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

Part 4:
Secondary shock calibration

Méthodes pour l'étalonnage de capteurs de vibrations et de chocs —
Partie 4: Étalonnage secondaire de chocs

Reference number
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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.

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 5347-4 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 4:
Secondary shock calibration

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 secondary shock calibration of accelerometers. It applies to rectilinear accelerometers of the strain gauge, piezoresistive and piezoelectric types and to secondary standard accelerometers.

This part of ISO 5347 is applicable for a time range from 0,1 ms to 10 ms and a dynamic range from 100 m/s^2 to 10^5 m/s^2.

The limits of uncertainty applicable are ± 5 % of the reading.

2 Apparatus

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

2.2 Reference standard accelerometer, calibrated by a primary shock calibration method.

2.3 Shock machine (see figure 1), with a hammer (a steel ball is recommended) which is permitted to move and to strike a steel anvil to which the accelerometer (reference standard accelerometer and accelerometer to be calibrated) are attached back-to-back.

The hammer imparts a motion to the anvil which is permitted to accelerate freely while the hammer is automatically caught up.

Steel springs or cushioning pads of rubber or paper shall be used on top of the anvil to obtain the desired pulse duration.

The shock pulses obtained shall have the shape of a half-sine wave.

The resonance frequencies of the hammer and of the anvil shall be at least $10/T$, where T is the pulse duration, in seconds.

In order to avoid influences from resonances in the shock machine structure, the hammer and the anvil shall operate freely from the structure.

The anvil shall be supported by a thin rod of brittle material or by a magnet. It is recommended that a sensor be used to trigger the shock-measuring equipment.

2.4 Acceleration/time recording equipment.

The equipment shall comprise a memory oscilloscope or transient recorder for two channels with peak amplitude detector and a display for peak pulse amplitude, or a strip chart or $X-Y$ recorder to obtain a readout of the stored transient.

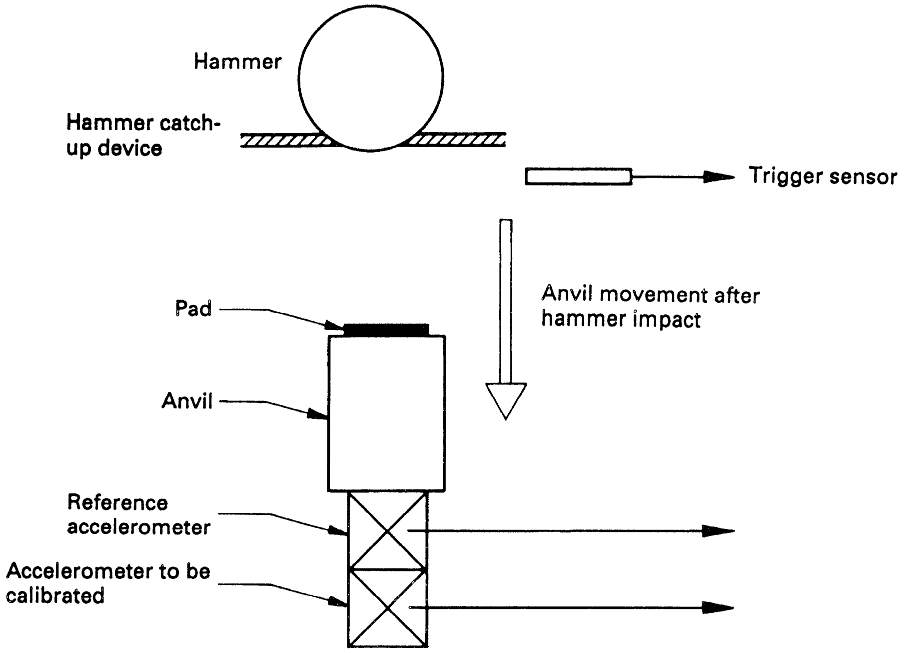

Figure 1 — Shock machine

The equipment shall have the following characteristics:

- range: 1 µs to 10 ms and 0 to 50 V;
- uncertainty for amplitude: maximum ± 2 % of reading;
- amplitude linearity: ± 1 % max. deviation from best fit line.

As the recording equipment acts as a low-pass filter, the same requirements specified for the low-pass filters (see 2.5) are valid for this equipment.

The frequency response shall be flat within ± 3 dB from 0,008/T to 10/T Hz, where T is the pulse duration.

2.5 Low-pass filter.

The use of low-pass filters shall be avoided.

If filters have to be used, the − 3 dB lower limiting frequency shall be lower than 0,008/T and the − 3 dB upper limiting frequency shall be above 10/T, where T is the pulse duration.

NOTE 1 The same requirements are valid for amplifiers and recording equipment.

2.6 Other apparatus requirements.

The mounted resonance frequencies of the accelerometers shall be higher than 20/T, where T is the pulse duration for a half-sine wave.

The reference accelerometer shall be structurally rigid. The base strain sensitivity shall be $< 0{,}2 \times 10^{-8}$ m/s^2 at a base strain of $2{,}5 \times 10^{-4}$ m/s^2, the transverse sensitivity < 2 % and the stability of the accelerometer/amplifier combination shall be better than 0,2 % of the reading per year at reference values.

If there are filters in the amplifier, the filter cut-off frequency shall comply with the filter settings specified in 2.5. The frequency response shall be flat within ± 3 dB from 0,008/T to 10/T, where T is the pulse duration.

3 Preferred pulse durations and accelerations

The following shock pulse durations, in milliseconds, shall be used:

- 0,1; 0,2; 0,5; 1; 2; 5; 10.

The following accelerations, in metres per second squared, shall be used:

- 100, 200, 500;
- 1 000, 2 000, 5 000;
- 10 000, 20 000, 50 000, 100 000.

4 Method

4.1 Test procedure

For shock calibrations, the sinusoidal vibration calibration factor shall be used as reference calibration factor.

The shock motion calibrations are then used to measure the amplitude linearity deviations at high accelerations, when applicable.

By giving the hammer different velocities and using different anvils and different springs or cushion pads, determine the shock calibration factors at the standard selected shock pulse durations and accelerations, and for the standard amplifier range switch positions.

The results shall be given as a percentage deviation from the sinusoidal reference calibration factor.

4.2 Expression of results

Calculate the calibration factor, S, expressed in volts per (metre per second squared) [V/(m/s^2)], using the following formula:

$$S = \frac{A_{\mathrm{peak}}}{A_{\mathrm{st,peak}}} \times S_{\mathrm{st}}$$

where

A_{peak}	is the acceleration peak value of the pick-up to be calibrated;
$A_{\mathrm{st,peak}}$	is the acceleration peak value of the reference standard;
S_{st}	is the calibration factor of the reference standard, in volts per (metre per second squared).

NOTE 2 If there is a zero shift in the signal, the zero point immediately before the shock and the shifted zero point immediately after the shock shall be connected by a straight line, this line being the baseline for acceleration determination.

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 95 % 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 = 95 %), X_{95}, shall be calculated from the following formula:

$$X_{95} = \pm \sqrt{X_{\mathrm{r}}^2 + X_{\mathrm{s}}^2}$$

where

X_{r} is the random uncertainty;

X_{s} is the systematic uncertainty.

The random uncertainty for the specified confidence level, $X_{\mathrm{r(95)}}$, is calculated from the following formula:

$$X_{\mathrm{r(95)}} = \pm\, t \left[\frac{e_{\mathrm{r1}}^2 + e_{\mathrm{r2}}^2 + e_{\mathrm{r3}}^2 + \ldots + e_{\mathrm{r}n}^2}{n(n-1)} \right]^{1/2}$$

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, $X_{\mathrm{s(95)}}$, shall be taken into account by using the following formula:

$$X_{\mathrm{s(95)}} = \frac{K}{\sqrt{3}} \times e_{S,\mathrm{sh2}}$$

where

K equals 2,0 for the 95 % confidence level;

$e_{S,\mathrm{sh2}}$ is the absolute uncertainty for the shock calibration factor of the accelerometer to be calibrated for the calibrated pulse times, accelerations and amplifier gain settings, expressed in volts per (metre per second squared) (see A.2).

A.2 Calculation of the absolute uncertainty for the shock calibration factor, $e_{S,\mathrm{sh2}}$, for calibrated pulse times, accelerations and amplifier gain settings

The absolute uncertainty for the shock calibration factor of the accelerometer to be calibrated, $e_{S,\mathrm{sh2}}$, in volts per (metre per second squared), for the calibrated pulse times, accelerations and amplifier gain settings is calculated from the following formula:

$$\frac{e_{S,\mathrm{sh2}}}{S_{\mathrm{sh}}} = \pm \left[\left(\frac{e_{S,\mathrm{sh1}}}{S_{\mathrm{sh1}}} \right)^2 + \left(\frac{e_a}{a_{\mathrm{max}}} \right)^2 \right]^{1/2}$$

where

S_{sh} is the shock calibration factor (amplitude-dependent), in volts per metre second squared;

$e_{S,\mathrm{sh1}}$ is the absolute uncertainty for the shock calibration factor of the reference accelerometer, in volts per metre second squared;

S_{sh1} is the shock calibration factor (amplitude-dependent) for the reference accelerometer, in volts per metre second squared;

a_{max} is the maximum acceleration measured by the acceleration/time recording equipment, in metres per second squared;

e_a is the total error in comparison measurements of the two peak accelerations, in metres per second squared — the error includes reading errors or chart-recording and chart-reading errors, and signal channels difference errors.

A.3 Calculation of the total absolute uncertainty for the shock calibration factor, $e_{S,\mathrm{sh2,t}}$, over the complete range

The absolute uncertainty for the shock calibration factor, calculated in accordance with A.2, is only valid for reference shocks and reference equipment settings. For general use, the total absolute uncertainty for the shock calibration factor, $e_{S,\mathrm{sh2,t}}$, in volts per (metre per second squared), over the complete range is calculated from the following formula:

$$\frac{e_{S,\mathrm{sh2,t}}}{S_{\mathrm{sh}}} = \pm \left[\left(\frac{e_{S,\mathrm{sh2}}}{S_{\mathrm{sh}}} \right)^2 + \left(\frac{L_{\mathrm{fA2}}}{100} \right)^2 + \left(\frac{L_{\mathrm{fP2}}}{100} \right)^2 + \left(\frac{L_{\mathrm{aA2}}}{100} \right)^2 + \left(\frac{L_{\mathrm{aP2}}}{100} \right)^2 + \left(\frac{I_{\mathrm{A2}}}{100} \right)^2 + \left(\frac{I_{\mathrm{P2}}}{100} \right)^2 + \left(\frac{R_2}{100} \right)^2 + \right.$$
$$\left. + \left(\frac{E_{\mathrm{A2}}}{100} \right)^2 + \left(\frac{E_{\mathrm{P2}}}{100} \right)^2 + \left(\frac{L_{\mathrm{fL}}}{100} \right)^2 + \left(\frac{L_{\mathrm{aL}}}{100} \right)^2 + \left(\frac{I_{\mathrm{L}}}{100} \right)^2 + \left(\frac{E_{\mathrm{L}}}{100} \right)^2 + \left(\frac{E_{\mathrm{M}}}{100} \right)^2 \right]^{1/2}$$

where

S_{sh} is the shock calibration factor (amplitude-dependent), in volts per (metre per second squared);

$e_{S,\mathrm{sh2}}$ is the absolute uncertainty for the shock calibration factor, of the accelerometer to be calibrated, in volts per (metre per second squared) (see A.2);

L_{fA2} is the frequency linearity deviation, expressed as a percentage of the calibration factor for the amplifier for the pick-up to be calibrated;

L_{fP2} is the frequency linearity deviation, expressed as a percentage of the calibration factor for the pick-up to be calibrated;

L_{aA2} is the amplitude linearity deviation, expressed as a percentage of the calibration factor for the amplifier for the pick-up to be calibrated;

L_{aP2} is the amplitude linearity deviation, expressed as a percentage of the calibration factor for the pick-up to be calibrated;

I_{A2} is the instability error for the amplifier gain and source impedance error, expressed as a percentage of the calibration factor for the amplifier for the pick-up to be calibrated;