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Part 23: Residual resistance ratio measurement - Residual resistance ratio of cavity-grade Nb superconductors

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Introduction

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For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



COMMITTEE DRAFT FOR VOTE (CDV)

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SUPERSEDES DOCUMENTS:
90/499/RR

IEC TC 90 : SUPERCONDUCTIVITY	
SECRETARIAT: Japan	SECRETARY: Mr Jun Fujikami
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	
☒ SUBMITTED FOR CENELEC PARALLEL VOTING Attention IEC-CENELEC parallel voting The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.	☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING

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Recipients of this document are invited to submit, with their comments, notification of any relevant "In Some Countries" clauses to be included should this proposal proceed. Recipients are reminded that the CDV stage is the final stage for submitting ISC clauses. (SEE [AC/22/2007](#) OR [NEW GUIDANCE DOC](#)).

TITLE:

Superconductivity - Part 23: Residual resistance ratio measurement - Residual resistance ratio of cavity-grade Nb superconductors

PROPOSED STABILITY DATE: 2030

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SUPERCONDUCTIVITY –

**Part 23: Residual resistance ratio measurement –
Residual resistance ratio of cavity-grade Nb superconductors**

FOREWORD

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- IEC 61788-23 has been prepared by IEC technical committee 90: Superconductivity. It is an International Standard.
- This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.
- This edition includes the following significant technical changes with respect to the previous edition:
- a) The scope of this standard was modified to restrict the range of residual resistance ratio to that encountered by providers of material for superconducting radio-frequency cavities.
 - b) The references to technical material were updated and corrected.

119 The text of this International Standard is based on the following documents:

FDIS	Report on voting
90/478/FDIS	90/482/RVD

120
121 Full information on the voting for its approval can be found in the report on voting indicated in
122 the above table.

123 The language used for the development of this International Standard is English.

124 This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in
125 accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available
126 at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are
127 described in greater detail at www.iec.ch/standardsdev/publications.

128 A list of all parts in the IEC 61788 series, published under the general title *Superconductivity*,
129 can be found on the IEC website.

130 The committee has decided that the contents of this document will remain unchanged until the
131 stability date indicated on the IEC website under webstore.iec.ch in the data related to the
132 specific document. At this date, the document will be

- 133 • reconfirmed,
134 • withdrawn,
135 • replaced by a revised edition, or
136 • amended.

137

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INTRODUCTION

High-purity niobium is the chief material used to make superconducting radio-frequency cavities. Similar grades of niobium may be used in the manufacture of superconducting wire. Procurement of raw materials and quality assurance of delivered products often use the residual resistance ratio (RRR) to specify or assess the purity of a metal. RRR is defined for non-superconducting metals as the ratio of electrical resistance measured at room temperature (293 K) to the resistance measured for the same specimen at low temperature (~4,2 K). The low-temperature value is often called the residual resistance. Higher purity is associated with higher values of RRR.

Niobium presents special problems due to its transformation to a superconducting state at ~9 K, so DC electrical resistance is effectively zero below this temperature. The definition above would then yield an infinite value for RRR. This document describes a test method to determine the residual resistance value by using a plot of the resistance to temperature as the test specimen is gradually warmed through the superconducting transition in the absence of an applied magnetic field. This results in a determination of the residual resistance at just above superconducting transition, ~10 K, from which RRR is subsequently determined.

International Standards also exist to determine the RRR of superconducting wires. In contrast to superconducting wires, which are usually a composite of a superconducting material and a non-superconducting material and the RRR value is representative of only the non-superconducting component, here the entire specimen is composed of superconducting niobium. Frequently, niobium is procured as a sheet, bar, tube, or rod, and not as a wire. For such forms, test specimens will likely be a few millimetres in the dimensions transverse to electric current flow. This difference is significant when making electrical resistance measurements, since niobium samples will likely be much longer than that for the same length-to-diameter ratio as a wire, and higher electrical current may be required to produce sufficient voltage signals. Guidance for sample dimensions and electrical connections is provided in Annex A. Test apparatus should also take into consideration aspects such as the orientation of a test specimen relative to the liquid helium surface, accessibility through ports on common liquid helium dewars, design of current contacts, and minimization of thermal gradients over long specimen lengths. These aspects distinguish this document from similar wire standards.

Other test methods have been used to determine RRR. Some methods use a measurement at a temperature other than 293 K for the high resistance value. Some methods use extrapolations at 4,2 K in the absence of an applied magnetic field for the low resistance value. Other methods use an applied magnetic field to suppress superconductivity at 4,2 K. A comparison between this document and some other test methods is presented in Annex A. Note that systematic differences of up to 10 % are produced by these other methods, which is larger than the target uncertainty of this document. It is therefore important to apply this document or the appropriate corrections listed in Annex A according to the test method used.

Whenever possible, this test method should be transferred to vendors and collaborators who also perform RRR measurements. To promote consistency, the results of inter-laboratory comparisons are described in Clause C.2.

SUPERCONDUCTIVITY –

Part 23: Residual resistance ratio measurement – Residual resistance ratio of cavity-grade Nb superconductors

1 Scope

This part of IEC 61788 addresses a test method for the determination of the residual resistance ratio (RRR), r_{RRR} , of cavity-grade niobium. This method is intended for high-purity niobium grades with $150 < r_{RRR} < 600$. The test method is valid for specimens with rectangular or round cross-section, cross-sectional area greater than 1 mm² but less than 20 mm², and a length not less than 10 nor more than 25 times the width or diameter.

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.

IEC 60050-815, *International Electrotechnical Vocabulary – Part 815: Superconductivity* (available at: www.electropedia.org)

3 Terms and definitions

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

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>

3.1 residual resistance ratio RRR

r_{RRR}
ratio of resistance at room temperature to the resistance just above the superconducting transition

$$r_{RRR} = R_1 / R_2 \quad (1)$$

where

R_1 is the resistance at 293 K;

R_2 is the resistance just above the superconducting transition, at ~10 K.

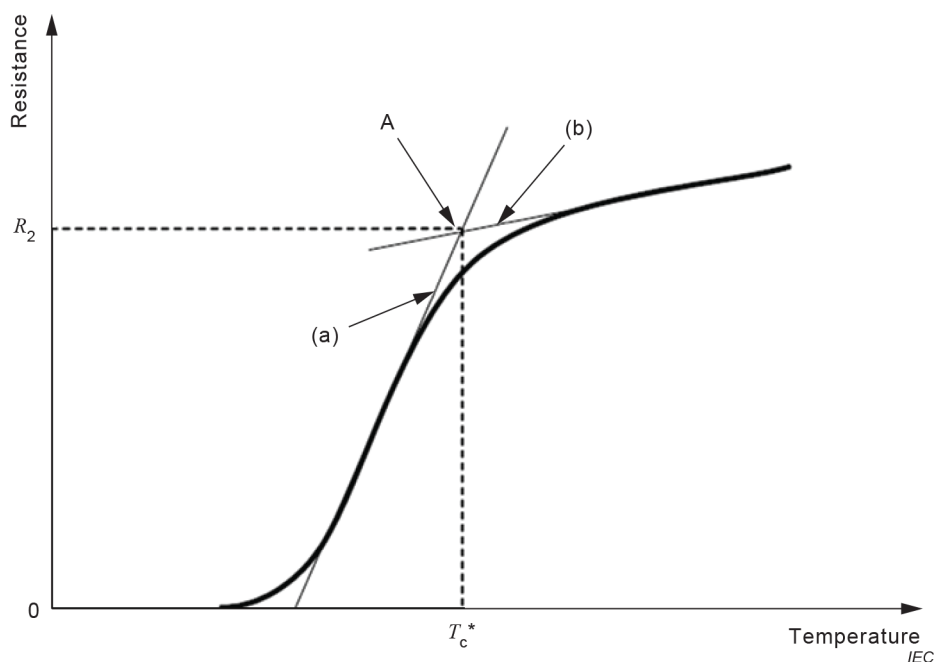


Figure 1 – Relationship between temperature and resistance near the superconducting transition

Note 1 to entry: In this document, the room temperature is defined as 20 °C = 293 K, and r_{RRR} is obtained as follows: Figure 1 shows schematically resistance versus temperature data and the graphical procedure used to determine the value of R_2 . In Figure 1, the region of maximum slope is extrapolated upward in resistance, as shown by line (a), and the region of minimum slope at temperatures above the transition temperature is extrapolated downward in temperature, as shown by line (b). The intersection of these extrapolations at point A determines the value of R_2 as well as a temperature value T_c^* .

Note 2 to entry: The value T_c^* is similar to the transition value defined in [1]¹, and should not be confused with the value defined at the midpoint of the transition, called T_c in [2].

Note 3 to entry: Some standards or documented techniques, e.g. [3], [4], [5], [6], define r_{RRR} with the value of R_1 determined at a temperature other than 293 K, or the value of R_2 determined at a temperature below the superconducting transition. The user of this document should be alert for such differences in definition.

4 Principle

The 4-point DC electrical resistance technique shall be performed both at room temperature and at cryogenic temperature. The test of resistance shall be done as a function of temperature. Another test method of resistance as a function of time with increasing temperature is described in Annex A.4.2.

The relative combined standard uncertainty of this method is 3 % with coverage factor 2.

Measurements shall have the following attributes.

- a) Measuring current is sufficiently high to provide voltage signals of the order of 1 µV. For electrical safety, maximum current density should never exceed 1 A mm⁻².

¹ Numbers in square brackets refer to the Bibliography.