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Methods for the calibration of vibration and shock transducers —

Part 33: Testing of magnetic field sensitivity

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

Partie 33: Essai de sensibilité aux vibrations transversale

Reference number
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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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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This second edition cancels and replaces the first edition (ISO 5347-19:1993), which has been technically revised.

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

Methods for the calibration of vibration and shock transducers —

Part 33: Testing of magnetic field sensitivity

1 Scope

This document specifies a method, procedures and the specifications for an apparatus to be used for testing the magnetic field sensitivity of vibration and shock transducers. It is applicable to all kinds of vibration and shock transducers.

This document is applicable for a reference test sinusoidal magnetic field having a root mean square (r.m.s.) value more than 10^{-3} T at 50 Hz or 60 Hz. Typically, a test magnetic field of 10^{-2} T at 50 Hz or 60 Hz is used.

This document is primarily intended for those who are required to meet internationally standardized methods for the measurement of magnetic field sensitivity under laboratory conditions.

NOTE 1 T (tesla) = 1 Wb/m^2.

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 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Uncertainty of measurement

Uncertainty of measurements can be expressed as relative expanded uncertainty. If the test signal is big and the signal-to-noise ratio (SNR) is more than 20 dB, ignoring the influence of the ambient vibration and apparatus background noise, a relative expanded uncertainty of 10 % (coverage factor $k = 2$) or less can be achieved according to this document. However, when the test signal is small and the SNR is not more than 20 dB, the uncertainty components caused by ambient vibration and apparatus background noise cannot be ignored. Conversely, it shall be taken into account carefully because it has now become as a main part of the uncertainty.

All users of this document shall assess and report the uncertainty of measurement according to ISO 16063-1:1998, Annex A. The uncertainty of measurement is expressed as expanded uncertainty for a coverage factor of 2 or a confidence level of 95 %. It is the responsibility of the laboratory or end user to make sure that the reported values of uncertainty are credible.

5 Requirements for apparatus

5.1 General

This clause gives specifications for the apparatus necessary to comply with this document and notably to obtain the uncertainties of Clause 4.

5.2 Magnetic field sensitivity tester

The magnetic field sensitivity of the transducer is expressed as the maximum output of the transducer in a test magnetic field divided by the magnetic flux density of this test magnetic field, see Formula (2). In order to get the magnetic field sensitivity, S_B, observe and do the following.

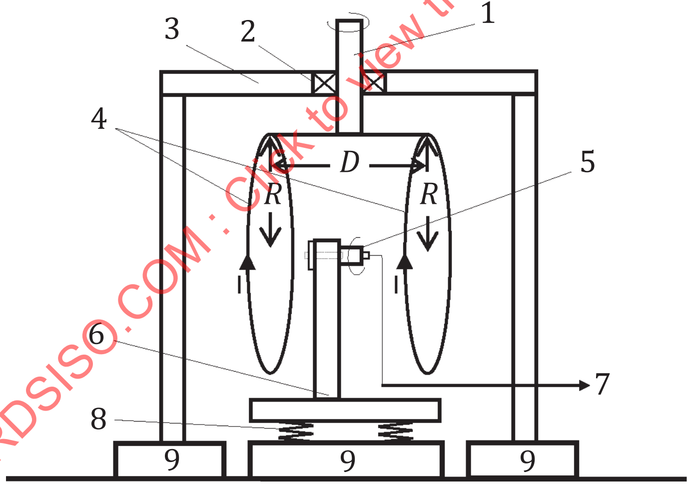
— Ensure that the test magnetic field passes through the transducer in all directions.

— Test and obtain all the output data of the transducer from each direction.

— Compare all of these output data and find out the maximum one, that is $X_{B,\text{max}}$.

— Calculate the magnetic field sensitivity, S_B, according to Formula (2).

An apparatus named "magnetic field sensitivity tester" is specially manufactured for magnetic field sensitivity testing. The structural schematic diagram of the tester is shown in Figure 1.



Key

1	rotation axis	7	transducer output
2	bearing	8	vibration isolation system
3	support	9	base
4	two coils	*D*	distances between the planes of two coils
5	transducer to be tested	*R*	radius of coils
6	test platform		

Figure 1 — Structural schematic diagram of a magnetic field sensitivity tester

The magnetic field sensitivity tester shall meet the following specifications.

a) A pair of coils (two coils) is symmetrically mounted above the test platform. It can be rotated horizontally around its vertical rotation axis. The distances between the planes of the two coils shall be equal to their radius (that is, $D = R$, see Figure 1).

b) The test platform used for mounting the transducer to be tested shall be made of non-ferro-magnetic material. The transducer can be horizontally mounted on the test platform and shall be at the centre of the two coils. Furthermore, it shall at least be able to be rotated 180° freely around its own geometric axis sensitivity, and the mass of the test platform shall be more than 50 times that of the transducer to be tested.

   NOTE 1 The centre of the two coils means the centre of gravity of the two coils.

c) The vibration isolation system is used to reduce the ambient vibration. The eigenfrequency of the vibration isolation system should be less than 30 Hz.

d) Produce an adjustable alternating current (AC) of 50 Hz or 60 Hz that flows through the two coils in the same direction and generates a needed test magnetic field.

e) In the area the transducer occupied, the magnetic field shall be within the needed test magnetic flux density with a relative tolerance of ±3 %.

NOTE 2 Due to the magnetic field generated by two coils being superimposed and compensated for each other, the magnetic field is uniform near the centre of two coils where the transducer is mounted.

The flux density of the magnetic field in the centre of two coils can be calculated by Formula (1):

$$B = \mu_0 \times I \times N \times \frac{R^2}{(R^2 + 0{,}25D^2)^{1{,}5}} \tag{1}$$

where

B is the r.m.s. value of the magnetic flux density of the magnetic field in the centre of the two coils, in tesla;

μ_0 is equal to $4\pi \cdot 10^{-7}\ \mathrm{T \cdot m/A} = 1{,}257 \cdot 10^{-6}\ \mathrm{T \cdot m/A}$;

I is the r.m.s. value of the current, in amperes;

N is the number of turns;

R is the radius of each coil, in metres;

D is the distance between the two planes of the two coils, in metres.

EXAMPLE 1 Two coils: $D = R = 150$ mm, $N = 333$. When I = 5,0 A, at the centre of two coils, $B = 10^{-2}$ T.

EXAMPLE 2 Two coils: $D = R = 250$ mm, N = 333. When I = 8,35 A, at the centre of two coils, $B = 10^{-2}$ T.

5.3 Conditioning amplifier

The conditioning amplifier shall have a low background noise, with low-pass and high-pass filters used to cut unwanted signals during the test.

Maximum expanded uncertainty (k= 2): 1 % of gain.

During the measurement operation, a ground loop among the transducer, test platform (see Figure 2), the amplifier and the read out device should be prevented.

5.4 Voltmeter

A true r.m.s. voltmeter shall be used.

Maximum expanded uncertainty (k= 2): 1 % of reading.

NOTE Other instruments with the same or smaller uncertainty, such as a signal analyzer, etc., can also be used in place of a voltmeter.

5.5 Teslameter

A r.m.s. teslameter shall be used.

Maximum expanded uncertainty (k= 2): 2 % of reading.

6 Ambient conditions

Testing shall be carried out under the following conditions:

a) room temperature, (23 ± 5) °C;

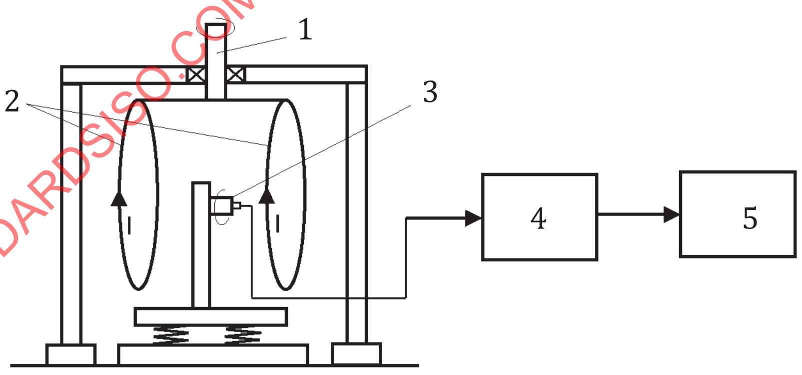
b) relative humidity, 75 % max.;

c) signal-to-noise ratio, SNR ≥ 20 dB. If the SNR < 20 dB (for example, some transducers have a very weak output in magnetic field and SNR < 20 dB), the uncertainty components caused by ambient vibration and apparatus background noise cannot be ignored and shall be taken into account.

7 Method

7.1 Apparatus setup

The magnetic field sensitivity tester, conditioning amplifier and voltmeter are connected as shown in Figure 2. Appropriate measurement ranges and band-pass filter settings shall be carefully chosen for improving the SNR.



Key

1 rotation axis
2 two coils
3 transducer to be tested
4 conditioning amplifier
5 voltmeter

Figure 2 — Schematic of apparatus connection

a) Use low-noise conditioning amplifier and input cables.

b) Select appropriate ranges for the conditioning amplifier and voltmeter.

c) Check and try to improve the signal-to-noise ratio SNR by turning on/off the magnetic field by repeating step a) and step b).

d) Avoid any vibration and noise around the tester during testing.

7.2 Adjusting test magnetic field

Obtain a needed magnetic flux density by adjusting the current and measuring the magnetic flux density using a teslameter.

The teslameter probe is very sensitive to the direction of the test magnetic field. Read the instruction manual carefully for correct use.

7.3 Mounting transducer

Mount the transducer to be tested horizontally in the test platform using a non-magnetic mounting stud. The output of the transducer shall be connected to the voltmeter via a conditioning amplifier. Any ferro-magnetic material should not be allowed to get close to the volume between the two coils. Ferro-magnetic material outside the coil also influences the magnetic field inside the coils.

First, adjust the test magnetic field and then mount the transducer. In some cases, the magnetic field may have a slight change after the transducer is mounted. That is because these transducers are partly made of the ferro-magnetic material.

7.4 Test procedure

a) Slowly rotate the two coils 360° while carefully observing the voltmeter. Locate the transducer maximum output in this test plane and record it.

b) Change test plane. Rotate the transducer around its own geometric sensitivity axis in small angle increments (e.g. 15°).

c) Repeat step a) and step b), until the transducer is rotated 180° around its own geometric sensitivity axis. A series of maximum output values are thus obtained and recorded.

d) Compare all of these maximum output values and select the biggest one as the transducer maximum output, $X_{B,\max}$.

The above test procedures can also be achieved automatically with the assistance of a computer (see Annex A). Annex B provides an alternative procedure using three orthogonal coils.

It is important to eliminate ambient vibration and apparatus background noise in the test procedures.

NOTE 1 The test plane is the plane formed by the vector of magnetic field (through the centre line of coils) while the coil is rotating during test.

During measurement, the current can change due to thermal heating. In this case, the current shall be observed and controlled to the nominal value over time.

NOTE 2 Prevent the danger of overheating the magnetic coils by long-term operation.

7.5 Expression of results

The magnetic field sensitivity of the transducer, S_B, can be calculated using Formula (2):

$$S_B = \frac{X_{B,\max}}{B} \tag{2}$$

where

$X_{B,\max}$ is the transducer maximum output in the magnetic field as the equivalent based on its sensitivity. For the acceleration transducer r.m.s. values, the unit is m/s^2, for velocity transducer r.m.s. values, the unit is mm/s and for displacement transducer r.m.s. values, the unit is mm.

B is the magnetic flux density r.m.s. value of the test magnetic field, in T.

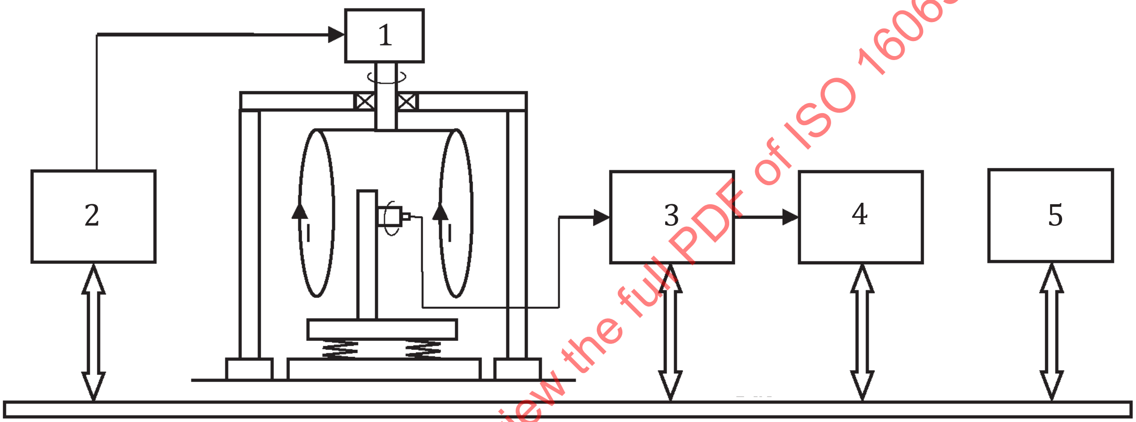
The output of the transducer in the magnetic field may have some harmonic components and the fundamental frequency (testing frequency).

Annex A
(informative)

Automatic test system of magnetic field sensitivity

A.1 Apparatus and automatic test system

The magnetic field sensitivity tester and other apparatus are connected to a computer via a bus. The specifications for all the apparatus to be used are as same as those given in Clause 5. An automatic testing system for the magnetic field sensitivity is shown in Figure A.1.



Key

1 stepper motor
2 stepper motor driver/controller
3 conditioning amplifier
4 voltmeter
5 computer

Figure A.1 — Schematic of the automatic test system of magnetic field sensitivity

A.2 Adjusting test magnetic field and mounting transducer

Adjust the magnetic field to a needed value, as given in 7.2.

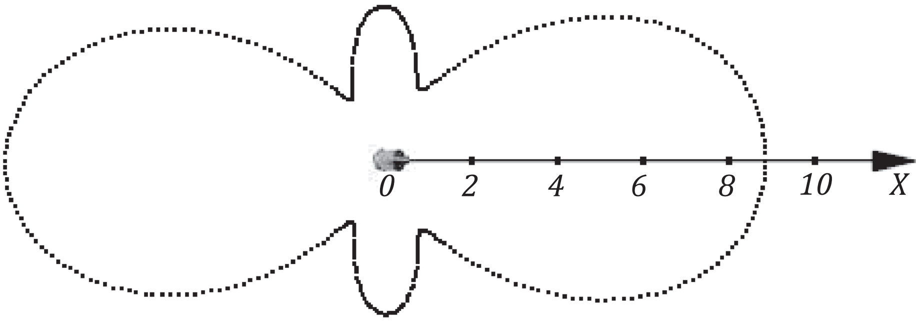
Mount the tested transducer on the test platform, as given in 7.3.

A.3 Test procedures and expression of results

A.3.1 A computer controls the stepper motor to rotate the two coils by a small angle (such as 1°). Meanwhile, the voltmeter obtains data synchronously. While the two coils are rotated by 360°, the test in this plane is completed and an output curve of the transducer in the magnetic field can be obtained as shown in Figure A.2.

Type: BJ No. 0043, J = 45°

K = 3°, $V_{B,\max}$ = 0,887 m * s^{-2} , B = 0,01T



NOTE Output curve expressed in the form of polar coordinate. The pole represents the tested transducer; the polar axis represents the transducer sensing direction, the polar angles represent the angles between the magnetic field and the transducer sensing direction, and the polar radius represents the output of the transducer in that direction.

Figure A.2 — Example of an output curve of the transducer in magnetic field in one test plane

A.3.2 Change the test plane. Rotate the transducer around its geometric sensitive axis by a small angle [see 7.4 b)].

A.3.3 Repeat the operations in step A.3.1 and step A.3.2, until the transducer is rotated around its geometric sensitive axis by 180°. All the tests are completed.

A.3.4 With the assistance of computer, the maximum output, $X_{B,\mathrm{max}}$, is found out from these data and the magnetic field sensitivity, S_B, is calculated according to Formula (2). Besides, an output curve of the transducer in the magnetic field in all test planes can be obtained, such as shown in Figure A.3.

Type: BJ No. 0043, J = 45°, K = 3°

S_B = 88, 7 m * s^{-2} * T^{-1} , B = 0,01T

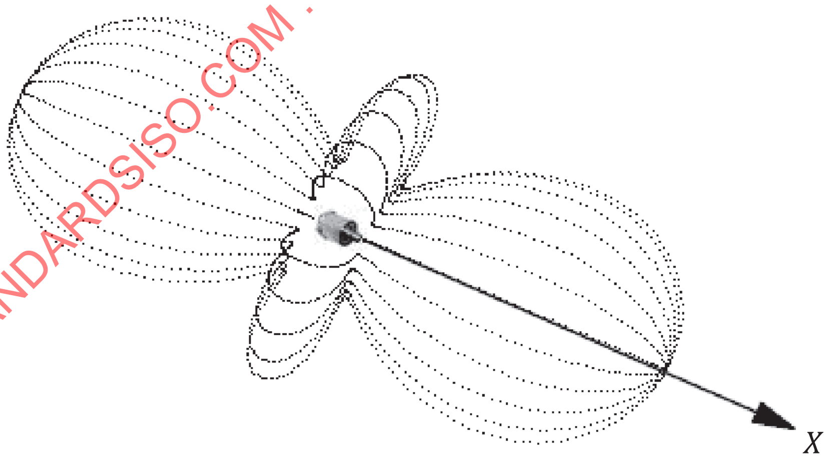


Figure A.3 — Example of an output curve of the transducer in magnetic field in all test planes

Annex B
(informative)

Alternative procedure with three orthogonal coils

B.1 General

This annex describes an alternative mechanical test setup that uses three pairs of Helmholtz coils on three perpendicular axes x, y and z. In this test setup, neither the coils nor the transducer to be tested are turned. Instead, the three-dimensional direction of the magnetic field is turned by vector addition of the three shares of x, y and z coils.

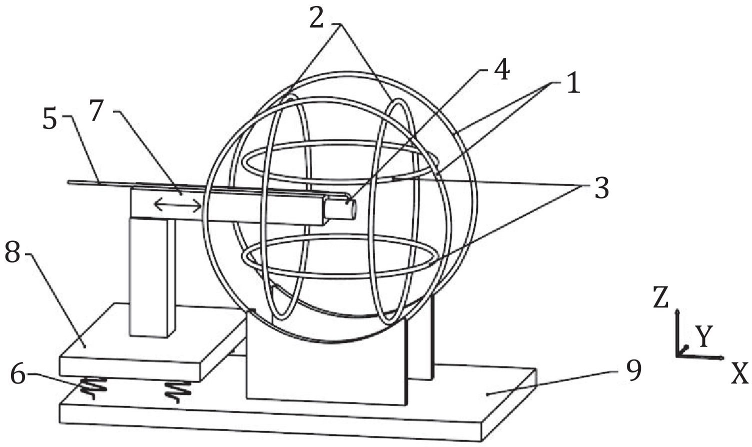
B.2 Mechanical setup

Three pairs of Helmholtz coils are located in an x, y and z direction respectively, fixed by non-metallic, non-magnetic mechanical elements, which produce a cube of a nearly uniform magnetic field. The transducer to be tested is mounted on a very stable, vibration-insolated platform exactly in the middle of all the coils. Its main axis is orientated to the x-direction (see Figure B.1).

Other configurations with additional coils are possible. Those coils help to increase the uniformity of the field and extend the usable size of the magnetic cube.

Each set of coils represents one of the directions (x, y or z). All coils of one set are electrically-connected in series and so always get the same current value. The supply wires of the coils should be twisted to avoid straying magnetic fields.

The coil pair for the x-direction does not have the same diameter as the coil pair for the y-direction for mechanical reasons. This can be compensated for using a different current or a different number of windings. The same applies for the coil pair of the z-direction. A typical coil has 40 windings and a diameter of 20 cm. However, the dimensions depend on the target value to provide the magnetic field. The provision of a magnetic field for each coil pair can be calculated using Formula (1).



Key

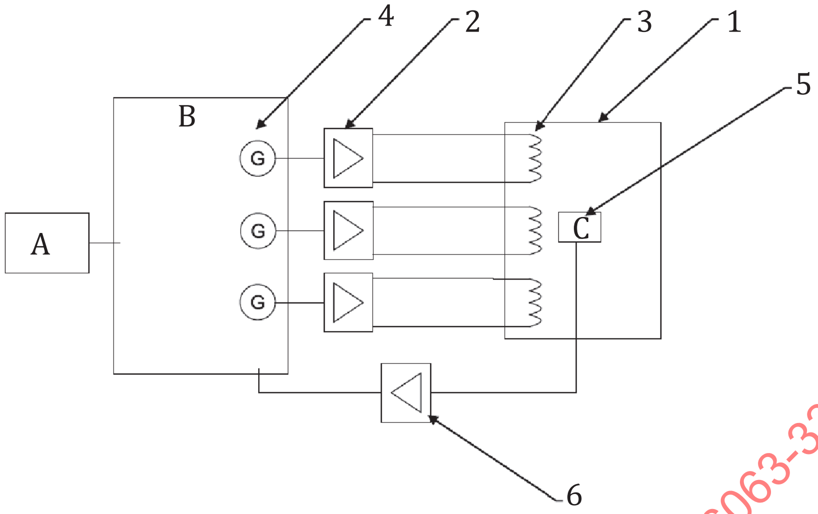
1 pair of coils y-axis
2 pair of coils x-axis
3 pair of coils z-axis
4 transducer to be tested
5 transducer output
6 vibration isolation system
7 movable transducer base
8 test platform
9 base

Figure B.1 — Structural schematic diagram of a 3D magnetic field sensitivity tester

B.3 Electrical control

Each of the three sets of coils are connected to a separate power amplifier, which is working in constant current mode. The amplifier inputs are connected to separate signal generators. The three signal generators are a part of a controller, which provides alternating voltages with the right phase and amplitude (see Figure B.2). While the frequency and phase is the same for each direction, the amplitudes change depending on the desired magnetic field direction in space. The amplifiers may provide a current monitor output for the controller to keep the current exactly on the desired value, even with non-perfect amplifiers.

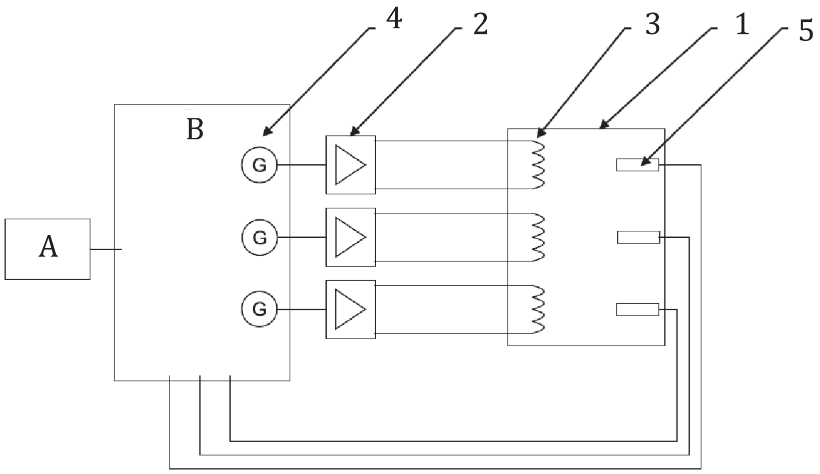
For a desired magnetic flux density, *B*, the required current can be calculated from Formula (1). Alternatively, the transfer coefficient between coil current I and magnetic flux density, *B*, is determined with a teslameter for each set of coils previously mentioned. See Figure B.3. Investigations of the reproducibility are recommended.



Key

1	3D coil-system	A	PC
2	power amplifiers	B	controller
3	pair of coils	C	transducer to be tested
4	generator		
5	transducer to be tested		
6	conditioning amplifier		

Figure B.2 — Schematic of electrical connection for the 3D magnetic field sensitivity tester of testing the device under test



Key

1	3D coil-system	A	PC
2	power amplifiers	B	controller
3	pair of coils		
4	generator		
5	teslameter		

Figure B3 — Schematic of electrical connection for the 3D magnetic field sensitivity tester to verify the magnetic field vector

B.4 Test procedure

To obtain the magnetic sensitivity measurement with the method described in Clause 7,

— place the sensor in the middle of a coil pair (the main direction of geometric sensitive axis of the transducer to be tested is the x-axis),

— turn the coils stepwise around the sensor until 360° is reached,

— turn the sensor around the x-axis by, for example 15°, and

— repeat the procedure until a sensitivity diagram (see Figure B.4) is shown.

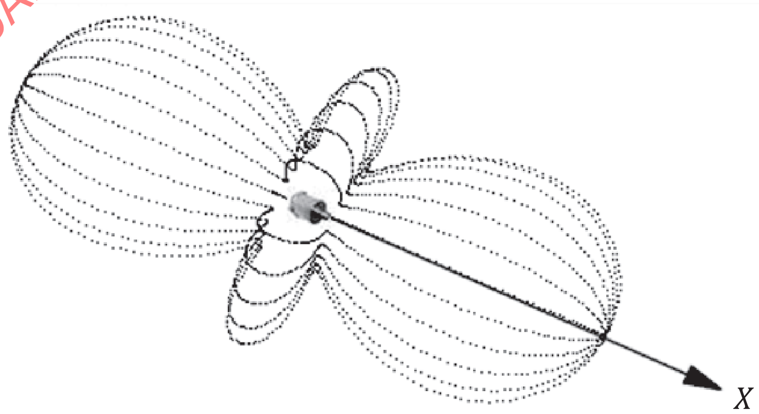


Figure B.4 — Example of an output curve of the transducer in magnetic field in all test planes (all measurements cross the x-axis at 0° and 180°)