitivity of the accelerometer to (180 ± n)° relative to the vertical plane. Record the accelerometer output voltages, $u_{180\pm n}$.

Calculate the accelerometer sensitivity, S_g, in volts per metre per second squared (V/(m/s^2) using the following formula:

$$S_g = \frac{u_n + u_{-n} - u_{180+n} - u_{180-n}}{4 \cdot g \cdot \cos n} \qquad (4)$$

where

S_g is the accelerometer sensitivity calibrated at an acceleration equal to (g·cos n)

u_n is the value for the accelerometer output at the first geometric axis of rotation (+n°), in volts (V).

$u_{180\text{-}n}$ is the value for accelerometer output at the second geometric axis of rotation (180-n)°, in volts (V).

u_{180+n} is the value for accelerometer output at the third geometric axis of rotation (180+n)°, in volts (V).

u_{-n} is the value for accelerometer output at the forth geometric axis of rotation (-n°), in volts (V).

g is the magnitude of the acceleration due to gravitation that is applied in the laboratory (g_n or g_l) , in metres per second squared (m/s^2).

n is the angle between the gravitational vector and the geometric axis of sensitivity of the accelerometer, in degrees (°).

5.4 Calibration setup

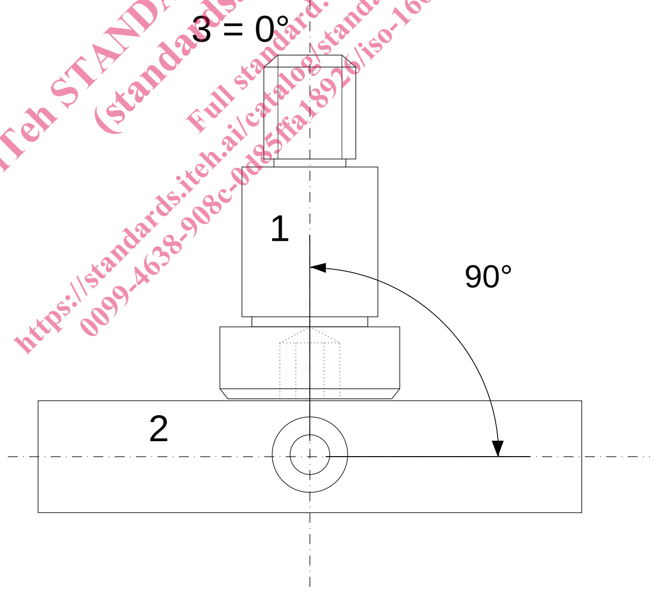

Figure 1 — Accelerometer setup showing 0° measurement position

Key

1 Accelerometer
2 Mounting platform
3 Angle between the gravitational vector and the geometric axis of sensitivity of the accelerometer