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

Part 3:
Secondary vibration calibration

*Méthodes pour l'étalonnage de capteurs de vibrations et de chocs —
Partie 3: Étalonnage secondaire de vibrations*

Reference number
ISO 5347-3:1993(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 5347-3 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 3:
Secondary vibration 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 vibration calibration of rectilinear pick-ups and working pick-ups.

It is applicable for the following parameters:

— frequency range: 20 Hz to 5 000 Hz;

— dynamic range: 0,1 µm to 10 mm (frequency-dependent);
1 mm/s to 10 m/s (frequency-dependent);
10 m/s^2 to 1 000 m/s^2 (frequency-dependent).

The limits of uncertainty applicable are as follows:

for displacement and velocity pick-ups 20 Hz to 1 000 Hz: ± 4 % of reading;

for accelerometers 20 Hz to 1 000 Hz: ± 2 % of reading;

for accelerometers 20 Hz to 2 000 Hz: ± 3 % of reading;

for accelerometers 20 Hz to 5 000 Hz: ± 5 % of reading.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 5347. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 5347 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5347-1:1993, *Methods for the calibration of vibration and shock pick-ups — Part 1: Primary vibration calibration by laser interferometry.*

3 Apparatus

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

3.2 Primary standard accelerometer, calibrated together with amplifier in accordance with the laser-interferometer method (see ISO 5347-1) within ± 0,5 % at selected frequency and acceleration.

3.3 Frequency generator and indicator, having the following characteristics:

— uncertainty for frequency: maximum ± 0,1 % of reading;

— frequency stability: better than ± 0,1 % of reading over the measurement period;

— amplitude stability: better than ± 0,1 % of reading over the measurement period.

3.4 Power amplifier/vibrator combination, having the following charateristics:

— total distortion: 5 % max.;

— transverse, bending and rocking accelerations: kept to a minimum, 10 % max. of the acceleration in the intended direction at used frequencies; above 1 000 Hz, 30 % is permitted;

— hum and noise: 40 dB min. below full output;

— acceleration amplitude stability: better than ± 0,1 % of reading over the measurement period.

Base strain introduced to the pick-up from the attachment surfaces shall not influence the calibration factor.

3.5 Voltage instrumentation measuring true r.m.s. at accelerometer output, having the following characteristics:

— frequency range: 20 Hz to 5 000 Hz;

— uncertainty, maximum: ± 0,1 % of reading;

The r.m.s. value shall be multiplied by a factor of $\sqrt{2}$ to obtain (single) amplitude used in the formulae.

3.6 Distortion-measuring instrumentation, capable of measuring total distortion of 0 to 10 % and having the following characteristics:

— frequency range: 5 Hz to 10 kHz;

— uncertainty, maximum: ± 10 % of reading.

3.7 Oscilloscope (not mandatory), for checking of waveform of the pick-up signal, having a frequency range from 5 Hz to 5 000 Hz.

4 Preferred amplitudes and frequencies

Six amplitudes and six frequencies equally covering the pick-up range shall be chosen from the following series:

a) **Amplitude**, in metres per second squared:

1, 2, 5, 10 or their multiples of ten.

b) **Frequency**, in hertz:

20, 40, 80, 160, 315, 630, 1 250, 2 500, 5 000.

Values chosen shall be the same as for the standard accelerometer calibration values.

5 Method

5.1 Test procedure

Mount the primary standard accelerometer (3.2) and the pick-up to be calibrated back-to-back on the vibrator head. The test set-up shall be as shown in figure 1.

Check the distortion and transverse movement for the two pick-ups at the calibration frequencies and levels.

Measure the output voltage for the two pick-ups.

Determine the reference calibration factor at the reference frequency, for accelerometers preferably at 160 Hz (second choice: 80 Hz), and at the reference amplitude, for accelerometers preferably at 100 m/s^2 (second choice: 10 m/s^2).

Then determine the calibration factor at the other calibration frequencies and amplitudes. The results shall be given as a percentage deviation from the reference calibration factor.

5.2 Expression of results

If the two pick-ups sense the same vibration parameter, calculate the calibration factor of the pick-up to be calibrated, S_2, using the following formula:

$$S_2 = \frac{x_2}{x_1} \times S_1$$

where

S_1 is the calibration factor of the primary standard;

x_1 is the output from the primary standard;

x_2 is the output from the pick-up to be calibrated.

If the two pick-ups sense different vibration parameters, calculate the calibration factor of the secondary pick-up, using the following formulae:

$$S_v = 2\pi f \times S_a$$

$$S_d = 4\pi^2 f^2 \times S_a$$

$$S_d = 2\pi f \times S_v$$

where

S_a is the acceleration calibration factor;

S_v is the velocity calibration factor;

S_d is the displacement calibration factor;

f is the frequency of the vibrator, in hertz.

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.

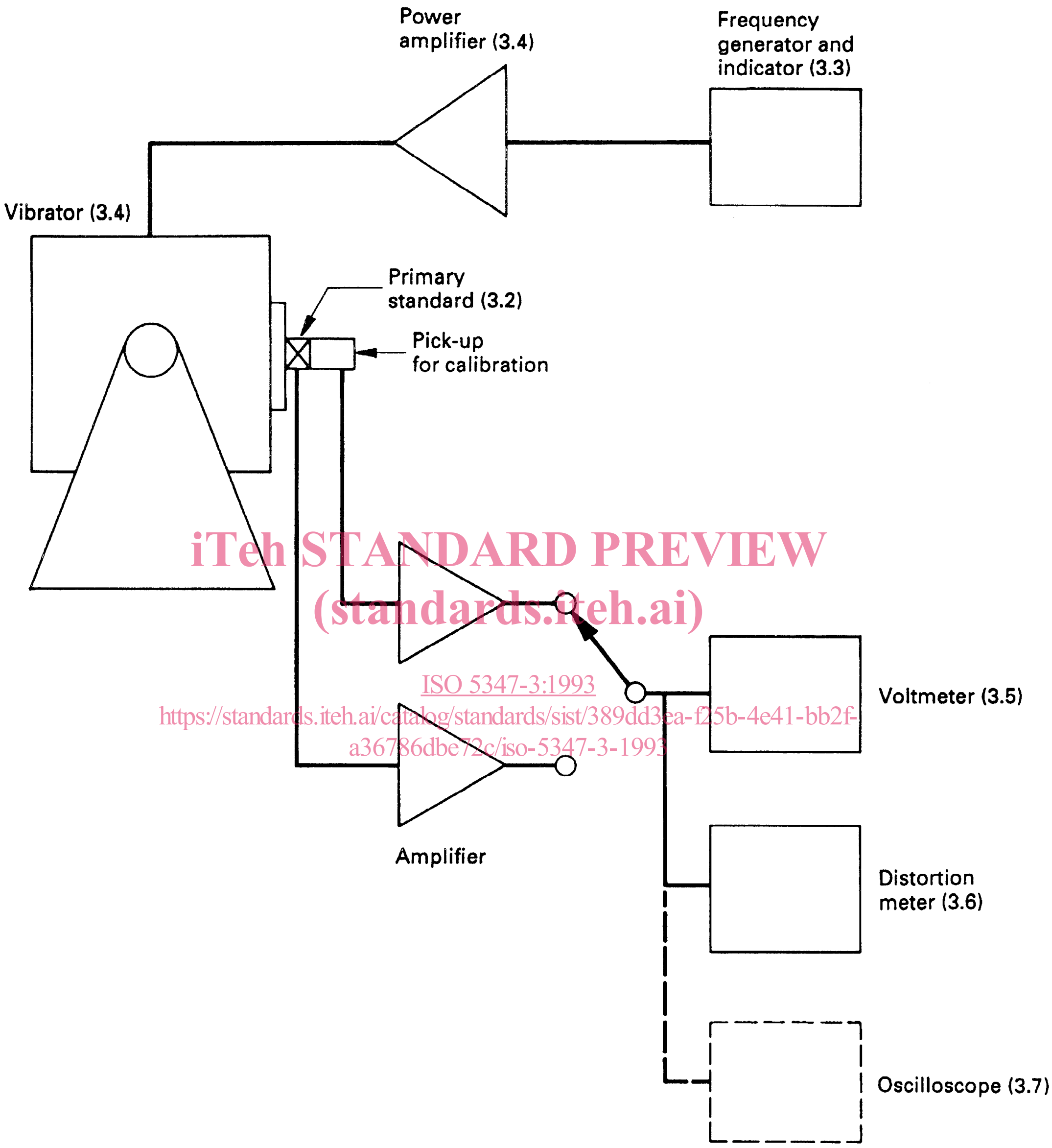

Figure 1 — Measuring system for secondary calibration method

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:

$$X_{95} = \pm \sqrt{X_r^2 + X_s^2}$$

where

X_r is the random uncertainty;

X_s is the systematic uncertainty.

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

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

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

$$X_{s(95)} = \frac{K}{\sqrt{3}} \times e_{S_2}$$

where

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

e_{S_2} is the absolute uncertainty for the calibration factor of the secondary pick-up for the calibrated frequencies, amplitude and amplifier gain settings (see A.2).

A.2 Calculation of the absolute uncertainty for the calibration factor, e_{S_2}, for calibration frequencies, amplitudes and amplifier gain settings

The absolute uncertainty for the calibration factor for the secondary pick-up, e_{S_2}, for the calibration frequencies, amplitudes and amplifier gain settings is calculated by the law of combination of errors from the following formula:

$$\frac{e_{S_2}}{S_2} = \pm \left\{ \left(\frac{e_{S_1}}{S_1} \right)^2 + \left(\frac{2e_V}{V} \right)^2 + \left[\frac{1}{2} \left(\frac{d_{tot}}{100} \right)^2 \right]^2 + \left(\frac{a_T T_1}{100 a_{rms}} \right)^2 + \left(\frac{a_T T_2}{100 a_{rms}} \right)^2 + \left(\frac{2 a_H}{a_{rms}} \right)^2 \right\}^{1/2}$$

If the calibration factor has been calculated by using the value of f (see 5.2), add the following factor to the formula above:

$$\left(\frac{e_f}{f}\right)^2$$

If the calibration factor has been calculated by using the value of f^2 (see 5.2), add the following factor to the formula above:

$$\left(\frac{2e_f}{f}\right)^2$$

where

S_2 is the calibration factor of the pick-up to be calibrated (see 5.2);

S_1 is the calibration factor of the primary standard;

S_d is the displacement calibration factor (see 5.2);

S_v is the velocity calibration factor (see 5.2);

S_a is the acceleration calibration factor (see 5.2);

e_{S_1} is the total absolute uncertainty for the reference standard pick-up and amplifier combination (not 0,5 %) calculated in accordance with total uncertainty calculation of the primary standard calibration method (see ISO 5347-1); it is dependent on selected frequency, amplitude and primary standard amplifier gain setting (see note 1);

V is the pick-up output, in volts;

e_V is the absolute error for the pick-up voltmeter output, in volts;

d_{tot} is the total distortion and is equal to $100\left(\frac{a_{tot}^2 - a_{rms}^2}{a_{rms}^2}\right)^{1/2}$, expressed as a percentage,

in which

a_{tot} is the total true r.m.s. acceleration, in metres per second squared;

a_{rms} is the true r.m.s. acceleration at driving frequency, in metres per second squared;

a_T is the transverse, rocking and bending vibration, in absolute measures;

T_2 is the maximum transverse sensitivity of the pick-up to be calibrated, expressed as a percentage of the transducer sensitivity in the measuring direction;

T_1 is the maximum transverse sensitivity of the reference pick-up, expressed as a percentage of the transducer sensitivity in the measuring direction;

a_H is the amplitude caused by hum and noise, in metres per second squared;

f is the frequency of the vibrator, in hertz;

e_f is the absolute uncertainty for the frequency of the vibrator, in hertz.

NOTE 1 The total absolute uncertainty for the calibration factor of the primary standard pick-up and amplifier combination, e_{S_1}, when they are used for values outside calibrated frequencies and amplitudes in accordance with the primary vibration calibration method, is calculated from the following formula:

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

where

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