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2007-04

Superconductivity –

Part 4: Residual resistance ratio measurement – Residual resistance ratio of Nb-Ti composite superconductors

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FOREWORD

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International Standard IEC 61788-4 has been prepared by IEC technical committee 90: Superconductivity.

This second edition cancels and replaces the first edition published in 2001. It constitutes a technical revision. The main revisions are the replacement of "accuracy" by "uncertainty" and a change in Figure 1, where the relationship between temperature and voltage is changed to the relationship between temperature and resistance.

The text of this standard is based on the following documents:

FDIS	Report on voting
90/203/FDIS	90/205/RVD

Full information on the voting for the approval of this standard 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 list of all parts of the IEC 61788 series, published under the general title *Superconductivity,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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

INTRODUCTION

Copper is used as a matrix material in multifilamentary superconductors and works as an electrical shunt when the superconductivity is interrupted. It also contributes to recovery of the superconductivity by conducting heat generated in the superconductor to the surrounding coolant. The cryogenic-temperature resistivity of copper is an important quantity, which influences the stability of the superconductor. The residual resistance ratio is defined as a ratio of the resistance of the superconductor at room temperature to that just above the superconducting transition.

In this International Standard, the test method of residual resistance ratio of Nb-Ti composite superconductors is described. The curve method is employed for the measurement of the resistance just above the superconducting transition. Other methods are described in Clause A.4.

SUPERCONDUCTIVITY –

Part 4: Residual resistance ratio measurement – Residual resistance ratio of Nb-Ti composite superconductors

1 Scope

This part of IEC 61788 covers a test method for the determination of the residual resistance ratio (*RRR*) of a composite superconductor comprised of Nb-Ti filaments and Cu, Cu-Ni or Cu/Cu-Ni matrix. This method is intended for use with superconductors that have a monolithic structure with rectangular or round cross-section, *RRR* less than 350, and cross-sectional area less than 3 mm^2. All measurements are done without an applied magnetic field.

The method described in the body of this standard is the "reference" method and optional acquisition methods are outlined in Clause A.4.

2 Normative references

The following referenced document is indispensable for the application 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.

IEC 60050-815, *International Electrotechnical Vocabulary (IEV) – Part 815: Superconductivity*

3 Terms and definition

For the purpose of this document, the terms and definitions given in IEC 60050-815 and the following apply.

residual resistance ratio
RRR
the ratio of resistance at room temperature to the resistance just above the superconducting transition.

In this standard for Nb-Ti composite superconductors, the room temperature is defined as 20 °C, and the residual resistance ratio is obtained in equation (1) below where the resistance (R_1) at 20 °C is divided by the resistance (R_2) just above the superconducting transition.

$$RRR = \frac{R_1}{R_2} \qquad (1)$$

Figure 1 shows schematically a resistance versus temperature curve acquired on a specimen while measuring the cryogenic resistance. Draw a line in Figure 1 where the resistance sharply increases (a), and draw also a line in Figure 1 where the temperature increases but the resistance remains almost the same (b). The value of resistance at the intersection of these two lines, A, is defined as resistance (R_2) just above the superconducting transition.

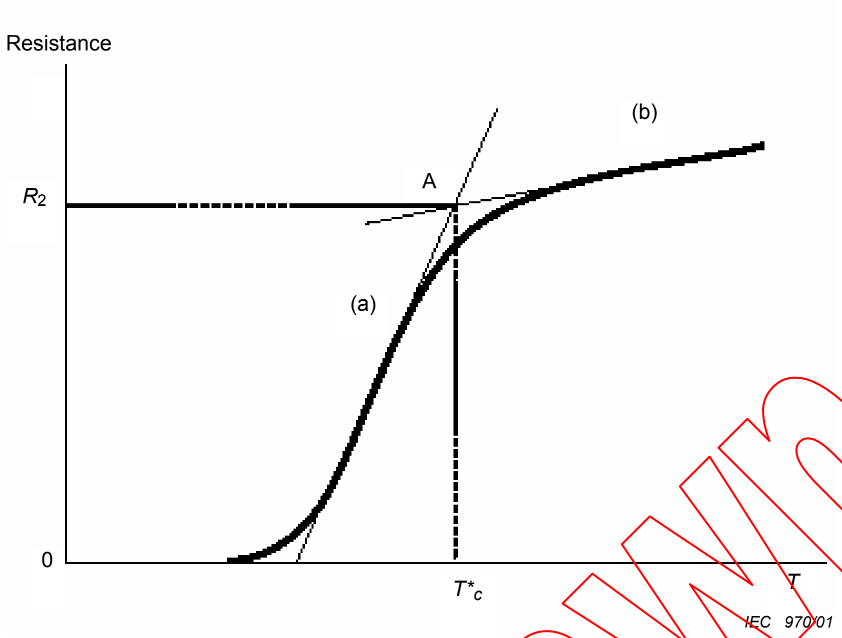

Figure 1 – Relationship between temperature and resistance

4 Requirements

The resistance measurement both at room and cryogenic temperatures shall be performed with the four-terminal technique.

The target relative combined standard uncertainty of this method is that the coefficient of variation (COV) in the intercomparison test shall be 5 % or less.

The maximum bending strain, induced during mounting the specimen, shall not exceed 2 %.

5 Apparatus

5.1 Material of measuring mandrel or of measuring base plate

Material of the measuring mandrel for a coiled specimen or of the measuring base plate for a straight specimen shall be copper, aluminium, silver, or the like whose thermal conductivity is equal to or better than 100 W/(m·K) at liquid helium temperature (4,2 K). The surface of the material shall be covered with an insulating layer (tape or a layer made of mylar, polyester, teflon, etc.) whose thickness is 0,1 mm or less.

5.2 Diameter of the measuring mandrel and length of the measuring base plate

Diameter of the measuring mandrel shall be large enough to keep bending strain of the specimen less than or equal to 2 %.

The measuring base plate shall be at least 30 mm long in one dimension.

5.3 Cryostat for the resistance, R_2, measurement

The cryostat shall include a specimen support structure and a liquid helium reservoir for the resistance, R_2, measurement. The specimen support structure shall allow the specimen, which is mounted on a measurement mandrel or a measurement base plate, to be lowered and raised into, and out of, a liquid helium bath. In addition, the specimen support structure shall be made so that a current can flow through the specimen and the resulting voltage generated along the specimen can be measured.

6 Specimen preparation

The test specimen shall have no joints or splices, and shall be 30 mm or longer. The distance between two voltage taps (L) shall be 25 mm or longer. A thermometer for measuring cryogenic temperature shall be attached near the specimen.

Some mechanical method shall be used to hold the specimen against the insulated layer of the measurement mandrel or base plate. Special care shall be taken during instrumentation and installation of the specimen on the measurement mandrel or on the measurement base plate so that there is no excessive force, which may cause undesired bending strain or tensile strain, being applied to the specimen.

The specimen shall be instrumented with current contacts near each end of the specimen and a pair of voltage contacts over a central portion of the specimen. The specimen shall be mounted on a measurement mandrel or on a measurement base plate for these measurements. Both resistance measurements, R_1 and R_2, shall be made on the same specimen and the same mounting.

7 Data acquisition and analysis

7.1 Resistance (R_1) at room temperature

The mounted specimen shall be measured at room temperature (T_m (°C)), where T_m satisfies the following condition, $0 \leq T_m \leq 35$. A specimen current (I_1 (A)) shall be applied so that the current density is in the range of 0,1 A/mm² to 1 A/mm² based on the total wire cross-sectional area, and the resulting voltage (U_1 (V)), I_1 and T_m shall be recorded. Equation (2) below shall be used to calculate the resistance (R_m) at room temperature. The resistance (R_1) at 20 °C (293 K) shall be calculated using equation (3) for a wire with Cu matrix. The value of R_1 shall be set equal to R_m, without any temperature correction, for wires that do not contain a pure Cu component.

$$R_m = \frac{U_1}{I_1} \tag{2}$$

$$R_1 = \frac{R_m}{[1 + 0{,}00393 \times (T_m - 20)]} \tag{3}$$

7.2 Resistance (R_2*) just above the superconducting transition

Under a strained condition of the specimen, the measured cryogenic resistance, R_2*, is not a correct value for R_2. The corresponding correction of the strain effect will be described in 7.3.

7.2.1 The specimen, which is still mounted as it was for the room temperature measurement, shall be placed in the cryostat for electrical measurement specified under 5.3. Alternate cryostats that employ a heating element to sweep the specimen temperature are described in Clause A.2.