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Methods for the calibration of vibration and shock transducers —

Part 34: Testing of sensitivity at fixed temperatures

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

Partie 34: Essai de sensibilité à des températures fixes

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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

This first edition of ISO 16063-34 cancels and replaces ISO 5347-17:1993, which has been technically revised. The main changes are as follows:

— a method for the determination of complex sensitivity using a laser interferometer has been added;

— a method for the determination of complex sensitivity using a reference transducer inside the temperature chamber has been added;

— a procedure for testing phase changes has been added;

— Annex A for the determination of the achievement time of the setpoint temperature for the device under test has been added;

— Annex B for the evaluating uncertainty caused by temperature tolerance has been added.

A list of all parts in the ISO 16063 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to establish the procedures for testing the complex sensitivity of vibration transducers at fixed temperatures in the temperature range from –190 °C to 800 °C and frequency range from 10 Hz to 3 kHz.

The three methods described in this document allow the determination of the complex sensitivity or temperature response of complex sensitivity of a transducer to sinusoidal vibration in the temperature chamber.

Principles, procedures, and uncertainties of calibrations such as a comparison to a reference transducer or an absolute measurement by laser interferometer are given in this document. Calibrations are carried out using one of the three methods, depending on the different principles to be used and the temperature and frequency range limitations.

Methods for the calibration of vibration and shock transducers —

Part 34:
Testing of sensitivity at fixed temperatures

1 Scope

This document details specifications for the instrumentation and methods to be used for testing fixed temperature sensitivity of vibration transducers. It applies to rectilinear velocity and acceleration transducers.

The methods specified use both a comparison to a reference transducer and an absolute measurement by laser interferometer.

This document is applicable for a frequency range from 10 Hz to 3 kHz (method-dependent), a dynamic range from 1 m/s^2 to 100 m/s^2 (frequency-dependent) and a temperature range from −190 °C to 800 °C (method-dependent). Although it is possible to achieve these ranges among all the described systems, generally each has limitations within them.

Method 1 (using a laser interferometer) is applicable to magnitude of sensitivity and phase calibration in the frequency range 10 Hz to 3 kHz at fixed temperatures (see Clause 7). Method 2 (using a reference transducer inside a chamber whose temperature limit is −70 °C to 500 °C) can be used for magnitude of sensitivity and phase calibration in the frequency range 10 Hz to 1 kHz at fixed temperatures (see Clause 8). Method 3 (using a reference transducer outside the chamber) can only be used for the determination of the temperature response of complex sensitivity over a certain temperature range (see Clause 9).

NOTE Method 1 and Method 2 can provide the deviation of complex sensitivity over a certain temperature range if the calibration is also done at the reference temperature (room temperature 23 °C ± 5 °C).

To ensure the consistency of the use and test condition, the transducer, its cable and the conditioning amplifier are intended to be considered as a single unit and tested together.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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*

ISO 16063-11:1999, *Methods for the calibration of vibration and shock transducers — Part 11: Primary vibration calibration by laser interferometry*

ISO 16063-21:2003, *Methods for the calibration of vibration and shock transducers — Part 21: Vibration calibration by comparison to a reference transducer*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1
temperature response
sensitivity of the transducer at a given frequency as a function of its steady-state temperature

Note 1 to entry: Temperature response is measured at specified frequencies within the rated frequency range of the transducer.

Note 2 to entry: In general, the sensitivity is a complex-valued function quantity and can be expressed in terms of its magnitude and phase.

4 Uncertainty of measurement

The limits of the uncertainty of measurement in terms of expanded uncertainty applicable to this document are as follows.

a) For the magnitude of sensitivity:

— when using a laser interferometer (Method 1): 0,5 % of the measured value at reference conditions; 1 % of the measured value outside reference conditions,

— when using a reference transducer (Method 2): 1 % of the measured value at reference conditions; 2 % of the measured value outside reference conditions,

— when using a reference transducer (Method 3): 2 % of the measured value at reference conditions; 3 % of the measured value outside reference conditions.

b) For the phase shift of sensitivity:

— when using a laser interferometer (Method 1): 0,5° at reference conditions; 1° outside reference conditions,

— when using a reference transducer (Method 2): 1° at reference conditions; 2,5° outside reference conditions,

— when using a reference transducer (Method 3): 2° at reference conditions; 3° outside reference conditions.

c) Recommended reference conditions are as follows:

— frequency f = 160, 80, 40 or 16 Hz (or angular frequency ω = 1 000 rad/s, 500 rad/s, 250 rad/s or 100 rad/s),

— acceleration (acceleration amplitude or RMS value): 50 m/s^2, 20 m/s^2, 10 m/s^2 or 5 m/s^2.

NOTE In practice, these limits can be exceeded depending on the vibratory characteristics of the fixture on the exciter; higher uncertainty values are accepted at some frequencies according to use requirements.

To undertake measurements over the proposed temperature range in supporting uncertainty budgets for transverse, bending, rocking accelerations, hum and noise, and relative motion issues, those measurements should be done at room temperature because the selected ceramic rod shall be rigid throughout the proposed temperature range.

The uncertainty of measurement shall be assessed and reported according to ISO 16063-11:1999, Annex A, and ISO 16063-21:2003, Annex A, to document the level of uncertainty expressed as expanded uncertainties for a coverage factor of 2 or a confidence probability of 95 %. It is the responsibility of the laboratory or end user to make sure that the reported values of expanded uncertainty are credible.

5 Ambient conditions

Calibration shall be carried out under the following ambient conditions:

a) room temperature, (23 ± 5) °C;

b) relative humidity, 75 % max.

6 Apparatus

The usual laboratory apparatus and, in particular, the following.

6.1 Vibration exciter.

Orientated vertically or horizontally, the vibrator exciter shall be used to cover the requested frequency and dynamic ranges.

6.2 Fixture.

Made of machinable ceramics, the fixture shall have low thermal conductivity and high stiffness. By mounting the tested transducer on the top of a ceramic rod, the rod protrudes into the temperature chamber from a vibration exciter on which it is placed. To reflect the laser, the surface of the mounting transducer should be optically polished, covered by a mirror, or be plated with chrome, or as adequate.

6.3 Temperature chamber.

The chamber should have a temperature range from −190 °C to 800 °C and should be specially designed so that the air temperature in the working space (the part of the chamber in which the device under test [DUT] can be maintained within the specified temperature tolerances) evenly achieves temperature uniformity within ±2 °C at fixed temperatures. At the top of the chamber, a hole should be sealed with glass, so that the laser passes through. An additional aperture on the side of the chamber is required to enable cables to be fed from the transducer under test to the external conditioning amplifier. A suitable sealing arrangement needs to be provided to maintain the chamber temperature. The design of the equipment shall also take into consideration the clamping of the transducer cables to reduce cable strain and flap. The indicated temperature range and temperature uniformity within ±2 °C are not mandatory. The chamber shall cover the required temperature range. Temperature uniformity within ±2 °C is recommended in some cases.

6.4 Temperature sensor.

The air temperature in the chamber is measured and controlled by a temperature sensor located close to the transducer under test. The location of the temperature sensor has no influence on the mounting and vibration of the transducer. Beside the control sensor, a second measurement sensor for temperature should be introduced; at least thermal stability of the air in the temperature chamber should be monitored separately.

6.5 Interferometer.

Refer to ISO 16063-11:1999, 3.6.

6.6 Reference transducer.

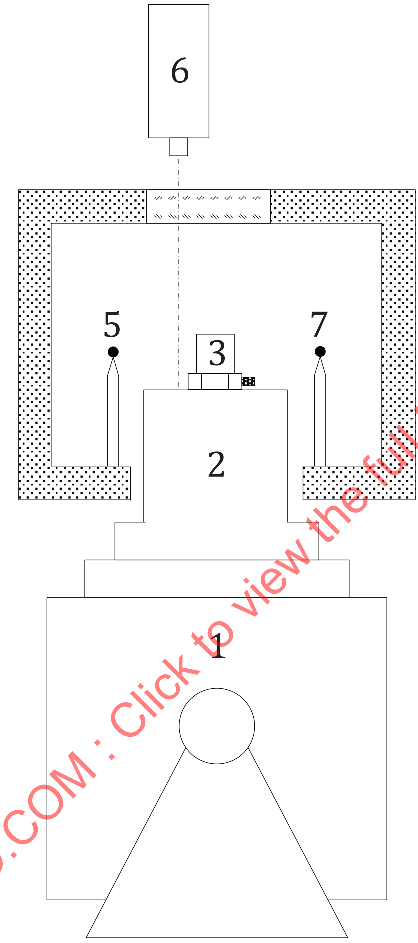
Together with the conditioning amplifier, the reference transducer should be calibrated according to Clause 7 with documented uncertainty (for Method 2) and calibrated by primary or comparison means with documented uncertainty (for Method 3). For Method 3, the temperature influence on the reference transducer shall be less than ±0,5 % of the reading.

Other apparatuses (e.g. data acquisition instrumentation) shall be as specified in ISO 16063-11:1999, Clause 3 for Method 1 and in ISO 16063-21:2003, Clause 4 for Methods 2 and 3.

7 Method 1: Determination of complex sensitivity using a laser interferometer

7.1 General

This test system primarily contains a vibration exciter equipped with a specially designed fixture for mounting a transducer, a temperature chamber and a laser interferometer; see Figure 1.



Key

1 vibration exciter (vertical or horizontal)
2 fixture (ceramic rod)
3 transducer under test
4 temperature chamber
5 control temperature sensor
6 interferometer
7 measure temperature sensor

Figure 1 — Test system with a laser interferometer

When testing by laser interferometer, the fixture transfer function error may be ignored, and the frequency response of the tested transducer's complex sensitivity for a certain frequency range at a fixed temperature can be determined. The laser interferometer can be positioned to measure the amplitude of the top of the ceramic rod close to the transducer under test. To reduce bending, tipping and transverse motion errors, several measurements can be taken around the base of the transducer under test and the average measurement can be used in the acceleration calculation.

The fringe-counting method and sine-approximation method are used to determine the complex sensitivity in the case of a fixed temperature. The fringe-counting method is applicable to sensitivity magnitude testing in the frequency range from 10 Hz to 800 Hz; this method may also be applied to higher frequencies if the quantization error is suppressed by special means. The sine-approximation method is applicable to sensitivity magnitude and phase shift testing in the frequency range from 10 Hz to 3 kHz. For more details, see ISO 16063-11.

7.2 Method

7.2.1 Test procedure

Install the equipment as per Figure 1.

The transducer under test is mounted by using the recommended torque from the manufacture's manual under ambient conditions. Tests in this condition permit the comparison of the complex sensitivity of the transducer at other temperatures.

Set the temperature of the chamber to the specified value. Once the temperature measured by the temperature sensor has reached the set value, maintain this temperature until the transducer under test has achieved temperature stability (see Annex A). Stability is recommended within ±2 °C. Then set the test frequency and adjust the vibrator amplitude to a certain level and measure the complex sensitivity using a laser interferometer. Several test frequencies are needed to determine the frequency response of complex sensitivity. Change the temperature and repeat the procedure above. The temperature response of the tested transducer can then be obtained.

NOTE The temperature stability within ±2 °C is not mandatory. However, in some cases where the transducer sensitivity is changed greatly around a temperature, especially at extreme temperatures, bigger tolerances can result in higher uncertainty (see Annex B).

The design of the system should also ensure that there is no condensation/icing on the glass window and the reflective surface on the ceramic rod occurs which would prejudice the laser interferometer amplitude measurement. For temperature ranges containing positive and negative temperatures, it is better to perform the positive temperature test first and then to dry the chamber and perform the negative temperature test to avoid ice and frost.

7.2.2 Expression of results

If the fringe-counting method is used, calculate the sensitivity magnitude S_t according to ISO 16063-11:1999, 7.3. The magnitude S_t of the transducer at the selected frequency or frequency response can be obtained at a fixed temperature.

If the sine-approximation method is used, calculate the sensitivity magnitude S_t and phase shift $\Delta\varphi_t$ according to ISO 16063-11:1999, 9.4. The magnitude S_t and phase shift $\Delta\varphi_t$ of the transducer at the selected frequency or frequency response can be obtained at a fixed temperature.

If the test data under room temperature are available, calculate the change of the complex sensitivity with respect to the temperature. The results can be expressed as a curve of temperature response for the transducer.

NOTE 1 The testing frequency range can be from 10 Hz to 3 kHz or even higher, depending on the working range of the vibration exciter, on the mass of the fixtures and the tested transducer, etc.

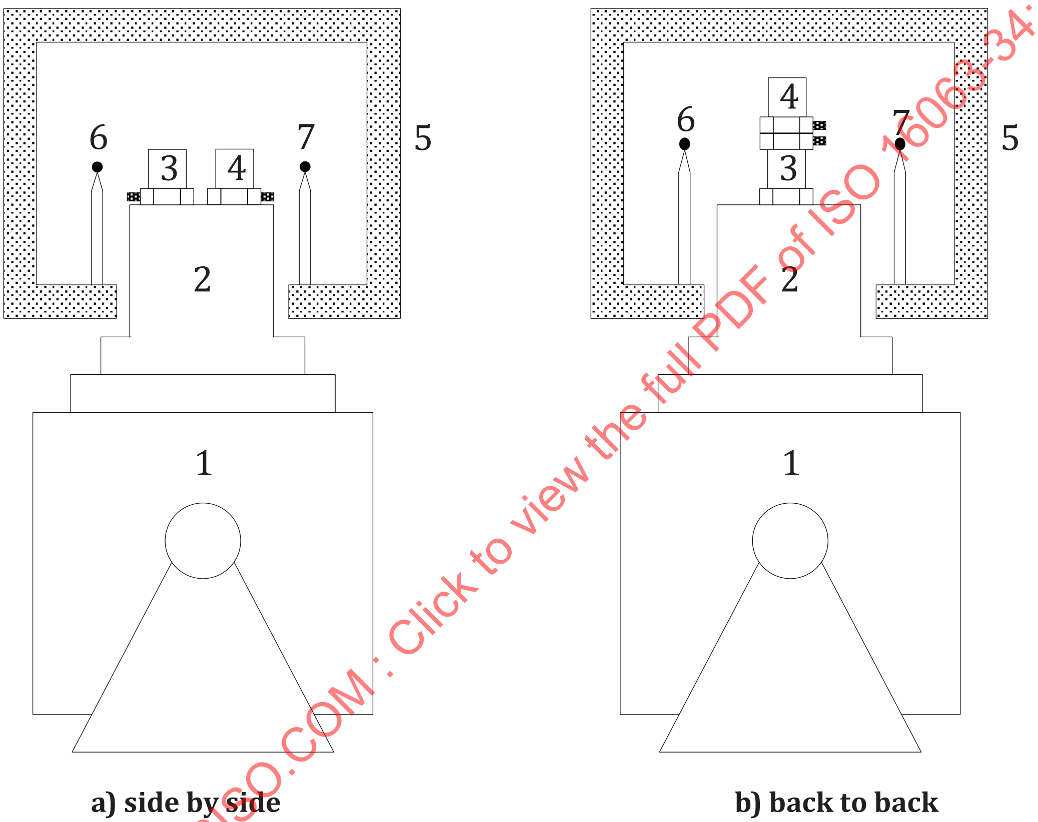
NOTE 2 Instead of an interferometer, a laser vibrometer can be used as the reference standard.

8 Method 2: Determination of complex sensitivity using a reference transducer inside a temperature chamber

8.1 General

This test system primarily contains a vibration exciter, a temperature chamber and a reference transducer. The method specified allows for the reference and tested transducer to be mounted in a suitable way on the fixture inside the temperature chamber; see Figure 2. This method is limited to the known frequency and temperature ranges of the reference transducer.

The method is applicable to complex sensitivity testing of the transducer in the frequency range from 10 Hz to 1 kHz and the temperature range from –70 °C to 500 °C.



Key

1 vibration exciter(vertical or horizontal)
2 fixture (ceramic rod)
3 transducer under test
4 reference transducer
5 temperature chamber
6 control temperature sensor
7 measure temperature sensor

Figure 2 — Test system with a reference transducer inside a temperature chamber

8.2 Method

8.2.1 Test procedure

Install the equipment as per Figure 2 a).

Under ambient conditions, the transducer under test and the reference transducer are mounted side by side [c.f. Figure 2 a)] or back-to-back [c.f. Figure 2 b)] on the top of the fixture by using the recommended torque from the manufacture’s manual. Tests in back-to-back configuration reduce the influence of rocking motions.

This setup permits the comparison of the complex sensitivity of the transducer at other temperatures.

Set the temperature of the chamber to the specified value. Once the temperature has reached the set value, maintain this temperature until the transducer under test has achieved temperature stability (see Annex A). Stability is recommended within ±2 °C. Then set the test frequency and adjust the vibrator amplitude to a certain level and measure the complex sensitivity of the tested transducer in comparison to the reference transducer. Several test frequencies are needed to determine the frequency response of the transducer’s complex sensitivity. Change the temperature and repeat the procedure above. The temperature response of the tested transducer can then be obtained.

8.2.2 Expression of results

Calculate the sensitivity amplitude S_t and phase shift $\Delta\varphi_t$ according to ISO 16063-21:2003, Clause 6. The magnitude S_t and phase shift $\Delta\varphi_t$ of the transducer at the selected frequency or the frequency response can be obtained at a fixed temperature.

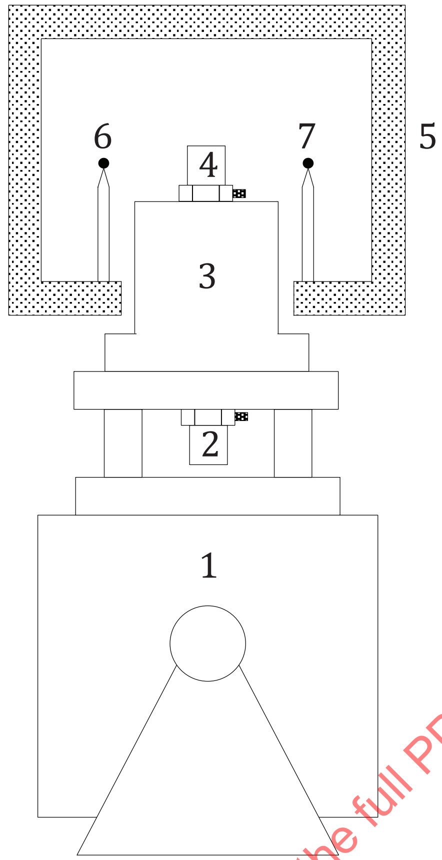
If the testing data under room temperature are available, calculate the change of sensitivity with respect to temperature. The results can be expressed as a curve of the temperature response for the transducer.

9 Method 3: Determination of complex sensitivity using a reference transducer outside the temperature chamber

9.1 General

This test shall be done in addition to a comparison calibration because it assesses the change of the complex sensitivity with respect to room temperature. The testing system consists of a vibration exciter equipped with a specially designed fixture; see Figure 3.

This method is applicable to the change of complex sensitivity calibration in the frequency range from 10 Hz to 1 kHz and the temperature range from −190 °C to 800 °C. Because the fixture transfer function errors have not been compensated for and the transfer ratios vary with frequency, the sensitivity obtained is proportional to the transfer ratio. The results can only be expressed as a change of the complex sensitivity versus temperatures at the selected frequency.



Key

1 vibration exciter(vertical or horizontal)
2 reference transducer
3 fixture (ceramic rod)
5 transducer under test
5 temperature chamber
6 control temperature sensor
7 measure temperature sensor

Figure 3 — Test system with a reference transducer outside the temperature chamber

9.2 Method

9.2.1 Test procedure

Install the equipment as per Figure 3.

Firstly, test the transducer in the temperature chamber at room temperature by comparison to the reference transducer. Record the sensitivity (calibration factor S_0) of the transducer and phase shift φ_0 between the output of the tested transducer and the reference transducer at specified frequencies and amplitudes.

Then set the temperature of the chamber to the specified value. When the temperature has reached the set value, maintain this temperature until the transducer under test has achieved temperature stability (see Annex A). Stability is recommended within ±2 °C. Adjust the frequencies and amplitudes to the same levels as above and measure the sensitivity (calibration factor S_t) of the tested transducer and phase shift φ_t between the output of the tested transducer and the reference transducer at the testing temperature.

Change the temperature and repeat the procedure above. The temperature response of the complex sensitivity can then be obtained.

9.2.2 Expression of results

Calculate the change of the tested transducer sensitivity S_{rel} as a percentage deviation of the calibration factor at the testing temperature relative to room temperature at selected frequency and amplitude, using Formula (1):

$$S_{rel} = \frac{S_t - S_0}{S_0} \times 100\% \quad (1)$$

where

S_t is the calibration factor of the tested transducer at a fixed temperature;

S_0 is the calibration factor of the tested transducer at room temperature.

Calculate the phase shift deviation $\Delta\varphi_t$ of the tested transducer at testing temperature relative to room temperature at selected frequency and amplitude from Formula (2):

$$\Delta\varphi_t = \varphi_t - \varphi_0 \quad (2)$$

where

φ_t is the phase shift between the output of the tested transducer and the reference transducer at testing temperature;

φ_0 is the phase shift between the output of the tested transducer and the reference transducer at room temperature.

The results can be expressed as a curve of the temperature response for the tested transducer.

10 Preferred amplitudes, frequencies and temperatures

Preferred amplitudes, frequencies and temperatures may be chosen from the following series, with at least six levels equally covering the transducer temperature and frequency range.

a) Amplitude, in metres per second squared:

1, 2, 5, 10 and their multiples of ten;

b) Frequency, in hertz:

10, 16, 20, 40, 80, 160, 315, 630, 1 000, 1 250, 1 600, 2 000, 2 500, 3 000;

c) Temperature, in degrees Celsius:

–190, –150, –120, –100, –70, –50, –40, –25, –10, 0, 5, 40, 70, 100, 155, 200, 300, 400, 500, 600, 700, 800.

Special attention should be paid in the process of heating and cooling Temperature overshoot shall not exceed 5 °C over the set temperature when it is at the maximum (or minimum) operating temperature of the transducer. The temperature in the chamber should be increased or decreased with the gradual change of temperature.

On completion of the temperature sensitivity calibration, the transducer under test should be allowed to slowly return to ambient temperature. After a suitable rest period, the device should again be calibrated to ensure that the device has regained its original ambient sensitivity or that a permanent change in sensitivity has occurred. For some transducers, it may take more than a day to recover.

In cases where a connecting ceramics rod is used between the vibrator and temperature chamber, care should be taken to avoid test frequencies at which high transverse motion of the rod occurs. As the transducer under test and the reference can be positioned side by side, an investigation of the rocking motion resonances of the shaker should be evaluated to exclude those frequencies or excitation parameters in the test. It should achieve identical excitation parameters to the two transducers.

The lowest resonance frequency of the fixture (connecting rod combination) shall be far greater than the upper test frequency.

11 Test report

As a minimum, the following information shall be included in the test report:

— reference to this document, i.e. ISO 16063-34:2019;

— the method used;

— the results, including a reference to the clause which explains how the results were calculated and:

  — values of test temperatures, frequencies and vibration amplitudes,

  — values of complex sensitivity or temperature response,

  — expanded uncertainty of measurement (including temperature uncertainty, if possible), k factor if different from $k = 2$;

— any deviations from the procedure;

— any unusual features observed;

— the date of the test.

— the following conditions and characteristics:

a) ambient conditions:

  — room temperature,

  — relative humidity;

b) mounting technique:

  — material of mounting surface,

  — characteristics of mounting components or adapters (if used),

  — cable fixing,

  — orientation (vertical or horizontal),

  — mounting torque;

c) all amplifier settings (if adjustable) when the transducer is calibrated in combination with a signal conditioner or amplifier:

  — gain,

  — cut-off frequencies;

d) laser light reflection:

  — reflector (plated rod surface or mirror, etc.),

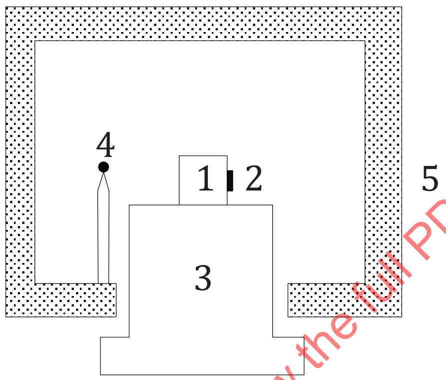
  — position of the laser light spot on the reflective surface.

All references used in the calibration should be listed, such as reference transducer and amplifier, test amplifier and data acquisition.

Annex A
(informative)

Determination of the achieving time of setpoint temperature for a device under test

When testing at fixed temperatures, it is not feasible to mount the temperature sensor on the device under test (DUT), therefore before testing the time taken for the DUT to achieve setpoint temperature, stability should be known. A dummy transducer of approximately the same size as the DUT can be used to determine this time. Replace the DUT with the dummy transducer and mount the temperature sensor onto it using a mounting screw or by bundling it with wire; see Figure A.1.

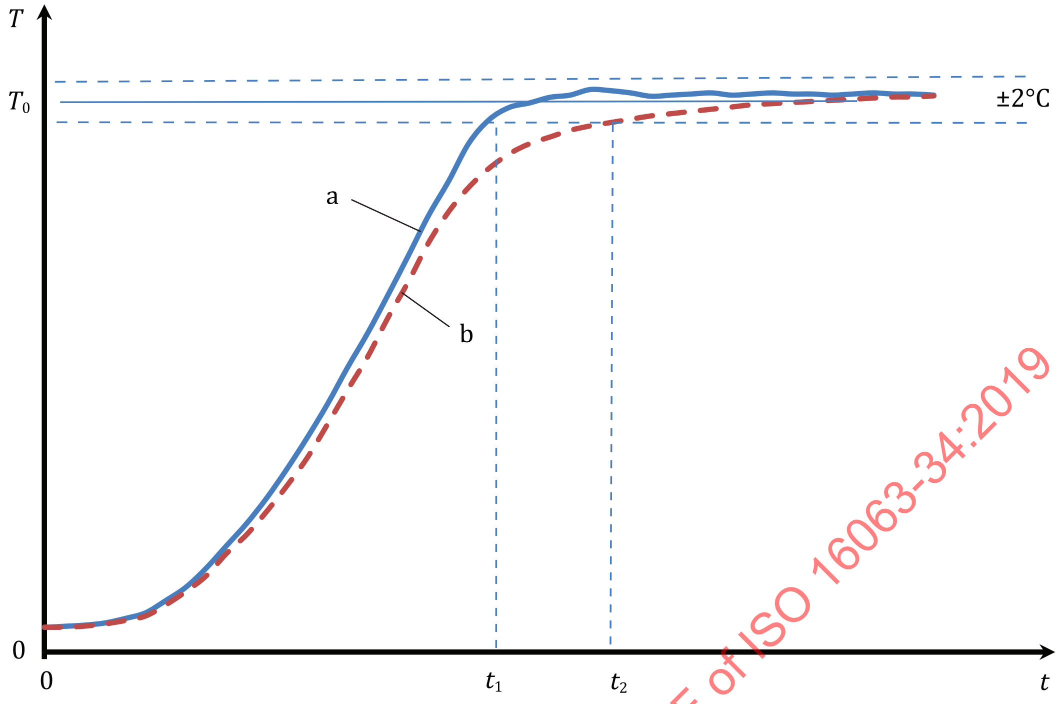


Key

1 dummy transducer
2 measure temperature sensor
3 fixture (ceramic rod)
4 control temperature sensor
5 temperature chamber

Figure A.1 — Test system for the determination of achieving time with a dummy transducer

Set the temperature of the chamber to the preferred value T_0. Once the temperature measured by the temperature sensor has reached the temperature tolerance, record this time point as t_1. Maintain this temperature and observe the output of the temperature sensor until the DUT has achieved the temperature stability tolerance; record this time point as t_2. The time interval between t_2 and t_1 can be considered as the achievement time of the setpoint temperature for the DUT; see Figure A.2. This time interval can be determined with the above procedures for every preferred temperature.



Key

T	temperature
T_0	temperature to be controlled
t	time
t_1	reached tolerance time of control temperature sensor
t_2	reached tolerance time of measure temperature sensor
a	Curve measured by the control temperature sensor.
b	Curve measured by the measure temperature sensor.

Figure A.2 — Temperature rise curves