

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



**Superconductivity –** **STANDARD PREVIEW**  
**Part 12: Matrix to superconductor volume ratio measurement – Copper to non-**  
**copper volume ratio of Nb<sub>3</sub>Sn composite superconducting wires**

**Supraconductivité –**  
**Partie 12: Mesure du rapport volumique matrice/supraconducteur –**  
**Rapport volumique cuivre/non-cuivre des fils en composite supraconducteur**  
**Nb<sub>3</sub>Sn**

[IEC 61788-12:2013](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-)

<https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc->



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2013 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### Useful links:

IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,...).

It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).

### A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Liens utiles:

Recherche de publications CEI - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,...).

Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).



IEC 61788-12

Edition 2.0 2013-06

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Superconductivity –** **STANDARD PREVIEW**  
**Part 12: Matrix to superconductor volume ratio measurement – Copper to non-**  
**copper volume ratio of Nb<sub>3</sub>Sn composite superconducting wires**

[IEC 61788-12:2013](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-152118916-072106/iec-61788-12)

**Supraconductivité –**  
**Partie 12: Mesure du rapport volumique matrice/supraconducteur –**  
**Rapport volumique cuivre/non-cuivre des fils en composite supraconducteur**  
**Nb<sub>3</sub>Sn**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX

U

ICS 29.050

ISBN 978-2-83220-864-9

**Warning! Make sure that you obtained this publication from an authorized distributor.**  
**Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions.....	7
4 Principle.....	8
5 Apparatus.....	8
6 Measurement procedure.....	8
6.1 Preparation of specimen.....	8
6.1.1 General.....	8
6.1.2 Procedures.....	8
6.2 Measurement.....	9
6.2.1 Photo of cross-section.....	9
6.2.2 Transfer.....	9
6.2.3 Cutting.....	9
6.2.4 Measurement of paper mass.....	9
6.3 Test procedure for the second specimen.....	9
6.4 Paper mass.....	9
7 Calculation of results.....	9
8 Uncertainty of the test method.....	10
9 Test report.....	10
9.1 Copper to non-copper volume ratio.....	10
9.2 Identification of test specimen.....	10
Annex A (normative) Measurement – Image processing method.....	11
Annex B (normative) Measurement – Copper mass method.....	12
Annex C (normative) Measurement method using planimeter.....	13
Annex D (informative) Specimen polishing method.....	14
Annex E (informative) Difference of the copper to non-copper volume ratio before and after the Nb <sub>3</sub> Sn generation heat treatment process.....	15
Annex F (informative) Paper mass bias at copy.....	16
Annex G (informative) Cross-sections of Cu/Nb <sub>3</sub> Sn wires.....	17
Annex H (informative) Uncertainty considerations.....	18
Annex I (informative) Uncertainty evaluation in the test method of the copper to non-copper volume ratio of Nb <sub>3</sub> Sn composite superconducting wires.....	23
Figure G.1 – Cross-sections of four Cu/Nb <sub>3</sub> Sn wire types according to the layout of the stabilizer.....	17

ITeCh STANDARD PREVIEW  
(standards.iteh.ai)

IEC 61788-12:2013

<https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-b803d/iec-61788-12-2013>

Table H.1 – Output signals from two nominally identical extensometers .....	19
Table H.2 – Mean values of two output signals .....	19
Table H.3 – Experimental standard deviations of two output signals .....	19
Table H.4 – Standard uncertainties of two output signals .....	20
Table H.5 – Coefficient of variations of two output signals .....	20

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

[IEC 61788-12:2013](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013)

<https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SUPERCONDUCTIVITY –**

**Part 12: Matrix to superconductor volume ratio measurement – Copper to non-copper volume ratio of Nb<sub>3</sub>Sn composite superconducting wires**

**FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61788-12 has been prepared by IEC technical committee 90: Superconductivity.

This second edition cancels and replaces the first edition published in 2002. It constitutes a technical revision. The main revision is the addition of two new annexes, "Uncertainty considerations" (Annex H) and "Uncertainty evaluation in the test method of the copper to non-copper volume ratio of Nb<sub>3</sub>Sn composite superconducting wires" (Annex I).

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

FDIS	Report on voting
90/322/FDIS	90/325/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 stability 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.

**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 publication using a colour printer.**

## iTeh STANDARD PREVIEW (standards.iteh.ai)

[IEC 61788-12:2013](#)

<https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013>

## INTRODUCTION

The copper to non-copper volume ratio of superconducting wires serves as an important numeric value used when determining the critical current density and its stability, which are two of the important characteristics of superconducting wires. This standard is concerned with the standardization of the test method for the copper to non-copper volume ratio of copper stabilized Nb<sub>3</sub>Sn multi-filamentary composite superconducting wires (hereinafter referred to as Cu/Nb<sub>3</sub>Sn wires).

Cu/Nb<sub>3</sub>Sn wires can be classified into four types according to the layout of the stabilizer as shown in Annex G: the external stabilizer type, the internal stabilizer type, the distributed stabilizer type and the contiguous stabilizer with distributed barrier type. The test method specified by this standard may be applicable to a type whose cross-section is of the external stabilizer or the internal stabilizer type regardless of the production process employed.

With regard to the internal stabilizer type, the internal structure of some Cu/Nb<sub>3</sub>Sn wires prevents copper from being dissolved and removed. This precludes the application of the copper mass method, unlike with copper matrix Nb-Ti superconducting wires. New methods are therefore needed, as detailed in the following:

- the paper mass method, where a photo of the cross-section of the wire being measured is traced onto tracing paper, or a copy is made of the photo using a copying machine; the paper is then cut out into different portions to measure the mass of each piece of paper;
- the image processing method, where the image of the photo of the cross-section is digitized and the areas are analyzed with software;
- the copper mass method, where the copper of the specimen is dissolved in nitric acid solution to leave only the non-copper portion, and to measure the mass of the specimen and the non-copper portion of specimen.

[IEC 61788-12:2013](#)

This standard is concerned with the paper mass method which is adopted more generally. As supplementary methods, the image processing method and the copper mass method adopted for Cu/Nb<sub>3</sub>Sn wires are specified in Annex A and Annex B, respectively. The method using a planimeter is specified in Annex C. In Annex D an example of a polishing method is also specified.



## SUPERCONDUCTIVITY –

### Part 12: Matrix to superconductor volume ratio measurement – Copper to non-copper volume ratio of Nb<sub>3</sub>Sn composite superconducting wires

#### 1 Scope

This part of IEC 61788 describes a test method for determining the copper to non-copper volume ratio of Cu/Nb<sub>3</sub>Sn wires.

The test method given hereunder is applicable to Nb<sub>3</sub>Sn composite superconducting wires with a cross-sectional area of 0,1 mm<sup>2</sup> to 3,0 mm<sup>2</sup> and a copper to non-copper volume ratio of 0,1 or more. It does not make any reference to the filament diameter; however, it is not applicable to those superconducting wires with their filament, Sn, Cu-Sn alloy, barrier material and other non-copper portions dispersed in the copper matrix or those with the stabilizer dispersed. Furthermore, the copper to non-copper volume ratio can be determined on specimens before or after the Nb<sub>3</sub>Sn formation heat treatment process.

The Cu/Nb<sub>3</sub>Sn wire has a monolithic structure with a round or rectangular cross-section.

Though uncertainty increases, this method may be applicable to the measurement of the copper to non-copper volume ratio of the Cu/Nb<sub>3</sub>Sn wires whose cross-section and copper to non-copper volume ratio fall outside the specified ranges.

This test method may be applied to other composite superconducting wires after some appropriate modifications.

#### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <<http://www.electropedia.org>>

IEC 61788-5, *Superconductivity – Part 5: Matrix to superconductor volume ratio measurement – Copper to superconductor volume ratio of Cu/Nb-Ti composite superconductors*

#### 3 Terms and definitions

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

##### 3.1

##### **copper to non-copper volume ratio**

ratio of the volume of the copper stabilizing material to the volume without copper consisting of Cu/Nb<sub>3</sub>Sn wires

## 4 Principle

The principle of this method is described in the following. A photo of the polished cross-section of the sample wire shall be taken with a metallograph. This photo is traced onto tracing paper, or a copy is made of the photo using a copy machine. The tracing paper or copy is then cut out into different portions to measure the mass of each piece of paper. The copper to non-copper volume ratio can be obtained from the ratio of the paper mass of both portions.

## 5 Apparatus

The apparatus required for the test includes the following:

- metallograph;
- photomicrographic camera;
- polishing machine;
- balance;

A balance shall have a manufacturer's specified uncertainty of  $\pm 0,1$  mg or better.

- scissors or cutter.

## 6 Measurement procedure

### 6.1 Preparation of specimen

#### 6.1.1 General

The specimen shall be prepared from a Cu/Nb<sub>3</sub>Sn wire before or after the Nb<sub>3</sub>Sn generation heat treatment process. Two specimens shall be cut out of a Cu/Nb<sub>3</sub>Sn wire being measured.

NOTE In the case of measuring an internal tin processed wire before the treatment, the stabilizer copper is carefully distinguished from copper in other parts.

#### 6.1.2 Procedures

##### 6.1.2.1 Mold

The two specimens shall be molded at the same time for polishing. As the molding material, an appropriate resin shall be used to embed the specimen for observation through the metallograph. When molding, it shall be carefully checked that the cross-section of the specimen is at right angles to the polishing surface as much as possible.

##### 6.1.2.2 Polishing

The specimen shall be polished using emery paper and buffed using an abrasive material. A microscope shall be used to check that the polished surface is smooth enough to ensure good photographing, especially the boundary between the copper and non-copper portions and the periphery of the sample. The surface shall be re-polished, if these areas are not clear because of abrasive scratches. An example of the polishing method is specified in Annex D.

##### 6.1.2.3 Cleaning and drying

The polished specimen shall be cleaned using running water, distilled water, acetone or ethyl alcohol. It shall be checked that the cleaning agent does not dissolve the resin in which the specimen is embedded. An ultrasonic cleaning machine may be used if necessary. After cleaning, the specimen shall be dried with chilled or hot air to prevent the polished surface from oxidizing or discoloring.

## 6.2 Measurement

### 6.2.1 Photo of cross-section

A black-and-white or color picture of the cross-section shall be taken using the metallograph.

The magnification shall be selected for the entire cross-section of the specimen to fit within the size of the photo. A photomicrographic camera with as much depth of focus as possible shall be used, so that the boundary between copper and non-copper portions and the periphery of the specimen appear clear and vivid on the photo.

### 6.2.2 Transfer

The image of the cross-section shall be traced on tracing paper so that the copper portion and non-copper portion can be separated.

As an alternative method, a copy of the photo of the cross-section shall be made using a copying machine. A zoom ratio of the copier that will fit the image in a sheet of paper and allow the cutting work to be done easily shall be selected. If a copy is to be made using a copy machine, a copy of a scale shall be made at the same time, to check that the copier distortion is within  $\pm 1$  % (see Annex F).

### 6.2.3 Cutting

Scissors or a cutter shall be used to cut the tracing paper or the copy into the copper and non-copper portions.

### 6.2.4 Measurement of paper mass

The first specimen shall be measured twice. <https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013>

The paper mass of the copper portion and non-copper portion shall be measured with a combined standard uncertainty not to exceed 0,1 mg. Each portion shall be measured twice and the average of the two measurements shall be reported.

During the measurement, caution shall be taken to ensure that the measurement is not affected by humidity. If the mass continues to change, the specimen shall remain in the measurement chamber for about 10 min before resuming the measurement sequence.

## 6.3 Test procedure for the second specimen

The steps given under 6.2 shall be repeated to measure the paper mass for the second specimen.

## 6.4 Paper mass

The paper mass of the copper portion ( $M_{Cu}$ ) to that of the non-copper portion ( $M_{non}$ ) shall be obtained by averaging the paper mass measured at steps 6.2 and 6.3.

## 7 Calculation of results

For each measurement taken in 6.2 and 6.3, the copper to non-copper volume ratio shall be obtained from the ratio of the paper mass of the copper portion to that of the non-copper portion. Copper to non-copper volume ratio is expressed as  $M_{Cu}/M_{non}$

The ratio shall be rounded to two decimal places.

## 8 Uncertainty of the test method

The uncertainty of this test method is affected by the sag of the specimen occurring from polishing, transfer to tracing paper, distortion of the copying machine and uncertainty in cutting out portions from the paper. The relative combined standard uncertainty of this method shall not exceed 2,5 % (using a coverage factor of  $k = 1$ ) as shown in Clause I.1.

## 9 Test report

### 9.1 Copper to non-copper volume ratio

The report shall contain the following information:

- a) copper to non-copper volume ratio of each specimen;
- b) wire diameter or size of the cross-section if it is a rectangular shape;
- c) whether the specimens had or had not received the Nb<sub>3</sub>Sn generation heat treatment.

The report shall contain the following information if known:

- d) manufacturing method;
- e) configuration of the copper matrix;
- f) photo of cross-section;
- g) measurement conditions and information;
- h) raw measured data;
- i) information of measurement equipment.

### 9.2 Identification of test specimen IEC 61788-12:2013

The test specimen shall be identified by the following information if known:

- a) name of the manufacturer of the specimen;
- b) identification number;
- c) billet number.

## Annex A (normative)

### Measurement – Image processing method

#### A.1 Method

The following details describe the method that can be used to digitize the image on the cross-sectional photo (image processing method).

- a) Following the steps from 6.1 through 6.2.1, photos of the cross-section of the specimens shall be taken.
- b) Using a scanner, the image of the cross-section photos shall be captured in a personal computer.
- c) Using image analysis software, the number of pixels on the copper portion and non-copper portion shall be determined.
- d) The copper to non-copper volume ratio of the specimen shall be determined using the following equation:

$$R_{\text{Cu},i} = \frac{N_{\text{Cu}}}{N_{\text{non}}} \quad (\text{A.1})$$

where

$R_{\text{Cu},i}$  is the copper to non-copper volume ratio with image processing method;

$N_{\text{Cu}}$  is the number of pixels on the copper portion;

$N_{\text{non}}$  is the number of pixels on the non-copper portion.

#### A.2 Test report

The following information shall be reported in addition to the data listed in Clause 9: image analysis software used.

NOTE 1 Measurement uncertainty of the image processing method is determined by the quality of image of the photo of cross-section. What is necessary to ensure a given level of uncertainty is taking a clear image of the specimen cross-section with a well-polished condition.

NOTE 2 Reproducibility of the measurements taken through the image processing method applied to the image captured from the same position at the same magnification is estimated by a relative combined standard uncertainty not to exceed 5 %.

## Annex B (normative)

### Measurement – Copper mass method

#### B.1 Method

The following describes the application of the copper mass method (see IEC 61788-5), which is employed for measuring the copper to superconductor volume ratio of Nb-Ti superconducting wires, to Nb<sub>3</sub>Sn. This method can be applied only to the external stabilizer type Cu/Nb<sub>3</sub>Sn wire with a round cross-section that exhibits a nature whereby copper dissolves in nitric acid. Nevertheless, it shall be avoided to apply this method to such wires if they have barriers that can be broken in the process of dissolving by nitric acid.

- a) A specimen with a length of 300 mm to 500 mm shall be cut and the mass ( $M_1$ ), length ( $L$ ) and diameter ( $D$ ) of the specimen shall be determined. The diameter shall be measured at five equally divided points and, taking the average of the measurements, the volume ( $V_1$ ) shall be calculated:

$$V_1 = \pi(D/2)^2L \quad (\text{B.1})$$

- b) The copper of the specimen shall be dissolved in nitric acid solution completely to leave only the non-copper portion. At this time, the specimen shall be rinsed quickly with water once the copper has dissolved, thereby minimizing the amount of bronze dissolved.
- c) The specimen shall be dried completely after rinsing.
- d) The mass ( $M_2$ ) of non-copper portion shall be measured.
- e) The volume ( $V_2$ ) of the copper portion shall be calculated using 8,93 g/cm<sup>3</sup> as the specific mass of copper.

$$V_2 = (M_1 - M_2) / 8,93 \quad (\text{B.2})$$

- f) The copper to non-copper volume ratio with copper mass method ( $R_{\text{Cu,c}}$ ) shall be calculated from the volume ( $V_1$ ) of the specimen and volume ( $V_2$ ) of the copper portion.

$$R_{\text{Cu,c}} = V_2 / (V_1 - V_2) \quad (\text{B.3})$$

- g) The relative combined standard uncertainty of this method shall not exceed 2,5% (using a coverage factor of  $k = 1$ ) as shown in Clause I.3.

#### B.2 Test report

The following information shall be reported in addition to the data listed in Clause 9: the necessary information according to the test report in IEC 61788-5.

## Annex C (normative)

### Measurement method using planimeter

#### C.1 Method

The following details describe the method using an analogue or a digital planimeter.

- a) According to steps 6.1 to 6.2.1, a photo of the cross-section shall be taken.
- b) A copy of the photo of the cross-section shall be made using a copying machine. A zoom ratio of the copier shall be selected so that the size of the enlarged image is more than 120 mm in width and within a sheet of paper.
- c) The values of cross-sections for copper and non-copper parts shall be obtained using a planimeter. Measurement with 5 turns of the planimeter to integrate the area is recommended in order to reduce the uncertainty. The measurement shall be carried out twice for the same photo, and the average value shall be the cross-sectional area if the measured values are within 5 %. If this value is more than 5 %, the measurement shall be carried out again.

NOTE In the case of relative combined standard uncertainty of a planimeter within 0,5 %, either an analog or a digital planimeter apparatus can be used.

- d) In the case of an external stabilizer type, the cross-sectional area of the copper part shall be obtained by subtracting that of the non-copper part from the whole area of the specimen. In the case of an internal stabilizer type, the cross-sectional area of the non-copper part shall be obtained by subtracting that of the copper part from the whole area.

#### C.2 Test report

[IEC 61788-12:2013](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013)

[https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013)

[fb5e39cb803d/iec-61788-12-2013](https://standards.iteh.ai/catalog/standards/sist/494e1da4-741b-4d96-91cc-fb5e39cb803d/iec-61788-12-2013)

The following information shall be reported in addition to the data listed in Clause 9: type of planimeter and zoom ratio of the copy used.