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NATIONAL METROLOGY TECHNICAL SPECIFICATION
OF THE PEOPLE'S REPUBLIC OF CHINA

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Calibration Specification for (1 mT~2.5 T) Magnetometers

(1 mT ~ 2.5 T)磁强计校准规范

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Calibration Specification for (1 mT~2.5 T) Magnetometers

1 Scope

This Specification applies to the calibration of 1 mT ~ 2.5 T DC magnetic field magnetometers, and also to the calibration of the DC magnetic field measurement part of multifunctional magnetometers.

2 References

The following documents are referred to in this Specification:

JJF 1013-1989 Terms in common use and their definitions for the magnetic metrology

For dated references, only the dated version applies to this Specification; for undated references, the latest version (including all amendments) applies to this Specification.

3 Terms and units of measurement

3.1 magnetometer

An instrument used for measuring magnetic field strength or magnetic flux density (magnetic induction intensity).

3.2 zero drift

The amount by which the magnetometer reading deviates from zero when the probe is placed in a zero magnetic field cavity.

3.3 basic range

The measuring range with the best maximum permissible error of magnetic flux density.

4 General

A magnetometer is an instrument used to measure the magnetic flux density (magnetic induction intensity) of an object at a point in space, among which the Hall effect magnetometer is the most typical. Magnetometers are divided into digital magnetometers and pointer magnetometers according to the display mode. Their principle structure block diagrams are shown in Figure 1 and Figure 2, respectively. Magnetometer probes are divided into radial probes and axial probes according to the direction of the measured magnetic field.

5 Metering characteristics

5.1 Magnetic flux density indication error

The maximum allowable error generally does not exceed $\pm (0.02\% \sim 10\%)$.

5.2 Difference between the forward and reverse indications of the probe

The difference between the forward and reverse indications of the magnetometer probe generally does not exceed its maximum allowable error.

5.3 Zero drift

In the zero magnetic field cavity, the zero drift of the magnetometer generally does not exceed 1/3 of its maximum allowable error.

5.4 Up and down variation

The up and down variation of a pointer magnetometer generally does not exceed the error coefficient value related to its range value.

Note: The above indicators are not applicable to qualification judgment and are for reference only.

6 Calibration conditions

6.1 Environmental conditions

When calibrating the magnetometer, the environmental conditions shall meet the requirements of Table 1.

6.2 Measurement standards and other equipment

The magnetometer calibration device consists of a zero magnetic field cavity, a magnetic field coil (Helmholtz coil, solenoid, etc.), an electromagnet, an excitation power supply, a DC ammeter, a probe position adjustment device, a standard magnetometer (or a magnetometer standard table), etc. The calibration device must be

verified (or calibrated) against a higher-level measurement standard, and its combined standard uncertainty must not exceed 1/3 of the maximum allowable error of the calibrated magnetometer.

6.2.1 Zero magnetic field cavity

The magnetic flux density in the zero magnetic field cavity is no more than 1×10^{-6} T.

6.2.2 Magnetic field coil

When the magnetic flux density of the magnetic field is in the range of 1 mT ~ 100 mT, the magnetic field generator can use a magnetic field coil. The magnetic field coil can be a Helmholtz coil, a solenoid coil, or the like. In the uniform area of the coil magnetic field, the error caused by the magnetic field uniformity shall be no more than 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer, and the error introduced by the coil constant shall be no more than 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer.

6.2.3 Electromagnet

When the magnetic flux density of the magnetic field is in the range of 10 mT ~ 2.5 T, the magnetic field generator can be an electromagnet. The pole surfaces of the electromagnet shall be flat and the two pole surfaces shall be parallel. In the electromagnetic field homogeneity region, the error caused by the magnetic field homogeneity shall be no more than 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer.

6.2.4 Excitation power supply

The change in the excitation power supply current within 60 s shall not exceed 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer.

6.2.5 DC ammeter

The DC ammeter can be integrated into the excitation power supply or placed separately to measure the excitation current of the magnetic field coil. The error shall not exceed 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer.

6.2.6 Probe position adjustment system

The probe position adjustment system can adjust the spatial position of the standard magnetometer probe and the calibrated magnetometer probe, and has the function of probe direction rotation to ensure that the probe Hall plate is perpendicular to the magnetic field direction. The error caused by adjusting the probe position and direction shall not exceed 1/5 of the absolute value of the maximum allowable error of the calibrated magnetometer.

6.2.7 Standard magnetometer

The standard magnetometer may be a nuclear magnetic resonance magnetometer, a Hall effect magnetometer, or the like. The allowable error shall not exceed $1/3$ of the absolute value of the maximum allowable error of the calibrated magnetometer, and the error change within one year shall not exceed its maximum allowable error.

7 Calibration items and calibration methods

7.1 Calibration items

The calibration items are shown in Table 2.

7.2 Calibration methods

7.2.1 Appearance and power-on inspection

7.2.1.1 The housing, exposed switches, function buttons and corresponding markings of newly produced magnetometers shall be intact; magnetometers in use and after repair shall not have damage or defects that affect normal operation.

7.2.1.2 The product name and model, manufacturer name, factory serial number, etc. of the magnetometer shall be clearly marked.

7.2.1.3 The accessories of the magnetometer shall be complete. The probe and magnetometer shall be matched and their instruction manuals shall be provided.

7.2.1.4 The connection wires of the magnetometer shall not be loose; the switches and buttons shall function normally; it shall be able to work normally after power is turned on.

7.2.2 Zero drift

7.2.2.1 Preheat the magnetometer to be calibrated according to its instructions.

7.2.2.2 Place the magnetometer probe to be calibrated in the zero magnetic field cavity and adjust its range to the lowest range.

7.2.2.3 Zero the calibrated magnetometer and select a recording time based on the requirements (if no requirements are available, 60 seconds may be selected). Record the maximum value ($B_{\max}$) and minimum value ($B_{\min}$) of the readings within this time. The zero drift is calculated according to Formula (2).

$$B_p = B_{\max} - B_{\min} \quad (2)$$

Where:

B_p – zero drift of the calibrated magnetometer, T;

$B_{\max}$ – maximum value of magnetometer reading, T;

$B_{\min}$ – minimum value of magnetometer reading, T.

7.2.3 Magnetic flux density indication error

7.2.3.1 Selection of calibration points

Select the calibration points according to the usage requirements. If there is no requirement, select by referring to the following method:

- Pointer type magnetometer. For basic range, select points with digital graduation lines within the measuring range as calibration points, and the number of calibration points shall be no less than 3 points. For non-basic range, select two points as calibration points: the maximum point of basic range error and the upper limit point.
- Digital type magnetometer. The basic range can select (but not limited to) the upper limit of the range, 80% range point, 60% range point, 40% range point, and 20% range point as calibration points; for non-basic range, generally select 3 points.

The indication error of the magnetic flux density value of the calibrated magnetometer is calculated according to Formula (3).

$$E_x = B_x - B_s \quad (3)$$

Where:

E_x – indication error of magnetic flux density of the calibrated magnetometer;

B_x – indication value of the calibrated magnetometer;

B_s – magnetic field flux density reference value (standard value).

7.2.3.2 Magnetic field generator

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