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Methods for the calibration of vibration and shock transducers

Part 17: Primary calibration by centrifuge

National foreword

This British Standard is the UK implementation of ISO 16063-17:2016.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Methods for the calibration of vibration and shock transducers —

Part 17: Primary calibration by centrifuge

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

Partie 17: Étalonnage primaire par centrifugeur

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition of ISO 16063-17 cancels and replaces ISO 5347-7:1993, which has been technically revised.

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 16: Calibration by Earth's gravitation*

— *Part 17: Primary calibration by centrifuge*

— *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 32: Resonance testing — Testing the frequency and the phase response of accelerometers by means of shock excitation*

— *Part 41: Calibration of laser vibrometers*

— *Part 42: Calibration of seismometers with high accuracy using acceleration of gravity*

— *Part 43: Calibration of accelerometers by model-based parameter identification*

The following parts are under preparation:

— *Part 33: Testing of magnetic field sensitivity*

Methods for the calibration of vibration and shock transducers —

Part 17: Primary calibration by centrifuge

1 Scope

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

This part of ISO 16063 lays down detailed specifications for the instrumentation and procedure to be used for primary calibration of accelerometers using centrifuge calibration.

This part of ISO 16063 is applicable to rectilinear accelerometers with zero-frequency response, mainly of the strain gauge or piezoresistive type, and to primary standard and working transducers.

It is applicable for a calibration range from 10 m/s^2 to 20 000 m/s^2 (higher accelerations possible) at 0 Hz.

The limits of uncertainty applicable are ±1 % of reading.

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 condition monitoring — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 apply.

4 Requirements for apparatus and environmental conditions

4.1 Calibration environment

The standard reference atmospheric conditions are: (23 ± 3) °C and 75 % relative humidity max. The temperature, humidity and atmospheric pressure shall be measured and reported.

4.2 Balanced table or arm (rotational table)

The main component of the calibration apparatus consists of balanced table or arm which rotates about a vertical axis with uniform angular speed. For the calibration range from 10 m/s^2 to 100 m/s^2, the table/arm shall be level within ±0,5° of horizontal. For ranges higher than 100 m/s^2, levelling is allowed to within ±2°. The calibration apparatus shall be placed on a sufficiently heavy base which is sufficiently isolated from the floor vibration.

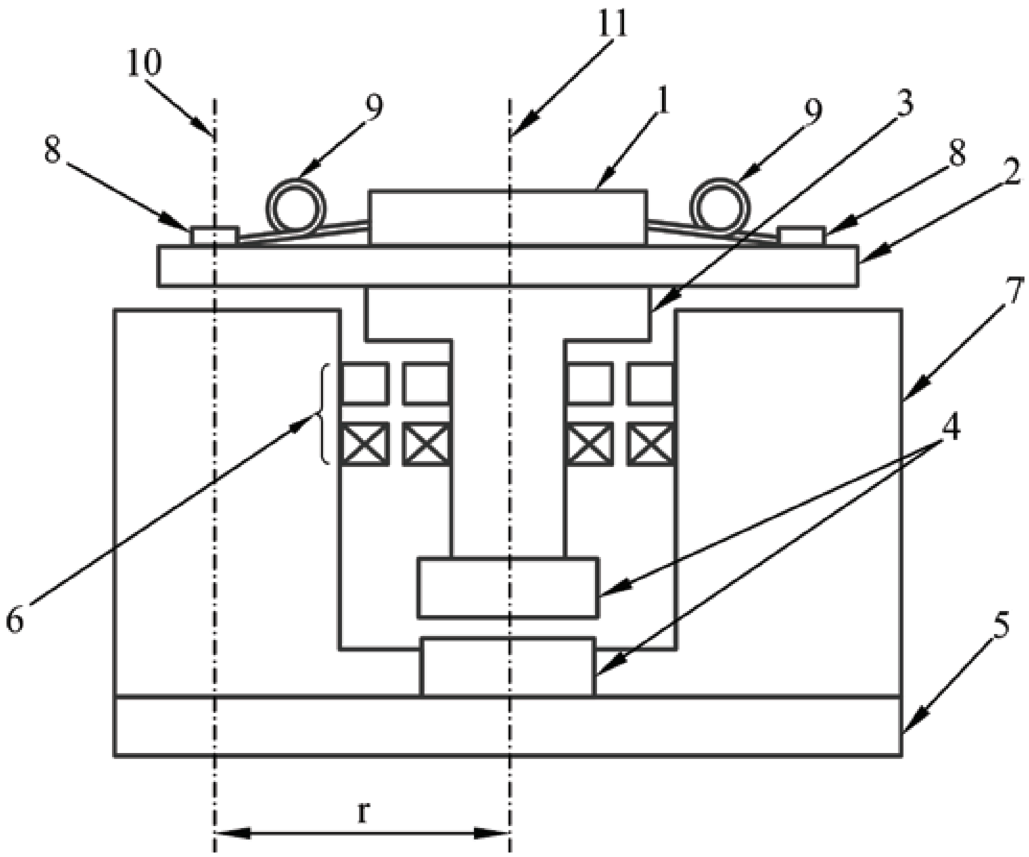
The rotational frequency shall be uniform within ±0,05 % of the nominal value.

The transducers axis of sensitivity shall be aligned within ±0,5°.

The radius of rotation to the centre of the transducer mass element shall be measured with an uncertainty less than ±0,15 %. If this is not possible, Method 2 shall be used (see Clause 7).

If the accelerometer is substituted by impedances not sensitive to acceleration, the hum and noise when the centrifuge is rotating at the calibration speeds shall be at least 0,5 % below reading.

The apparatus of the main component is illustrated by Figure 1.



Key

1 signal conditioner for transducers
2 balanced table
3 drive motor
4 bearing
5 vibration isolation stage
6 signal coupler
7 stone plate
8 transducers
9 cable
10 centre of mass
11 rotation centre

Figure 1 — Illustration of the apparatus of the main component

4.3 Rotational frequency measuring instrumentation

The relative expanded measurement uncertainty (k = 2) contribution of the measurement of rotational frequency shall be 0,05 % or less.

4.4 Voltage-measuring instrumentation

The relative expanded measurement uncertainty (k = 2) contribution of the voltmeter shall be 0,01 % or less.

5 Preferred values

Six acceleration values, in metres per second squared, equally covering the accelerometer range, shall be chosen from the following series: 10; 20; 50; 100; 200; 500 or their multiples of ten. The reference acceleration shall be 100 m/s^2 (second choice: 50 m/s^2).

6 Method 1 (with measurement of the radius of rotation)

6.1 Test procedure

Rotate the table or arm at different frequencies determined by calculation from the standard levels using Formula (1):

$$a = 4\pi^2 n^2 r \tag{1}$$

where

n is the rotational frequency, in hertz;

r is the radius of rotation to the centre of the accelerometer mass element, in metres.

Measure the transducer output at each rotational frequency.

Determine the reference calibration factor at the reference acceleration. Then, determine the sensitivity for the other calibration amplitudes. The results shall be given as a deviation from the reference calibration factor in percent.

6.2 Expression of results

The calibration factor, S, in volts per (metre per second squared) [V/(m/s^2)], is given by Formula (2):

$$S = \frac{V}{4\pi^2 n^2 r} \tag{2}$$

where

V is the transducer output, in volts;

n is the rotational frequency, in hertz;

r is the radius of rotation to the centre of the accelerometer mass element, in metres.

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.

7 Method 2 (without measurement of the radius of rotation)

7.1 Test procedure

If the rotational radius cannot be measured with the specified uncertainty, the transducer can be rotated in two different positions, the radial distance between these to be measured with uncertainty maximum of ±0,5 %.

Measure the two rotational frequencies giving the same transducer output at the two locations.

7.2 Expression of results

The calibration factor, S, in volts per (metre per second squared), is given by Formula (3):

$$S = \frac{V}{4\pi^2 {n_2}^2 \left| \dfrac{\Delta r}{1 - \left(n_2 / n_1\right)^2} \right|} \tag{3}$$

where

V is the accelerometer output, in volts;

n_1 is the rotational frequency at the first accelerometer position, in hertz;

n_2 is the rotational frequency at the second accelerometer position, in hertz;

Δr is the distance between the two accelerometer positions, in metres.

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.

Annex A
(informative)

Expression of uncertainty of measurement in calibration

A.1 Uncertainty analysis on Method 1

Components of uncertainty that contribute to the uncertainty of the measurement on Method 1 are listed in Table A.1. The combined standard uncertainty, u_c, can be expressed by Formula (A.1):

$$u_c = \sqrt{\sum_{i=1}^{10} (u_i)^2} \quad \text{(A.1)}$$

where u_i is uncertainty component in Table A.1, respectively.

The expanded uncertainty, U, shall be determined by multiplying u_c by coverage factor, k, where a value of $k = 2$.

Table A.1 — Uncertainty components on Method 1

i	Standard uncertainty component	Source of uncertainty	Relative uncertainty contribution $u_i(y)$
Acceleration generation			
1	$u(\alpha)$	Alignment effect for rotational plane α : deviation from rotational plane	$u_1(y) = \frac{9{,}8(1-\cos\alpha)}{a}$
2	$u(\beta)$	Alignment effect of transducer axe β : alignment deviation from transducer axe	$u_2(y) = (1-\cos\beta)$
3	$u(e_n)$	Rotational frequency effect e_n: rotational frequency deviation from nominal value	$u_3(y) = 2e_n / n$
4	$u(e_{\Delta n})$	Rotational frequency effect (cyclic) $e_{\Delta n}$: cyclic rotational frequency deviation	$u_4(y) = 2e_{\Delta n} / n$
5	$u(e_r)$	Rotational radius deviation effect e_r: deviation of radius	$u_5(y) = e_r / r$
Voltage measurement			
6	$u(e_{\mathrm{V}})$	Uncertainty of voltage measurement	$u_6(y)$
7	$u(a_{\mathrm{H}})$	Hum and noise effect	$u_7(y)$
8	$u(e_{\mathrm{P}})$	Effect of power supply	$u_8(y)$
Other factors			
9	$u(S_{\mathrm{T}})$	Effect of temperature	$u_9(y)$
10	$u(S_{\mathrm{hys}})$	Non linearity, hysteresis	$u_{10}(y)$

A.2 Uncertainty analysis on Method 2

Components of uncertainty that contribute to the uncertainty of the measurement on Method 2 are listed in Table A2. The combined standard uncertainty, u_c, can be expressed by Formula (A.2):

$$u_c = \sqrt{\sum_{i=1}^{10} (u_i)^2} \tag{A.2}$$

where u_i is uncertainty component in Table A.2, respectively.

The expanded uncertainty, U, shall be determined by multiplying, u_c, by coverage factor, k, where a value of $k = 2$.

Table A.2 — Uncertainty components on Method 2

i	Standard uncertainty component	Source of uncertainty	Relative uncertainty contribution $u_i(y)$
Acceleration generation			
1	$u(\alpha)$	Alignment effect for rotational plane α : deviation from rotational plane	$u_1(y) = \frac{9,8(1-\cos\alpha)}{a}$
2	$u(\beta)$	Alignment effect of transducer axe β : alignment deviation from transducer axe	$u_2(y) = (1-\cos\beta)$
3	$u(e_{n1})$	Rotational frequency effect at the first transducer position e_{n1}: rotational frequency deviation from nominal value at rotational n_2 frequency n_1	$u_3(y) = 2e_{n1} / n_1$
4	$u(e_{n2})$	Rotational frequency effect at the second transducer position e_{n2}: rotational frequency deviation from nominal value at rotational frequency	$u_4(y) = 2e_{n2} / n_2$
5	$u(e_{\Delta r})$	Distance measurement between the two transducer positions effect $e_{\Delta r}$: deviation of measurement between the positions, Δr: Distance between the positions	$u_5(y) = e_{\Delta r} / \Delta r$
Voltage measurement			
6	$u(e_V)$	Uncertainty of voltage measurement	$u_6(y)$
7	$u(a_H)$	Hum and noise effect	$u_7(y)$
8	$u(e_P)$	Effect of power supply	$u_8(y)$
Other factors			
9	$u(S_T)$	Effect of temperature	$u_9(y)$
10	$u(S_{hys})$	Non linearity, hysteresis	$u_{10}(y)$

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1) Reissue of the *Guide to the expression of uncertainty in measurement* (GUM), 1995.

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