BS EN 13600:2013

BSI Standards Publication

Copper and copper alloys — Seamless copper tubes for electrical purposes

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National foreword

This British Standard is the UK implementation of EN 13600:2013. It supersedes BS EN 13600:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NFE/34, Copper and copper alloys.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Date	Text affected

EUROPEAN STANDARD

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EN 13600

June 2013

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English Version

Copper and copper alloys - Seamless copper tubes for electrical purposes

Cuivre et alliages de cuivre - Tubes sans soudure en cuivre pour usages électriques

Kupfer und Kupferlegierungen - Nahtlose Rohre aus Kupfer für die Anwendung in der Elektrotechnik

This European Standard was approved by CEN on 25 April 2013.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

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Contents

Page

Foreword

This document (EN 13600:2013) has been prepared by Technical Committee CEN/TC 133 “Copper and copper alloys”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2013, and conflicting national standards shall be withdrawn at the latest by December 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13600:2002.

In comparison with EN 13600:2002, the following significant technical changes have been made:

— The Scope has been expanded.

— The outside diameters have been expanded.

— The wall thickness has been expanded.

— Cu-OFE (CW009A) and Cu-PHCE (CW022A) have been added.

— Tolerance on the outside diameter of round tubes and on wall thicknesses has been completely revised.

Within its programme of work, Technical Committee CEN/TC 133 requested CEN/TC 133/WG 4 "Extruded and drawn products, forgings and scrap" to prepare the following revision of the standard:

EN 13600:2002, *Copper and copper alloys — Seamless copper tubes for electrical purposes.*

The products specified in this European Standard are those which are especially suitable for electrical purposes, i.e. with specified electrical properties. Copper tubes for general purposes are specified in EN 12449.

Annex A (informative) gives guidance on the characteristics of coppers for electrical purposes.

This is one of a series of European Standards for copper products for electrical purposes. Other copper products are specified as follows:

— EN 13599, *Copper and copper alloys — Copper plate, sheet and strip for electrical purposes*

— EN 13601, *Copper and copper alloys — Copper rod, bar and wire for general electrical purposes*

— EN 13602, *Copper and copper alloys — Drawn, round copper wire for the manufacture of electrical conductors*

— EN 13604, *Copper and copper alloys — Semiconductor devices, electronic and vacuum products made from high conductivity copper*

— EN 13605, *Copper and copper alloys — Copper profiles and profiled wire for electrical purposes*

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece,

Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies the composition, property requirements including electrical properties, and tolerances on dimensions and form for seamless drawn copper tubes for electrical purposes, delivered in straight lengths or alternatively in level wound coils with the cross-sections and size ranges below:

— for round tubes in straight lengths with outside diameters from 3 mm up to and including 450 mm and wall thicknesses from 0,3 mm;

— for round tubes in level wound coils with outside diameters from 3 mm up to and including 30 mm and wall thicknesses from 0,3 mm;

— for square and rectangular tubes with major outside dimension from 5 mm up to and including 150 mm and wall thicknesses from 0,5 mm up to and including 10 mm.

The sampling procedures and test methods for verification of conformity to the requirements of this standard are also specified.

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.

EN 1655, *Copper and copper alloys — Declarations of conformity*

EN 1976, *Copper and copper alloys — Cast unwrought copper products*

EN 10204, *Metallic products — Types of inspection documents*

EN ISO 2626, *Copper — Hydrogen embrittlement test (ISO 2626)*

EN ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method (ISO 6506-1)*

EN ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method (ISO 6507-1)*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1)*

EN ISO 7438, *Metallic materials — Bend test (ISO 7438)*

EN ISO 8491, *Metallic materials — Tube (in full section) — Bend test (ISO 8491)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
seamless tube
hollow semi-finished product, circular, square or rectangular in cross-section, having a uniform wall thickness, which at all stages of production has a continuous periphery

Note 1 to entry: Tubes with a square or rectangular cross-section may have corners rounded along their whole length.

3.2
mean diameter
arithmetical mean of any two diameters normal to each other at the same cross-section of the tube

3.3
deviation from circular form
difference between the maximum and minimum outside diameters measured at any one cross-section of the tube

[SOURCE: EN 1057:2006+A1:2010, 3.6]

4 Designations

4.1 Material

4.1.1 General

The material is designated either by symbol or by number (see Table 1 and Table 2).

4.1.2 Symbol

The material symbol designation is based on the designation system given in ISO 1190-1.

NOTE Although material symbol designations used in this standard might be the same as those in other standards using the designation system in ISO 1190-1, the detailed composition requirements are not necessarily the same.

4.1.3 Number

The material number designation is in accordance with the system given in EN 1412.

4.2 Material condition

For the purposes of this standard, the following designations, which are in accordance with the system given in EN 1173, apply for the material condition:

D Material condition for the product as cold worked without specified mechanical properties;

H... Material condition designated by the minimum value of hardness requirement for the product with mandatory hardness requirements;

R... Material condition designated by the minimum value of tensile strength requirement for the product with mandatory tensile strength, 0,2 % proof strength and elongation requirements.

Products in the H... condition may be specified to Vickers or Brinell hardness. The material condition designation H... is the same for both hardness test methods.

Exact conversion between the material conditions designated H... and R... is not possible.

Material condition is designated by only one of the above designations.

4.3 Product

The product designation provides a standardised pattern of designation from which a rapid and unequivocal description of a product can be conveyed in communication. It provides mutual comprehension at the international level with regard to products which meet the requirements of the relevant European Standard.

The product designation is no substitute for the full content of the standard.

The product designation for products to this standard shall consist of:

a) denomination (tube);

b) number of this European Standard (EN 13600);

c) material designation, either symbol or number (see Table 1 and Table 2);

d) material condition designation (see Table 3);

e) cross-sectional shape (the following designations shall be used, as appropriate: RND for round, SQR for square, RCT for rectangular);

f) nominal dimensions:

1) round tube in straight lengths: outside diameter × wall thickness × length [either as manufactured length (ML) or fixed length (FL) (see 6.5.4)];

2) round tube in level wound coils: outside diameter × wall thickness × nominal coil weight;

3) square or rectangular tube: across-flats dimension(s) × wall thickness × length [either as manufactured length (ML) or fixed length (FL) (see 6.5.4)].

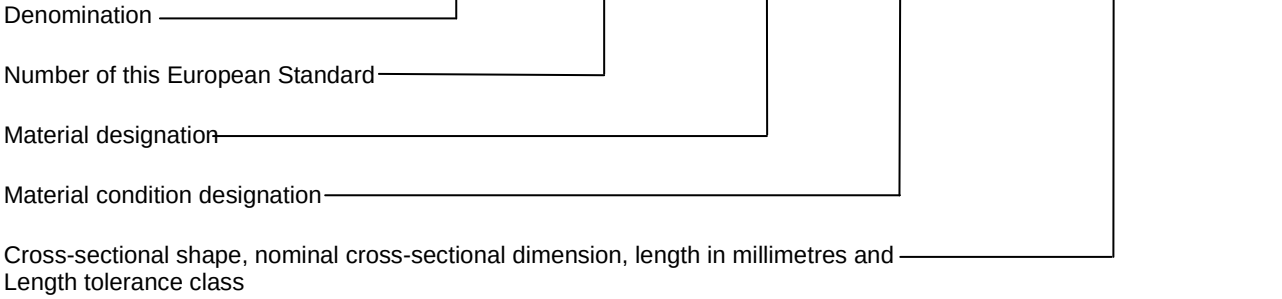
The derivation of a product designation is shown in Example 1 and other typical product designations are shown in Examples 2 and 3.

EXAMPLE 1 Tube for electrical purposes conforming to this standard, in material designated either Cu-ETP or CW004A, in material condition R250, round, with nominal outside diameter 100 mm and nominal wall thickness 5 mm, as manufactured length 3 000 mm, will be designated as follows:

Tube — EN 13600 — Cu-ETP — R250 — RND100 x 5 x 3000ML

or

Tube — EN 13600 — CW004A — R250 — RND100 x 5 x 3000ML



EXAMPLE 2 Tube for electrical purposes conforming to this standard, in material designated either Cu-0F or CW008A, in material condition H065, square, nominal width across-flats 120 mm, nominal wall thickness 10 mm, fixed length 4 500 mm, will be designated as follows:

Tube EN 13600 — Cu-OF— H065 — SQR120 × 10 × 4 500FL

or

Tube EN 13600 — CW008A — H065 — SQR120 × 10 × 4 500FL

EXAMPLE 3 Tube for electrical purposes conforming to this standard, in material designated either CuAg0,10 or CW013A, in material condition R290, rectangular, with nominal widths across-flats 140 mm and 80 mm, nominal wall thickness 5 mm, fixed length 3 500 mm, will be designated as follows:

Tube EN 13600 — CuAg0,10 — R290 — RCT140 × 80 × 5 × 3 500FL

or

Tube EN 13600 — CW013A— R290 — RCT140 × 80 × 5 × 3 500FL

5 Ordering information

In order to facilitate the enquiry, order and confirmation of order procedures between the purchaser and the supplier, the purchaser shall state on his enquiry and order the following information:

a) quantity of product required (mass, number of tubes);

b) denomination (tube);

c) number of this European Standard (EN 13600);

d) material designation (see Table 1 and Table 2);

e) material condition designation (see 4.2 and Table 3);

f) nominal dimensions:

1) round tube in straight lengths: outside diameter × wall thickness × length [either as manufactured length (ML) or fixed length (FL) (see 6.5.4)];

2) round tube in level wound coils: outside diameter × wall thickness × nominal coil weight;

NOTE For round tubes, upon agreement between purchaser and supplier, the inside diameter can be used as an alternative to the wall thickness.

3) square or rectangular tube: across-flats dimension(s) × wall thickness × length [either as manufactured length (ML) or fixed length (FL) (see 6.5.4)].

It is recommended that the product designation, as described in 4.3, is used for items b) to f).

In addition, the purchaser shall also state on the enquiry and order any of the following, if required:

g) test method to be used for the measurement of hardness, i.e. Vickers or Brinell (see 8.3);

h) whether special tolerances on dimensions and form are required;

i) whether special surface conditions are required (see 6.7);

j) whether deburring is required (see 6.5.4.1);

k) whether a declaration of conformity is required (see 9.1);

l) whether an inspection document is required, and if so, which type (see 9.2);

m) whether there are any special requirements for marking, packaging or labelling (see Clause 10).

EXAMPLE Ordering details for 1 000 pieces tube for electrical purposes conforming to EN 13600, in material designated either Cu-ETP or CW004A, in material condition R250, round, with nominal outside diameter 100 mm and nominal wall thickness 5 mm, as manufactured length 3 000 mm:

1000 pieces Tube EN 13600 — Cu-ETP— R250 — RND100 × 5 × 3000ML

or

1000 pieces Tube EN 13600 — CW004A — R250 — RND100 × 5 × 3000ML

6 Requirements

6.1 Composition

The composition shall conform to the requirements for the appropriate material given in Table 1 and Table 2.

NOTE For characteristics of coppers for electrical purposes, see Annex A.

6.2 Mechanical properties

The mechanical properties shall conform to the appropriate requirements given in Table 3. The tests shall be carried out in accordance with either 8.2 (tensile test) or 8.3 (hardness test).

6.3 Electrical properties

The electrical properties shall conform to the appropriate requirements given in Table 4. The test shall be carried out in accordance with 8.4.

6.4 Freedom from hydrogen embrittlement

Tubes in copper grades Cu-OF (CW008A), CuAg0,10P (CW016A), CuAg0,10(OF) (CW019A), Cu-PHC (CW020A) and Cu-HCP (CW021A) shall show no evidence of cracking, when tested and visually examined in accordance with 8.5.

6.5 Dimensions and tolerances

6.5.1 Outside dimensions

The dimensional tolerances are applied on the outside dimensions and wall thickness, if not otherwise agreed between the purchaser and the supplier.

For round tubes, the diameter shall conform to the tolerances given in Table 5.

For square and rectangular tubes, the outside dimensions shall conform to the tolerances given in Table 6.

6.5.2 Corner radii

The corner radii of square and rectangular tubes shall conform to the requirements given in Table 7.

6.5.3 Wall thickness

The wall thickness of round, square and rectangular tubes, measured at any one point, shall conform to the tolerances given in Table 8.

6.5.4 Length

6.5.4.1 General

Tubes shall be supplied either in manufactured lengths or fixed lengths, with ends either sawn or sheared.

If deburring of the cut ends of the tubes is required, it shall be agreed between the purchaser and the supplier [see Clause 5 list entry j)].

6.5.4.2 Manufactured lengths

Manufactured lengths (ML) shall be supplied in the nominal lengths. The tolerances are by agreement between the purchaser and the supplier.

It is permissible for 10 % of the number of tubes in a consignment to be shorter, but not less than 50 % of the nominal length.

6.5.4.3 Fixed lengths

Tubes supplied as fixed lengths (FL) shall conform to the tolerances given in Table 9.

The deviation from squareness of the cut shall be a maximum of 2 % of the diameter or major across-flats dimension of the tube and is included in the fixed length tolerance.

6.5.5 Form tolerances

6.5.5.1 General

The form tolerances given in 6.5.5.2 and 6.5.5.3 apply to:

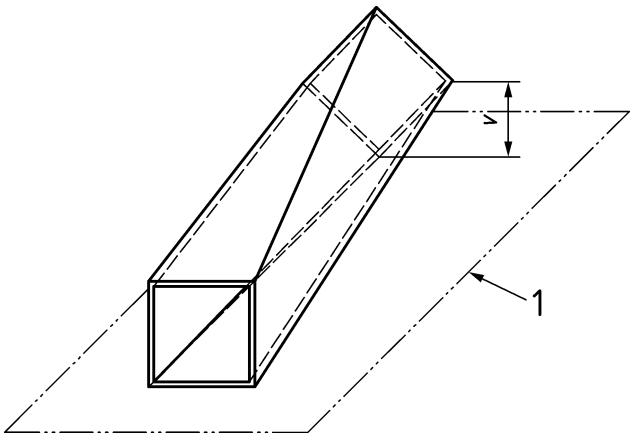
a) outside dimensions equal to or greater than 10 mm;

b) all material conditions except H035 and R200.

The deviation shall be measured with the tube supported on a horizontal reference plane such that the deviation is minimised by the mass of the tube.

6.5.5.2 Twist

Square and rectangular tubes shall conform to the tolerances given in Table 10. The twist v shall be measured as indicated in Figure 1.



Key
1 reference plane
v twist

Figure 1 — Measurement of twist

6.5.5.3 Straightness

Tubes shall conform to the tolerances given in Table 11.

6.6 Mass tolerances

The mass of a consignment shall conform to the following mass tolerances:

— straight lengths: ± 10 %;

— level wound coils: ± 20 %.

6.7 Surface condition

The products shall be clean and free from injurious defects, which shall be specified by agreement between the purchaser and the supplier at the time of enquiry and order. A superficial film of residual lubricant is normally present on cold drawn products and is permissible unless otherwise specified.

It is permissible for annealed tubes to have a superficial, dull, iridescent oxide film on both the internal and external surfaces.

Discontinuous irregularities on the external and internal surfaces of the tubes are permitted, if they are within the dimensional tolerances.

Special requirements, e.g. degreasing, shall be agreed between the purchaser and the supplier [see Clause 5 list entry i)].

7 Sampling

7.1 General

When required, (e.g. if necessary in accordance with specified procedures of a supplier's quality management system, or when the purchaser requests inspection documents with test results, or for use in cases of dispute), an inspection lot shall be sampled in accordance with 7.2 and 7.3.

7.2 Analysis

The sampling rate shall be in accordance with Table 12. A test sample, depending on the analytical technique to be employed, shall be prepared from each sampling unit and used for the determination of the composition.

When preparing the test sample, care should be taken to avoid contaminating or overheating. Carbide tipped tools are recommended; steel tools, if used, should be made of magnetic material to assist in the subsequent removal of extraneous iron. If the test samples are in finely divided form (e.g. drillings, millings), they should be treated carefully with a strong magnet to remove any particles of iron introduced during preparation.

In cases of dispute concerning the results of analysis, the full procedure given in ISO 1811-2 should be followed.

Results may be used from analyses carried out at an earlier stage of manufacturing the product, e.g. at the casting stage, if the material identity is maintained and if the quality management system of the manufacturer is certified, e.g. as conforming to EN ISO 9001.

7.3 Mechanical and electrical tests

The sampling rate shall be in accordance with Table 12. Sampling units shall be selected from the finished products. The test samples shall be cut from the sampling units. Test samples, and test pieces prepared from them, shall not be subjected to any further treatment, other than any machining operations necessary in the preparation of the test pieces.

8 Test methods

8.1 Analysis

Analysis shall be carried out on the test pieces, or test portions, prepared from the test samples obtained in accordance with 7.2. Except in cases of dispute, the analytical methods used shall be chemical or spectrographic according to ISO standards in force. In cases of dispute, chemical methods of analysis shall be used. For expression of results, the rounding rules given in 8.7 shall be used.

8.2 Tensile test

The tensile properties shall be determined in accordance with EN ISO 6892-1 on the test pieces obtained in accordance with 7.3.

8.3 Hardness test

Hardness shall be determined on test pieces prepared from the test samples obtained in accordance with 7.3. The test shall be carried out in accordance with either EN ISO 6506-1 or EN ISO 6507-1 and the impression/indentation made on the outside surface, unless otherwise agreed.

For the Brinell test in accordance with EN ISO 6506-1, a 0,102 F/D^2 ratio of 10 shall be used, i.e. use a 1,00 mm diameter ball and a force of 98,07 N for thicknesses less than 2 mm, or a 2,5 mm diameter ball and a force of 612,9 N for thicknesses equal to or greater than 2 mm.

For the Vickers test in accordance with EN ISO 6507-1, a test force of 49,03 N for thicknesses less than 2 mm or 98,07 N for thicknesses equal to or greater than 2 mm shall be used.

8.4 Electrical resistivity test

The test method used shall be left to the discretion of the supplier, e.g. eddy current method or resistance bridge, if not otherwise specified.

The electrical resistivity shall be determined by direct measurement either at 20 °C ± 1 °C or at another temperature, when the result shall be corrected to the equivalent value at 20 °C, on the product in the as delivered condition.

8.5 Hydrogen embrittlement test

Tubes in the copper grades listed in 6.4 shall be subjected to the hydrogen embrittlement test, which shall be carried out in accordance with EN ISO 2626.

Test pieces shall be of convenient dimensions, but machined test pieces shall retain some part of the original surface to be on the outside of the bend. Any edges shall be rounded and smoothed.

After heating the test pieces in hydrogen, as described in EN ISO 2626, they shall be subjected to the close bend test. The bend test shall be carried out either:

a) on a strip cut from a tube, in accordance with EN ISO 7438; or

b) on a tube in full section, in accordance with EN ISO 8491.

8.6 Retests

If there is a failure of one, or more than one, of the tests in 8.1 to 8.5, two test samples from the same inspection lot shall be permitted to be selected for retesting the failed property(ies). One of these test samples shall be taken from the same sampling unit as that from which the original failed test piece was taken, unless that sampling unit is no longer available, or has been withdrawn by the supplier.

If the test pieces from both test samples pass the appropriate test(s), then the inspection lot represented shall be deemed to conform to the particular requirement(s) of this standard. If a test piece fails a test, the inspection lot represented shall be deemed not to conform to this standard.

8.7 Rounding of results

For the purpose of determining conformity to the limits specified in this standard, an observed or a calculated value obtained from a test shall be rounded in accordance with the following procedure, which is based upon the guidance given in ISO 80000-1:2009, Annex B. It shall be rounded in one step to the same number of figures used to express the specified limit in this European Standard. Except for tensile strength and 0,2 % proof strength, the rounding interval shall be 10 N/mm^2 [1)] and for elongation the value shall be rounded to the nearest 1 %.

The following rules shall be used for rounding:

a) if the figure immediately after the last figure to be retained is less than five, the last figure to be retained shall be kept unchanged;

b) if the figure immediately after the last figure to be retained is equal to or greater than five, the last figure to be retained shall be increased by one.

9 Declaration of conformity and inspection documentation

9.1 Declaration of conformity

When requested by the purchaser [see Clause 5 list entry k)] and agreed with the supplier, the supplier shall issue for the products the appropriate declaration of conformity in accordance with EN 1655.

1) 1 N/mm^2 is equivalent to 1 MPa.

9.2 Inspection documentation

When requested by the purchaser [see Clause 5 list entry l)] and agreed with the supplier, the supplier shall issue for the products the appropriate inspection document in accordance with EN 10204.

10 Marking, packaging, labelling

Unless otherwise specified by the purchaser and agreed by the supplier, the marking, packaging and labelling shall be left to the discretion of the supplier [see Clause 5 list entry m)].

Table 1 — Composition of Cu-OFE and Cu-PHCE

Material designation		Composition % (mass fraction)																	
Symbol	Number	Element	Cu	Ag	As	Bi	Cd	Fe	Mn	Ni	O	P	Pb	S	Sb	Se	Sn	Te	Zn
Cu-OFE	CW009A	min.	99,99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		max.	—	0,002 5	0,000 5	0,000 20	0,000 1	0,001 0	0,000 5	0,001 0	--[a]	0,000 3	0,000 5	0,001 5	0,000 4	0,000 20	0,000 2	0,000 20	0,000 1
Cu-PHCE	CW022A	min.	99,99	—	—	—	—	—	—	—	—	0,001	—	—	—	—	—	—	—
		max.	—	0,002 5	0,000 5	0,000 20	0,000 1	0,001 0	0,000 5	0,001 0	--[a]	0,006	0,000 5	0,001 5	0,000 4	0,000 20	0,000 2	0,000 20	0,000 1

[a] The oxygen content shall be such that the material conforms to the hydrogen embrittlement requirements of EN 1976.

Table 2 — Composition of copper grades, other than those made from Cu-OFE (CW009A) and Cu-PHCE (CW022A)

Material designation		Composition in % (mass fraction)								
		Element	Cu	Ag	Bi	O	P	Pb	other elements (see NOTE)	
Symbol	Number								total	excluding
Cu-ETP	CW004A	min.	99,90[a]	—	—	—	—	—	—	Ag, O
		max.	—	—	0,000 5	0,040[b]	—	0,005	0,03	
Cu-FRHC	CW005A	min.	99,90[a]	—	—	—	—	—	—	Ag, O
		max.	—	—	—	0,040[b]	—	—	0,06 [d]	
Cu-OF	CW008A	min.	99,95[a]	—	—	—	—	—	—	Ag
		max.	—	—	0,000 5	—[c]	—	0,005	0,03	
CuAg0,10	CW013A	min.	Rem.	0,08	—	–	—	—	—	Ag, O
		max.	—	0,12	0,000 5	0,040	—	—	0,03	
CuAg0,10P	CW016A	min.	Rem.	0,08	—	—	0,001	—	—	Ag, P
		max.	—	0,12	0,000 5	—[c]	0,007	—	0,03	
CuAg0,10(OF)	CW019A	min.	Rem.	0,08	—	—	—	—	—	Ag, O
		max.	—	0,12	0,000 5	—[c]	—	—	0,006 5	
Cu-PHC	CW020A	min.	99,95[a]	—	—	—	0,001	—	—	Ag, P
		max.	—	—	0,000 5	—[c]	0,006	0,005	0,03	
Cu-HCP	CW021A	min.	99,95[a]	—	—	—	0,002	—	——	Ag, P
		max.	—	—	0,000 5	—[c]	0,007	0,005	0,03	

NOTE The total of other elements (than copper) is defined as the sum of Ag, As, Bi, Cd, Co, Cr, Fe, Mn, Ni, O, P, Pb, S, Sb, Se, Si, Sn, Te and Zn, subject to the exclusion of any individual elements indicated.

[a] Including silver, up to a maximum of 0,015 %.

[b] Oxygen content up to 0,060 % is permitted, subject to agreement between the purchaser and the supplier.

[c] The oxygen content shall be such that the material conforms to the hydrogen embrittlement requirements of EN 1976.

[d] Higher total impurities content is permitted, subject to agreement between the purchaser and the supplier.

Table 3 — Mechanical properties

Designations			Nominal wall thickness	Hardness				Tensile strength R_m		0,2% proof strength $R_{p0,2}$		Elongation A
Material		Material condition	mm	HBW		HV		N/mm^2		N/mm^2		%
Symbol	Number		up to and including	min.	max.	min.	max.	min.	max.	min.	max.	min.
		D	—	As cold drawn without specified mechanical properties								
Cu-ETP	CW004A											
Cu-FRHC	CW005A	H035	40	35	60	35	65	—	—	—	—	—
Cu-OF	CW008A	R200	40	—	—	—	—	200	250	—	120	35
Cu-OFE	CW009A											
CuAg0,10	CW013A	H065	20	60	90	65	95	—	—	–	—	—
CuAg0,10P	CW016A	R250	20	—	—	—	—	250	300	150	—	15
CuAg0,10(OF)	CW019A											
Cu-PHC	CW020A	H090	10	85	105	90	110	—	—	—	—	—
Cu-HCP	CW021A	R290	10	—	—	—	—	290	360	250	—	5
Cu-PHCE	CW022A											
		H100	5	95	—	100	—	—	—	—	—	—
		R360	5	—	—	—	—	360	—	320	—	(3)

NOTE 1 1 N/mm^2 is equivalent to 1 MPa.

NOTE 2 Figures in parentheses are not requirements of this standard, but are given for information only.

Table 4 — Electrical properties (at 20 °C)

Designations				Volume resistivity $\frac{\Omega \times mm^2}{m}$	Mass resistivity[a] $\frac{\Omega \times g}{m^2}$	Conductivity	
Material		Material condition				MS/m	% IACS[b]
Symbol	Number			max.	max.	min.	min.
Cu-OFE Cu-PHCE	CW009A CW022A	annealed		0,017 07	0,151 7	58,6	101,0
				0,017 24	0,153 3	58,0	100,0
Cu-OFE Cu-PHCE	CW009A CW022A	other than annealed		to be agreed between the purchaser and the supplier			
Cu-ETP Cu-FRHC Cu-OF CuAg0,10 CuAg0,10(OF) Cu-PHC	CW004A CW005A CW008A CW013A CW019A CW020A	D		0,017 86	0,158 8	56,0	96,6
		H035	R200	0,017 24	0,153 3	58,0	100,0
		H065	R250	0,017 54	0,155 9	57,0	98,3
		H090	R290	0,017 86	0,158 8	56,0	96,6
		H100	R360				
CuAg0,10P Cu-HCP	CW016A CW021A	D		0,018 18	0,161 6	55,0	94,8
		H035	R200	0,017 54	0,155 9	57,0	98,3
		H065	R250	0,017 86	0,158 8	56,0	96,6
		H090	R290	0,018 18	0,161 6	55,0	94,8
		H100	R360				

NOTE 1 The % IACS values are calculated as percentages of the standard value for annealed high conductivity copper as laid down by the International Electrotechnical Commission. Copper having a volume resistivity of 0,017 24 $\mu\Omega \times m$ at 20 °C, is defined as corresponding to a conductivity of 100 %.

NOTE 2 1 MS/m is equivalent to 1 $m/(\Omega \times mm^2)$.

[a] Calculated with a density of copper 8,89 g/cm^3.

[b] IACS: International Annealed Copper Standard.

Table 5 — Tolerance on outside diameter of round tubes

Nominal outside diameter		Tolerances		Maximum deviation from circular form[a, d] for level wound coils
over	up to and including	applicable to mean diameter	applicable to any diameter including deviation from circular form[a, b, c] for straight lengths	
mm	mm	mm	mm	%
3[e]	10	± 0,05	± 0,08	± 5
10	20	± 0,06	± 0,10	± 8
20	30	± 0,08	± 0,15	± 12
30	50	± 0,10	± 0,20	—
50	80	± 0,15	± 0,30	—
80	120	± 0,20	± 0,40	—
120	150	± 0,30	± 0,60	—
150	300	± 0,60	± 1,20	—
300	450	± 1,0	± 2,0	—

a The tolerances in this column are not applicable to tubes with a ratio of outside diameter to wall thickness (OD/t) > 30.

b The tolerances in this column are not applicable to tubes in the annealed material condition (H035/R200), see Table 3.

c When the diameter is measured at a distance from the ends of the tube of up to 100 mm or the equivalent of one nominal outside diameter (whichever is the smaller), unless otherwise agreed, the tolerance may be increased by a factor of 3.

d Referring to nominal OD.

e Including 3.

Table 6 — Tolerance on across-flats dimensions of square and rectangular tubes

Values in millimetres

Nominal across-flats dimensions		Tolerances[a, b]
over	up to and including	
5[c]	15	± 0,10
15	30	± 0,15
30	50	± 0,20
50	80	± 0,25
80	120	± 0,30
120	150	± 0,35

a The tolerances in this column are not applicable to tubes in the annealed material condition (H035/R200), see Table 3.

b If tolerances all plus or all minus are required, double the values given.

c Including 5.

Table 7 — Corner radii of square and rectangular tubes

Dimensions in millimetres

Nominal wall thickness		**Maximum radii**	
over	up to and including	external corners	internal corners
0,5[a]	1,5	1,8	0,8
1,5	3	2,2	0,8
3	6	3,5	0,8
6	10	6,0	0,8

[a] Including 0,5.

Table 8 — Tolerances on wall thickness

Values in millimetres

Nominal outside diameter or major across-flats dimension[a]		**Tolerances on wall thickness[b, c] in % for wall thicknesses**				
over	up to and including	from 0,3 up to and including 1	over 1 up to and including 3	over 3 up to and including 6	over 6 up to and including 10	over 10
3[d]	15	± 13	± 12	± 10	—	—
15	30	± 13	± 12	± 10	± 10	—
30	50	± 13	± 12	± 12	± 10	± 10
50	100	—	± 12	± 12	± 10	± 10
100	250	—	± 13	± 13	± 12	± 11
250	450	—	—	± 15	± 14	± 13

[a] In the case of rectangular tube, the major across-flats dimension determines the thickness tolerance applicable to all wall thicknesses.

[b] The wall thickness tolerance is defined as the maximum deviation of the wall thickness at any point in percentage of the nominal wall thickness.

[c] If tolerances all plus or all minus are required, double the values given.

[d] Including 3.

Table 9 — Tolerances on fixed lengths for tubes in straight lengths

Values in millimetres

Nominal outside diameter		**Tolerances on fixed lengths**			
over	up to and including	up to and including 250	over 250 up to and including 1 000	over 1 000 up to and including 4 000	over 4 000
3[a]	30	+1 0	+3 0	+5 0	by agreement
30	100	+3 0	+5 0	+10 0	
100	450	+5 0	+8 0	+15 0	

[a] Including 3.

Table 10 — Maximum twist of square and rectangular tubes

Nominal across-flats dimensions mm		**Maximum permitted twist** v mm	
over	up to and including	in any 1 m length	in total length L (in m)[b]
10[a]	18	1,0	$1{,}0 \times L$
18	30	1,5	$1{,}5 \times L$
30	50	2,0	$2{,}0 \times L$
50	80	3,0	$3{,}0 \times L$
80	120	4,5	$4{,}5 \times L$
120	150	6,0	$6{,}0 \times L$

[a] Including 10.

[b] Up to 4 m. Over 4 m, the maximum twist is subjected to agreement.

Table 11 — Straightness

Values in millimetres

OD/t [a]		Maximum depth of arc	
over	up to and including	in any length of 1 m	in any length of 0,4 m
—	5	2	0,8
5	10	3	1,2
10	20	4	1,6
20	40	5	2,0
40	—	6	2,5

[a] *OD/t*: Ratio of outside diameter or major across-flats dimensions to wall thickness *t*.

Table 12 — Sampling rate

Mass per unit length kg/m	**Mass of inspection lot for one test sample** kg up to and including
up to and including 0,25	1 000
over 0,25 up to and including 5	1 500
over 5	2 500

NOTE Larger inspection lots require sampling in proportion, up to a maximum of five test samples.

Annex A
(informative)

Characteristics of coppers for electrical purposes

A.1 General grouping of copper types

The characteristic properties of coppers depend to a considerable extent on the presence or absence of certain elements, in particular oxygen, phosphorus and silver.

The various grades of copper fall into four types:

— tough pitch coppers (i.e. oxygen-containing coppers);

— oxygen-free coppers;

— deoxidised coppers;

— silver-bearing coppers.

NOTE The classification of coppers, as "unrefined copper" or "refined copper" as well as specific terms and definitions for the subdivisions of these classes are given in ISO 197-1.

A.2 General characteristics

In general, all coppers have excellent formability and solderability. Electrical conductivity and weldability both vary, depending on the purity of the copper grade.

A.3 Particular characteristics

Table A.1 describes the particular characteristics of coppers for electrical purposes. The table also indicates the material designation, i.e. symbols and numbers of the grades of copper corresponding to each type.

NOTE This standard does not necessarily specify all the grades of copper given in Table A.1.

Table A.1 — Particular characteristics of coppers for electrical purposes

Copper type	Characteristics	Material designation	
		Symbol	Number
Tough pitch coppers (oxygen containing coppers)	Coppers of this type are produced with a controlled amount of oxygen and have high electrical conductivity. Special precautions are necessary when heat-treating, welding or brazing these coppers in atmospheres containing hydrogen to avoid hydrogen embrittlement.	Cu-ETP1 Cu-ETP Cu-FRHC	CW003A CW004A CW005A
Oxygen-free coppers	Coppers of this type are produced in an oxygen-free environment without the use of deoxidisers and have high electrical conductivity. These coppers may be heat-treated, welded or brazed without the need for special precautions to avoid hydrogen embrittlement.	Cu-OF1 Cu-OF Cu-OFE	CW007A CW008A CW009A
Deoxidised coppers	Coppers of this type are produced with the addition of a controlled amount of deoxidiser, preferably phosphorus, and contain a controlled low amount of residual deoxidiser; these coppers have high electrical conductivity. These coppers may be heat-treated, welded or brazed without the need for special precautions to avoid hydrogen embrittlement.	Cu-PHC Cu-HCP Cu-PHCE	CW020A CW021A CW022A
Silver-bearing coppers	Tough pitch, oxygen-free and deoxidised coppers can be produced with additions of silver, up to 0,12 % (mass fraction). The effect of the silver content is to increase the resistance to softening without significantly affecting the electrical conductivity.	CuAg0,04 CuAg0,07 CuAg0,10 CuAg0,04P CuAg0,07P CuAg0,10P CuAg0,04(OF) CuAg0,07(OF) CuAg0,10(OF)	CW011A CW012A CW013A CW014A CW015A CW016A CW017A CW018A CW019A

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