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International comparison of measurements of the magnetic moment using vibrating sample magnetometers (VSM) and superconducting quantum interference device (SQUID) magnetometers

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International comparison of measurements of the magnetic moment using vibrating sample magnetometers (VSM) and superconducting quantum interference device (SQUID) magnetometers

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL COMPARISON OF MEASUREMENTS OF THE MAGNETIC MOMENT USING VIBRATING SAMPLE MAGNETOMETERS (VSM) AND SUPERCONDUCTING QUANTUM INTERFERENCE DEVICE (SQUID) MAGNETOMETERS

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IEC 62797, which is a technical report, has been prepared by IEC technical committee 68: Magnetic alloys and steels.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
68/448/DTR	68/454/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Following a proposal made at the meeting of IEC TC 68 Working Group 2 (Magnetic alloys and steels – Measuring methods) in Braunschweig (PTB, 13-14 November 2006), an intercomparison exercise was started regarding the measurement of the magnetic moment by means of the vibrating sample magnetometer (VSM) method. The VSM finds widespread use in industrial and research laboratories, because of its sensitivity, ruggedness, and relative simplicity of use [1][1]. It is not an absolute method and requires calibration by means of a reference sample. This is typically represented by a very pure Ni sphere, calibrated by means of an independent method [2]. The VSM is generally applied for the characterization of hard magnetic materials, but, depending on the specific sensitivity of the apparatus, can also be used to test paramagnetic and diamagnetic materials. Its application to magnetically soft materials is generally restricted to the determination of the saturation magnetization. In fact, being an open circuit method, the VSM is not suited to the measurement of the magnetization curve of soft magnetic materials.

The basic aim of this comparison is to verify the degree of reproducibility of the method, a prerequisite for the prospective development of a related IEC measuring standard. The existing ASTM Standard A894/894M-00 [3] is devoted to the determination of the saturation magnetization of nonmetallic magnetic materials. Ten different research laboratories, listed in Annex B, agreed to participate in the comparison exercise. Each laboratory was assumed to have appropriate traceability of measurements and was required to determine the measurement uncertainty according to the ISO/IEC Guide to the expression of uncertainty in measurement [4]. Two laboratories used superconducting quantum interference device (SQUID) magnetometers.

The comparison was coordinated by INRIM (Istituto Nazionale di Ricerca Metrologica, Torino, Italy) and the Hannam University (Taejon, Korea). A summarizing paper on these experiments was presented at the International Workshop on One- and Two-Dimensional Measurement and Testing (Vienna, September 2012) and is to be published on the Int. J. Appl. Electromagnetics and Mechanics [8].

1 Numbers in square brackets refer to the Bibliography.

INTERNATIONAL COMPARISON OF MEASUREMENTS OF THE MAGNETIC MOMENT USING VIBRATING SAMPLE MAGNETOMETERS (VSM) AND SUPERCONDUCTING QUANTUM INTERFERENCE DEVICE (SQUID) MAGNETOMETERS

1 Scope

This Technical Report provides the results of an international comparison of measurements of the magnetic moment, using vibrating sample magnetometers (VSM) and superconducting quantum interference device (SQUID) magnetometers.

The basic object of this comparison is to verify the degree of reproducibility of the method employed as a prerequisite for the prospective development of a related IEC measuring standard.

2 Overview

In this report an intercomparison exercise on the measurement of the magnetic moment by means of the vibrating sample magnetometer (VSM) and superconducting quantum interference device (SQUID) magnetometer is presented. The VSM finds widespread use in industrial and research laboratories, because of its sensitivity, ruggedness, and relative simplicity of use. The basic aim of this comparison was to verify the degree of reproducibility of the VSM method, as a prerequisite for the prospective development of a related IEC measuring standard. At present time, the VSM method is invoked in the ASTM Standard A984, which is devoted, however, exclusively to the determination of the saturation magnetization of nonmetallic magnetic materials. An exercise was carried out by ten different laboratories regarding the measurement of the hysteresis loop parameters in hard ferrites and the magnetic moment in tape samples by means of the VSM (SI units). Each laboratory was assumed to have appropriate traceability of measurements and was required to determine the measurement uncertainty according to the ISO/IEC Guide to the expression of uncertainty in measurement. The comparison was coordinated by INRIM. The results were analyzed according to standard rules (e.g. ISO and EURAMET guidelines).

The following relative standard deviations of the laboratories best estimates around the unweighted mean were found:

a) Anisotropic hard ferrites: coercive field H_{cJ} ~ 1,0 %; coercive field H_{cB} ~ 0,9 %; polarization at applied field H_a ~ 800 kA/m J_{800k} ~ 0,80 %; remanent polarization J_r ~ 1,8 %; maximum energy product $(BH)_{max}$ ~ 1,2 %.

b) Isotropic hard ferrites: coercive field H_{cJ} ~ 1,0 %; coercive field H_{cB} ~ 3,5 %; polarization at applied field H_a = 800 kA/m J_{800k} ~ 1,2 %; remanent polarization J_r ~ 3,2 %; maximum energy product $(BH)_{max}$ ~ 6,2 %.

c) Magnetic tape samples: magnetic moment at H_a = 400 kA/m m_{400k} ~ 1,8 % - 2,8 %; remanent magnetic moment m_r ~ 1,3 % - 1,6 %; squareness S ~ 2,0 %; coercive field H_{cJ} ~ 1,1 % - 2,2 %.