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Methods for the calibration of vibration and shock pick-ups —

Part 5:
Calibration by Earth's gravitation

Méthodes pour l'étalonnage de capteurs de vibrations et de chocs —
Partie 5: Étalonnage par gravitation tellurique

Reference number
ISO 5347-5:1993(E)

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.

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.

International Standard ISO 5347-5 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Sub-Committee SC 3, *Use and calibration of vibration and shock measuring instruments*.

ISO 5347 consists of the following parts, under the general title *Methods for the calibration of vibration and shock pick-ups*:

— *Part 0: Basic concepts*

— *Part 1: Primary vibration calibration by laser interferometry*

— *Part 2: Primary shock calibration by light cutting*

— *Part 3: Secondary vibration calibration*

— *Part 4: Secondary shock calibration*

— *Part 5: Calibration by Earth's gravitation*

— *Part 6: Primary vibration calibration at low frequencies*

— *Part 7: Primary calibration by centrifuge*

— *Part 8: Primary calibration by dual centrifuge*

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— *Part 9: Secondary vibration calibration by comparison of phase angles*

— *Part 10: Primary calibration by high-impact shocks*

— *Part 11: Testing of transverse vibration sensitivity*

— *Part 12: Testing of transverse shock sensitivity*

— *Part 13: Testing of base strain sensitivity*

— *Part 14: Resonance frequency testing of undamped accelerometers on a steel block*

— *Part 15: Testing of acoustic sensitivity*

— *Part 16: Testing of mounting torque sensitivity*

— *Part 17: Testing of fixed temperature sensitivity*

— *Part 18: Testing of transient temperature sensitivity*

— *Part 19: Testing of magnetic field sensitivity*

— *Part 20: Primary vibration calibration by the reciprocity method*

Annex A forms an integral part of this part of ISO 5347.

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Methods for the calibration of vibration and shock pick-ups —

Part 5:
Calibration by Earth's gravitation

1 Scope

ISO 5347 comprises a series of documents dealing with methods for the calibration of vibration and shock pick-ups.

This part of ISO 5347 lays down detailed specifications for the instrumentation and procedure to be used for primary calibration of accelerometers using Earth's gravitation.

This part of ISO 5347 applies to rectilinear accelerometers with zero-frequency response, mainly of the straingauge or piezoresistive type, to servopick-ups, and to primary standard and working pick-ups.

It is applicable for ± local Earth's gravitation at 0 Hz.

The limit of uncertainty applicable is ± 0,01 m/s^2.

2 Apparatus

2.1 Equipment capable of maintaining room temperature at 23 °C ± 3 °C.

2.2 Platform, arranged so that it is possible to rotate the accelerometer through 180° in a vertical plane which contains the sensitive axis of the accelerometer.

At the measuring positions, the platform angle in all directions shall be within ± 0,5° relative to the vertical plane.

2.3 Instrumentation for measuring accelerometer output, with a maximum uncertainty of ± 0,01 % of reading.

3 Preferred values

The positive and negative local values for the acceleration due to the Earth's gravity, expressed in metres per second squared, shall be used.

NOTE 1 Calibration at values between the positive and negative values for acceleration due to the Earth's gravity using a component of Earth's gravitation should not be used, as it is not usually possible to separate the output caused by this component from output due to the transverse sensitivity.

4 Method

4.1 Test procedure

As the acceleration due to the Earth's gravity varies with location and altitude (values from 9,78 m/s^2 to 9,83 m/s^2 are possible), the local value with four significant digits shall be used.

Set the sensitive accelerometer to 0° and then to 180° relative to the vertical plane. Measure the output voltage at the two levels.

4.2 Expression of results

Calculate the reference calibration factor, S, in volts per (metre per second squared) [V/(m/s²)], using the following formula:

$$S = \frac{V_a - V_b}{g_l}$$

where

V_a and V_b are the values for accelerometer output, in volts, at the two extremities of rotation over 180°;

g_l is the local value for the acceleration due to the Earth's gravity, in metres per second squared.

The values for $|V_a|$ and $|V_b|$ should also be reported.

When the calibration results are reported, the total uncertainty of the calibration and the corresponding confidence level, calculated in accordance with annex A, shall also be reported.

A confidence level of 99 % shall be used.

Annex A
(normative)

Calculation of uncertainty

A.1 Calculation of total uncertainty

The total uncertainty of the calibration for the specified confidence level (for the purposes of this part of ISO 5347, CL = 99 %), X_{99}, shall be calculated from the following formula:

$$X_{99} = \pm \sqrt{X_r^2 + X_s^2}$$

where

X_r is the random uncertainty;

X_s is the systematic uncertainty.

The random uncertainty for the specified confidence level, $X_{r(99)}$, is calculated from the following formula:

$$X_{r(99)} = \pm\, t \left[\frac{e_{r1}^2 + e_{r2}^2 + e_{r3}^2 + \ldots + e_{rn}^2}{n(n-1)} \right]^{1/2}$$

where

e_{r1}, e_{r2}, etc. are the deviations from the arithmetic mean of single measurements in the series;

n is the number of measurements;

t is the value from Student's distribution for the specified confidence level and the number of measurements.

The systematic errors shall, first of all, be eliminated or corrected. The remaining uncertainty, $X_{s(99)}$, shall be taken into account by using the following formula:

$$X_{s(99)} = \frac{K}{\sqrt{3}} \times e_S$$

where

K equals 2,6 for the 99 % confidence level;

e_S is the absolute uncertainty for the reference calibration factor, expressed in volts per (metre per second squared) (see A.2).

A.2 Calculation of the absolute uncertainty for the reference calibration factor, e_S

The absolute uncertainty for the reference calibration factor (i.e. at positive and negative local values for the acceleration due to gravity), e_S, in volts per (metre per second squared), is calculated by the law of the combination of errors from the following formula:

$$\frac{e_S}{S} = \pm \left[\left(\frac{e_{V_d}}{V_d} \right)^2 + \left(\frac{2e_{g_l}}{g_l} \right)^2 + (1 - \cos e_0)^2 + (1 - \cos e_{180})^2 \right]^{1/2}$$

where

S is the reference calibration factor (see 4.2);

V_d is the difference in accelerometer output, in volts, when rotating the accelerometer from 0° to 180° (i.e. $V_a - V_b$, see 4.2);

e_{V_d} is the absolute error for the difference in accelerometer output, V_d, in volts;

g_l is the local value for the acceleration due to the Earth's gravity, in metres per second squared;

e_{g_l} is the absolute uncertainty in the estimate of the local value for the acceleration due to the Earth's gravity, in metres per second squared;

e_0 is the absolute uncertainty, in degrees, for the 0° alignment;

e_{180} is the absolute uncertainty, in degrees, for the 180° alignment.

A.3 Calculation of the total absolute uncertainty for the reference calibration factor, e_{S_1}, for values outside $\pm g_l$

The total absolute uncertainty for the reference calibration, e_{S_1}, in volts per (metre per second squared), for values outside $\pm g_l$ is calculated from the following formula[1]:

$$\frac{e_{S_1}}{S} = \pm\left[\left(\frac{e_S}{S}\right)^2 + \left(\frac{L_{fA}}{100}\right)^2 + \left(\frac{L_{fP}}{100}\right)^2 + \left(\frac{L_{aA}}{100}\right)^2 + \left(\frac{L_{aP}}{100}\right)^2 + \left(\frac{I_A}{100}\right)^2 + \left(\frac{I_P}{100}\right)^2 + \left(\frac{R}{100}\right)^2 + \left(\frac{E_A}{100}\right)^2 + \left(\frac{E_P}{100}\right)^2\right]^{1/2}$$

where

e_S is the absolute uncertainty for the reference calibration factor, in volts per (metre per second squared);

S is the reference calibration factor, in volts per (metre per second squared);

L_{fA} is the frequency linearity deviation, expressed as a percentage of the reference calibration factor for the amplifier;

L_{fP} is the frequency linearity deviation, expressed as a percentage of the reference calibration factor for the accelerometer;

L_{aA} is the amplitude linearity deviation, expressed as a percentage of the reference calibration factor for the amplifier;

L_{aP} is the amplitude linearity deviation, expressed as a percentage of the reference calibration factor for the accelerometer;

I_A is the instability error for the amplifier gain and any source impedance error, expressed as a percentage of the reference calibration factor;

I_P is the instability error for the reference accelerometer, expressed as a percentage of the reference calibration factor;

R is the tracking error for the reference amplifier range (errors in gain for different amplification settings), expressed as a percentage of the reference calibration factor;

E_A is the error caused by environmental effects on the amplifier, expressed as a percentage of the reference calibration factor;

E_P is the error caused by environmental effects on the pick-up, expressed as a percentage of the calibration factor.

1) If an amplifier is not used, the terms with the subscript "A" are deleted.

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