

Specification for

Copper alloy ingots and copper alloy and high conductivity copper castings

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- London Metal Exchange
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- Association of Supervisory and Executive Engineers
- BEAMA Transmission & Distribution Association
- BNF Metals Technology Centre
- British Bronze & Brass Ingot Manufacturers
- British Malleable Tube Fittings Association
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- Copper Smelters' and Refiners' Association
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Foreword

This revision of this British Standard, which has been prepared under the direction of the Non-ferrous Metals Standards Committee, supersedes BS 1400:1973 which is withdrawn.

The general technical requirements of this edition differ from those of the previous edition only in minor respects. However, the range of alloys covered has been revised and the opportunity has been taken to align the chemical compositions and mechanical properties of individual alloys, where appropriate, with the corresponding alloys specified in ISO 1338:1977 “*Cast copper alloys — Compositions and mechanical properties*” published by the International Organization for Standardization (ISO).

Comparisons of the materials specified in the revised edition of BS 1400 with those specified in ISO 1338 are summarized in Appendix H.

Four alloys have been included for the first time, reflecting current interest: two high strength cupro-nickel alloys having high resistance to sea water, one containing chromium (CN1) and the other containing niobium (CN2); a nickel-containing tin bronze (CT2); and an aluminium silicon bronze (AB3).

Alloy CMA2, included in the previous edition, has been omitted from this edition.

The practice adopted in the previous edition of grouping the alloys into three categories has been retained, with some changes, as follows.

- Group A. Alloys in common use (preferred for all general purposes): PB4, LPB1, LB2, LB4, LG1^(B), LG2, SCB1, SCB3, SCB6, DCB1, DCB3, PCB1.
- Group B. Special purpose alloys (for applications requiring their particular properties): HCC1, CC1-TF, PB1, PB2, CT1, LG4^(A), AB1, AB2, CMA1, HTB1, HTB3.
- Group C. Alloys in limited production: LB1, G1, G3, G3-TF, LB5^(B), SCB4, CT2, AB3, CN1, CN2.

NOTE The superscripts (A), (B) have been used to indicate alloys that have been transferred from another group.

This general grouping has been maintained throughout this standard, and both tables quoting specification requirements and design information have been classified in this way.

This standard continues to specify inspection requirements for ingots and castings and lays down minimum requirements for the frequencies of chemical analyses and mechanical tests. In addition a series of optional inspection and test procedures for castings is incorporated as Appendix A which may be selected according to the requirements of the purchaser and specified according to a set form of coding. In most cases particular conditions will also need to be specified and these are to be laid down by the purchaser in a “purchaser’s test schedule”, as itemized in Appendix D, provided at the enquiry stage.

Appendix G gives design information, including guidance on alloy selection. It is emphasized that this section is for information only and does not form part of the main specification.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 32, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies requirements for the chemical compositions, mechanical properties and other characteristics for the following two types of product:

- a) copper alloy ingots intended to be remelted for the production of castings; *and*
- b) copper alloy and high conductivity copper castings.

NOTE 1 This standard is intended to apply to castings made by any metal casting process. However, in the case of mechanical properties, requirements are specified (see 6.2 and 8.1) only for castings made by the sand, chill, continuous and centrifugal processes. The information on casting processes given in G.3 includes shell moulding.

Methods for verifying that ingots and castings comply with the requirements of this British Standard are also specified.

NOTE 2 Optional supplementary inspection and test procedures, that enable castings to be ordered according to particular inspection and test requirements appropriate to the application of the castings, are given in Appendix A. A system of inspection coding is described (A.1) that enables the additional inspection and test procedures to be specified readily at the design stage, for quotation purposes and for order. It is emphasized that over-inspection will lead to unnecessarily high costs and longer delivery times with no compensating advantages. For these reasons it is essential to select only those supplementary procedures that are necessary for the design and the product concerned.

NOTE 3 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purpose of this British Standard the following definitions apply.

2.1

cast (non-continuous melting)

the product of:

- a) one furnace melt; *or*
- b) one crucible melt; *or*
- c) a number of furnace or crucible melts where such are aggregated and mixed prior to sampling.

2.2

cast (continuous melting)

in continuous melting for the production of castings, when the contents of a melting/holding furnace or crucible are supplemented from time to time by the addition of metal to maintain an adequate bulk of liquid metal, a cast is 250 kg or fraction thereof of metal poured

2.3

“TF” condition

the symbols “TF”, added to the material designations for copper chromium (CC1-TF) and nickel gunmetal (G3-TF), indicate castings supplied in the solution treated and precipitation hardened condition

NOTE Details of such treatments, applied in order to achieve the specified mechanical properties (see Table 8), are not specified.

3 Information to be supplied by the purchaser

The following information shall be supplied by the purchaser in the enquiry and order to assist the manufacturer in supplying the correct ingots or castings:

- a) whether ingots or castings are required and, if castings are required, the casting process to be used (see note 1 to clause 1, Table 8 and Table 15);
- b) the designation of the material (see Table 1 to Table 3 for ingot materials and Table 5 to Table 7 for casting materials);
- c) if centrifugal castings are required, whether the tensile test samples are to be either taken from the castings or separately cast [see item d) of 8.1.3].

NOTE The purchaser should also be aware of the importance of including, in his enquiry and order, the following information as appropriate:

- 1) for both ingots and castings, whether it is the purchaser's intention to inspect the material at the supplier's works (see note 3 to 7.1);
- 2) for castings only:
 - i) a fully detailed and fully dimensioned drawing of the casting(s) required;
 - ii) details of the actual pattern equipment if this is to be supplied by the purchaser;
 - iii) full details of any of the optional supplementary inspection and test procedures required (see Appendix A and Appendix F), including the inspection coding (see A.1) and a test schedule in accordance with the recommendation given in Appendix D;
 - iv) if castings in alloys AB1, AB2 and AB3 are not to be repaired (see clause 4);
 - v) if inspection and testing are to be carried out by the purchaser and the samples and test pieces are to be retained by the purchaser (see note 3 to 7.1);
 - vi) details of the tensile test samples to be taken for continuous castings and the results to be achieved [see item c) of 8.1.3];

- vii) if electrical conductivity tests are required for casting in high conductivity copper (HCC1) or alloy CC1-TF, the test conditions to be used (see 9.5);
- viii) whether a certificate of compliance is required (see 7.4);
- ix) details of retest procedures other than those permitted by 7.3 (see note to 7.3.1);
- x) any requirements for the taking of analysis samples from the melt [see item 4) of note to 7.2.1].

4 General requirements

Copper alloy ingots shall comply with the requirements specified in clause 5.

Copper alloy and high conductivity copper castings shall comply with the requirements specified in clause 6.

Inspection procedures and test methods for verifying that the ingots and castings comply with the requirements specified in clauses 5 and 6 shall be as specified in clauses 7 and 8.

NOTE 1 For optional supplementary inspection and test procedures see Appendix A.

NOTE 2 In the event of any dispute concerning compliance of the ingots or castings with the requirements of this standard, it is normal commercial practice for the supplier and the purchaser to have tests undertaken by a mutually acceptable independent testing authority and to accept the results of such tests as final.

The results obtained from analysis and mechanical property tests shall be rounded to the last place of figures specified as limits, by the application of the rounding rules in accordance with BS 1957.

NOTE 3 For further guidance see Appendix B.

Castings that have been subjected to reclamation (i.e. impregnation or weld repair) shall be re-inspected to verify compliance with the requirements of this standard and any supplementary requirements specified in accordance with Appendix A.

NOTE 4 In normal commercial practice, weld repair of castings in alloys AB1, AB2 and AB3 is permitted provided that the purchaser has not stipulated that the castings are to be repair free [see item b) 5) of the note to clause 3].

For castings in alloys other than AB1, AB2 and AB3, reclamation and repair welding are only permitted by the written approval of the purchaser and his acceptance of the proposed methods of reclamation repair.

5 Specific requirements for ingots

5.1 Chemical composition

The chemical compositions of ingots, shall be as given in Table 1 to Table 3.

5.2 Tensile properties

For ingots the tensile properties, determined by the method given in 9.2 on separately cast test bars taken in accordance with 7.2.2.1, 8.1.1 and 8.1.2 shall be as given in Table 4.

NOTE No tensile properties are specified for ingots in alloys not included in Table 4.

5.3 Microstructure of alloy HTB1

For ingots cast in HTB1 the proportion of alpha phase in the microstructure, determined by the method described in 9.4 on samples taken in accordance with 7.2.3 and 8.3, shall not be less than 15 % by area.

5.4 Freedom from defects

The ingots shall be clean and free from harmful defects.

NOTE Ingots may be deemed not to comply with this standard because of unacceptable casting defects, even though the ingots may comply with the other requirements specified.

5.5 Identification and marking

Each cast of ingots shall be identified by a convenient method, e.g. by a cast number stamped on each ingot.

The ingots shall be colour marked to identify the alloys in which they have been cast. The colours and colour combinations used to identify the alloys shall be in accordance with those given in Appendix C.

Table 1 — Chemical compositions of Group A ingots [see item b) of clause 3]

Designation	PB4	LPB1	LB2	LB4	LG1	LG2	SCB1	SCB3	SCB6	DCB1	DCB3	PCB1	Designation
Material	Phosphor-bronze (copper-tin-phosphorus)	Leaded phosphor-bronze	Leaded bronze	Leaded bronze	Leaded gunmetal	Leaded gunmetal	Brass for sand castings	Brass for sand castings	Brass for brazable casting	Brass for die castings	Brass for die castings	Brass for pressure die castings	Material
Nominal composition	Cu Sn10 Pb P	Cu Sn7 Pb P	Cu Pb10 Sn10	Cu Pb9 Sn5	Cu Sn3 Pb5 Zn8	Cu Sn5 Pb5 Zn5	Cu Zn25 Pb3 Sn2	Cu Zn33 Pb2	Cu Zn15 As	Cu Zn40	Cu Zn40 Pb	Cu Zn40 Pb	Nominal composition
Elements	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	Elements
Copper	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	70.0 77.0	63.0 66.0 ^b	83.0 87.0	59.0 62.0	58.0 62.0 ^b	57.0 60.0	Copper
Tin	9.7 —	6.5 8.5	9.2 11.0	4.2 6.0	2.0 3.5	4.0 6.0	1.0 3.0	— 1.5	— —	— —	— 1.0	— 0.5	Tin
Zinc	— 0.5	— 2.0	— 1.0	— 2.0	7.5 9.5	4.5 6.0	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	Zinc
Lead	— 0.75	2.0 3.8	9.0 10.5	8.5 10.5	4.0 6.0	4.0 6.0	2.0 5.0	1.0 2.8	— 0.5	— 0.25 ^a	0.5 2.5	0.5 2.5	Lead
Phosphorus	0.5 —	0.4 —	— 0.05	— 0.05	— —	— 0.02	— —	— 0.02	— —	— —	— —	— —	Phosphorus
Nickel	— 0.5	— 1.0	— 2.0	— 2.0	— 2.0	— 2.0	— 1.0	— 1.0	— —	— —	— 1.0	— —	Nickel
Iron	— —	— 0.2	— 0.15	— 0.15	— —	— 0.25	— 0.5	— 0.5	— —	— —	— 0.5	— 0.3	Iron
Aluminium	— —	— 0.01	— 0.01	— 0.01	— 0.01	— 0.01	— 0.01	— 0.1 ^c	— —	0.25 0.5	0.2 0.8	— 0.5	Aluminium
Manganese	— —	— —	— 0.2	— 0.2	— —	— —	— —	— 0.2	— —	— —	— 0.5	— —	Manganese
Antimony	— —	— 0.25	— 0.5	— 0.5	— —	— —	— —	— —	— —	— —	— —	— —	Antimony
Arsenic	— —	— —	— —	— —	— —	— —	— —	— —	0.05 0.20	— —	— —	— —	Arsenic
Iron + arsenic + antimony	— —	— —	— —	— —	— 0.75	— 0.50	— —	— —	— —	— —	— —	— —	Iron + arsenic + antimony
Silicon	— —	— 0.01	— 0.02	— 0.02	— 0.02	— 0.02	— —	— 0.03	— —	— —	— 0.05	— —	Silicon
Bismuth	— —	— —	— —	— —	— 0.10	— 0.05	— —	— —	— —	— —	— —	— —	Bismuth
Sulphur	— 0.1	— 0.1	— 0.1	— 0.1	— 0.1	— 0.1	— —	— —	— —	— —	— —	— —	Sulphur
Total of impurities	— 0.50	— 0.50	— 0.50	— 0.50	— 1.0	— 0.80	— 1.0	— 1.0	— 1.0 incl. Pb	— 0.75	— 0.5	— 0.5	Total of impurities

NOTE Specified impurities are shown in light type.

^a DCB1. 0.1 % maximum lead if required.^b Nickel to be counted as copper.^c For pressure tight castings aluminium shall not be greater than 0.02 %.

Table 2 — Chemical compositions of Group B ingots [see item b) of clause 3]

Designation	PB1	PB2	CT1	LG4	AB1	AB2	CMA1	HTB1 ^b	HTB3	Designation
Material	Phosphor-bronze (copper-tin-phosphorus)	Phosphor-bronze (copper-tin-phosphorus)	Copper-tin	Leaded gunmetal	Aluminium bronze (copper-aluminium)	Aluminium bronze (copper-aluminium)	Copper-manganese-aluminium	High tensile brass	High tensile beta brass	Material
Nominal composition	Cu Sn10 P	Cu Sn11 P	Cu Sn10	Cu Sn7 Pb3 Zn3	Cu Al10 Fe3	Cu Al10 Fe5 Ni5	Cu Mn13 Al8 Fe3 Ni3	Cu Zn35 Al Fe Mn	Cu Zn28 Al5 Fe Mn	Nominal composition
Elements	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	Elements
Copper	% %	% %	% %	% %	% %	% %	% %	% %	% %	Copper
Tin	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	57.0 —	55.0 —	Tin
Zinc	10.2 11.5	11.2 13.0	9.2 11.0	6.0 8.0 ^a	— 0.1	— 0.1	— 0.50	— 1.0	— 0.20	Zinc
Lead	— 0.05	— 0.30	— 0.05	1.7 3.2	— 0.50	— 0.50	— 1.0	Remainder	Remainder	Lead
Phosphorus	— 0.25	— 0.50	— 0.25	2.7 3.5	— 0.03	— 0.03	— 0.05	— 0.50	— 0.20	Phosphorus
Nickel	0.60 1.0	0.25 0.6	— 0.05	— 0.02	— —	— —	— 0.05	— 1.0	— —	Nickel
Iron	— 0.10	— 0.10	— 0.15	— 0.2	1.5 3.5	4.0 5.5	2.0 4.0	0.7 2.0	1.5 3.25	Iron
Aluminium	— 0.01	— 0.01	— 0.01	— 0.01	8.7 10.5	8.8 10.0	7.0 8.5	0.5 2.5	3.0 6.0	Aluminium
Manganese	— 0.05	— —	— 0.2	— —	— 1.0	— 3.0	11.0 15.0	0.1 3.0	1.5 4.0	Manganese
Antimony	— 0.05	— —	— 0.2	— 0.25	— —	— —	— —	— —	— —	Antimony
Arsenic	— —	— —	— —	— 0.15	— —	— —	— —	— —	— —	Arsenic
Iron + arsenic + antimony	— —	— —	— —	— 0.40	— —	— —	— —	— —	— —	Iron + arsenic + antimony
Silicon	— 0.02	— 0.02	— 0.02	— 0.01	— 0.2	— 0.1	— 0.15	— 0.10	— 0.10	Silicon
Bismuth	— —	— —	— —	— 0.05	— —	— —	— —	— —	— —	Bismuth
Magnesium	— —	— —	— —	— —	— 0.05	— 0.05	— —	— —	— —	Magnesium
Sulphur	— 0.05	— 0.1	— 0.05	— 0.1	— —	— —	— —	— —	— —	Sulphur
Total of impurities	— 0.60	— 0.20	— 0.80	— 0.70	— 0.30	— 0.20	— 0.30	— 0.20	— 0.20	Total of impurities

NOTE Specified impurities are shown in light type.

^a Tin + ½ nickel content shall be within the range 7.0 % to 8.0 %.

^b HTB1. Subject to microstructure requirements (see 5.3). If required lead may be specified as not more than 0.10 %.

Table 3 — Chemical compositions of Group C ingots [see item b) of clause 3]

Designation	LB1	LB5	G1	G3	SCB4	CT2	AB3	CN1	CN2	Designation
Material	Leaded bronze	Leaded bronze	Gunmetal	Nickel gunmetal	Naval brass for sand casting	Copper tin	Aluminium silicon bronze	Copper nickel chromium	Copper nickel niobium	Material
Nominal composition	Cu Pb15 Sn9	Cu Pb20 Sn5	Cu Sn10 Zn2	Cu Sn7 Ni5 Zn3	Cu Zn36 Sn	Cu Sn12 Ni	Cu Al6 Si2 Fe	Cu Ni30 Cr	Cu Ni30 Nb	Nominal composition
Elements	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	min. max.	Elements
	% %	% %	% %	% %	% %	% %	% %	% %	% %	
Copper	Remainder	Remainder	Remainder	Remainder	60.0 63.0	85.0 87.3 ^b	Remainder	Remainder	Remainder	Copper
Tin	8.0 10.0	4.0 6.0	9.7 10.5	6.5 7.5	1.0 1.5	11.2 13.0	— 0.10	— —	— —	Tin
Zinc	— 1.0	— 1.0	1.75 2.75	1.75 3.0	Remainder	— 0.4	— 0.40	— —	— —	Zinc
Lead	13.5 16.5	19.0 23.0	— 1.5	0.10 0.50	— 0.5 ^a	— 0.2 ^a	— 0.03	— 0.005	— 0.005	Lead
Phosphorus	— 0.1	— 0.10	— 0.02	— 0.02	— —	— 0.05 ^c	— —	— 0.005	— 0.005	Phosphorus
Nickel	— 2.0	— 2.0	— 1.0	5.25 5.75	— —	1.5 2.0	— 0.10	29.0 33.0	28.0 32.0	Nickel
Iron	— —	— 0.15	— 0.15 ^d	— d	— —	— 0.15	0.5 0.7	0.4 1.0	1.0 1.4	Iron
Aluminium	— —	— 0.01	— 0.01	— 0.01	— 0.01	— 0.01	6.0 6.4	— —	— —	Aluminium
Manganese	— —	— 0.2	— —	— 0.02	— —	— 0.2	— 0.50	0.5 1.0	1.1 1.4	Manganese
Antimony	— 0.5	— 0.50	— d	— d	— —	— 0.1	— —	— —	— —	Antimony
Arsenic	— —	— —	— —	— —	— —	— —	— —	— —	— —	Arsenic
Silicon	— —	— 0.01	— 0.02	— 0.01	— —	— 0.01	2.0 2.4	0.20 0.30	0.20 0.30	Silicon
Bismuth	— —	— —	— 0.03	— 0.02	— —	— —	— —	— 0.002	— 0.002	Bismuth
Sulphur	— 0.1	— 0.1	— 0.1	— 0.1	— —	— 0.05	— —	— 0.01	— 0.01	Sulphur
Magnesium	— —	— —	— —	— —	— —	— —	— 0.05	— —	— —	Magnesium
Niobium + tantalum	— —	— —	— —	— —	— —	— —	— —	— —	1.20 1.40	Niobium + tantalum
Carbon	— —	— —	— —	— —	— —	— —	— —	— 0.02	— 0.02	Carbon
Chromium	— —	— —	— —	— —	— —	— —	— —	1.6 2.0	— —	Chromium
Zirconium	— —	— —	— —	— —	— —	— —	— —	0.1 0.15	— —	Zirconium
Cobalt	— —	— —	— —	— —	— —	— —	— —	— 0.05	— 0.05	Cobalt
Total of impurities	— 0.30	— 0.30	— 0.50	— 0.50	— 0.75	— 0.80 ^a	— 0.80	— 0.20	— 0.30	Total of impurities

NOTE Specified impurities are shown in light type.

^a 0.1 % lead maximum may be specified.^b Copper content includes nickel.^c Phosphorus content may be increased by agreement.^d Iron + antimony + arsenic 0.20 % max.

Table 4 — Mechanical properties of separately cast test bars for ingots

Designation	Material	Tensile strength		0.2 % proof stress		Elongation on $5.65\sqrt{S_0}$	
		Sand cast min.	Chill cast min.	Sand cast min.	Chill cast min.	Sand cast min.	Chill cast min.
		N/mm ²	N/mm ²	N/mm ²	N/mm ²	%	%
AB1	Aluminium bronze	500	540	170 ^a	200 ^a	18	18
AB2	Aluminium bronze	640	650	250	250	13	13
AB3	Aluminium silicon bronze	460	—	180	—	20	—
CMA1	Copper-manganese-aluminium	650	670	280	310	18	27
HTB1	High tensile brass	470	500	170	210	18	18
HTB3	High tensile beta brass	740	—	400	—	11	—
CN1	High strength chromium cupro-nickel	480	—	300	—	18	—
CN2	High strength niobium cupro-nickel	480	—	300	—	18	—

^a For information only.

6 Specific requirements for castings

6.1 Chemical composition

The chemical compositions of castings shall be as given in Table 5 to Table 7.

6.2 Mechanical properties

For castings the mechanical properties, determined by the methods given in 9.2 on samples taken in accordance with 7.2.2.2, 8.1.1, 8.1.3 and 8.2, shall be given as in Table 8.

NOTE No mechanical properties are specified for castings in high conductivity copper (HCC1) or in alloys or casting processes other than those included in Table 8.

6.3 Microstructure of HTB1

For castings in alloy HTB1 the proportion of alpha phase in the microstructure, determined by the method given in 9.4, on samples taken in accordance with 7.2.3 and 8.3 shall not be less than 15 % by area.

6.4 Freedom from defects

The castings shall be clean and free from harmful defects.

NOTE 1 Castings may be deemed not to comply with this standard because of unacceptable casting defects, even though the castings may comply with the other requirements specified.

NOTE 2 Supplementary requirements for the detection of flaws and defects in castings by proof machining, pressure testing, penetrant flaw detection and radiographic examination may be specified at the purchaser's option [see item 2) iii) of the note to clause 3 and Appendix A].

6.5 Electrical resistivities of HCC1 and CC1-TF

The electrical resistivities of castings in high conductivity copper HCC1 and alloy CC1-TF, determined in accordance with 9.5, shall not exceed the following values:

- a) HCC1: 0.019 $\Omega\cdot\text{m}$ (approximately equivalent to an electrical conductivity of 90 % IACS¹⁾);
- b) CC1-TF: 0.022 $\Omega\cdot\text{m}$ (approximately equivalent to an electrical conductivity of 80 % IACS¹⁾).

NOTE 1 Copper that has an electrical resistivity of 0.017 241 $\Omega\cdot\text{m}$ is said to have an electrical conductivity of 100 % IACS¹⁾.

NOTE 2 For sampling, see 7.2.4.

6.6 Identification and marking

Castings inspected to supplementary procedures specified by the purchaser in accordance with Appendix A shall be individually marked, or batched and tallied, by a suitable means as soon as possible after casting. The identification shall be maintained in such a manner as to enable the castings to be correlated with their relevant inspection records at the time of their despatch from the foundry.

NOTE In normal commercial practice the inspection records are kept in such a manner as to enable them to be made available to the purchaser, or his representative, on request.

¹⁾ International Annealed Copper Standard [see IEC 28 (1925) "International Standard of resistance for copper", obtainable from the International Electrotechnical Commission (IEC), 3, Rue de Varembe, Geneva, Switzerland).