BS EN 1976:2012

BSI Standards Publication

# Copper and copper alloys — Cast unwrought copper products

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## National foreword

This British Standard is the UK implementation of EN 1976:2012.
It supersedes BS EN 1976:1998, which is withdrawn.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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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN 1976

October 2012

ICS 77.150.30

Supersedes EN 1976:1998

English Version

# Copper and copper alloys - Cast unwrought copper products

Cuivre et alliages de cuivre - Formes brutes de coulée en cuivre

Kupfer und Kupferlegierungen - Gegossene Rohformen aus Kupfer

This European Standard was approved by CEN on 18 August 2012.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

**Management Centre: Avenue Marnix 17, B-1000 Brussels**

# Contents

Page

# Foreword

This document (EN 1976:2012) 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of an identical text or by endorsement, at the latest by April 2013, and conflicting national standards shall be withdrawn at the latest by April 2013.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 1976:1998.

This is one of a series of European Standards for products manufactured from refined copper grades.

Other products are specified as follows:

— EN 1977, *Copper and copper alloys — Copper drawing stock (wire rod)*;

— EN 1978, *Copper and copper alloys — Copper cathodes*.

In comparison with the first edition of EN 1976:1998, the following significant changes were made:

a) Clause 3, Terms and definitions for the various refinery shapes have been added from ISO 197-2;

b) Table 2, Cu-FRHC, Other elements – content has been modified and a new footnote "d" has been added.

Within its programme of work, Technical Committee CEN/TC 133 requested CEN/TC 133/WG 1 "Unwrought copper products" to revise the following standard:

EN 1976:1998, *Copper and copper alloys — Cast unwrought copper products*.

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 and physical properties of cast unwrought copper products (refinery shapes) in thirteen grades of copper and nine silver-bearing copper grades. The refinery shapes included are horizontally, vertically and continuously cast wire bars, cakes, billets and ingots. Wire bars, cakes and billets are intended for fabricating into wrought products; ingots are intended for alloying in wrought and cast copper alloys.

A table indicating the refinery shapes in which each copper grade is normally available is given in Annex A. Annex B gives information on the relationships between electrical resistivity and conductivity of copper.

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

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

IEC 60468, *Method of measurement of resistivity of metallic materials*

ISO 4746, *Oxygen-free copper — Scale adhesion test*

## 3 Terms and definitions

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

**3.1**
**unwrought product**
**refinery shape**
general term for unwrought products obtained by refining or melting and casting processes, intended for further processing

EXAMPLE Examples of unwrought products are cathodes, wire bars, cakes, billets, ingots.

[SOURCE: ISO 197-2:1983, 2.1]

**3.2**
**wire bar**
cast unwrought product normally of approximately square cross-section, with or without tapered ends, principally used for rolling into drawing stock or flat products for subsequent processing into wire, strip or profile

[SOURCE: ISO 197-2:1983, 2.3]

**3.3**
**cake**
cast unwrought product of rectangular cross-section, generally used for rolling into plate, sheet, strip or profiles

[SOURCE: ISO 197-2:1983, 2.4]

**3.4**
**billet**
cast unwrought product of circular cross-section used for the production of tube, rod, bar, profiles or forgings

[SOURCE: ISO 197-2:1983, 2.5]

**3.5**
**ingot**
**ingot bar**
cast unwrought product in a form suitable only for remelting primarily for the production of copper and copper alloys

[SOURCE: ISO 197-2:1983, 2.6]

# 4 Designations

## 4.1 Material

### 4.1.1 General

The material is designated either by symbol or number (see Tables 1 to 4).

### 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 given 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 Product

The product designation provides a standardized pattern of designation from which a rapid and unequivocal description of a product is 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:

— denomination (Billet, Wire bar, Cake or Ingot);

— number of this European Standard (EN 1976);

— material designation, either symbol or number (see Tables 1 to 4);

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

— nominal dimensions (diameter, or width x thickness, and length);

— nominal unit mass, (if appropriate).

The derivation of a product designation is shown in the following example.

EXAMPLE Billets conforming to this standard, in material designated either Cu-ETP or CR004A, round cross-section, nominal diameter 250 mm × nominal length 1 000 mm, are designated as follows:

Billet EN 1976 — Cu-ETP — RND 250 × 1 000

or

Billet EN 1976 — CR004A — RND 250 × 1 000

Denomination

Number of this European Standard

Material designation

Cross-sectional shape and nominal dimensions in millimetres

## 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);

b) denomination (Billet, Wire bar, Cake or Ingot);

c) number of this European Standard (EN 1976);

d) material designation (see Tables 1 to 4);

e) cross-sectional shape required;

f) nominal dimensions (i.e. diameter, or width × thickness, and length) and nominal mass, where appropriate (see Table 7 for wire bar dimensions).

It is recommended that the product designation, as described in 4.2, 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) for Cu-ETP and Cu-FRHC only: if oxygen content is higher than 0,040 % (see Table 2, Footnote b);

h) for Cu-FRHC only: if the total impurities content is higher than 0,06 % (see Table 2, Footnote d);

i) for ingots only: whether they are to be marked with a furnace charge mark;

j) the tests, if any, which the purchaser requires to be carried out by the manufacturer on the product, selected from the tests appropriate to each copper grade given in Table 6;

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).

# 6 Requirements

## 6.1 Composition

The composition of the refinery shapes shall conform to the requirements for the appropriate grade given in Tables 1 to 4.

## 6.2 Electrical properties

The maximum mass resistivity at 20 °C of each refinery shape shall conform to the appropriate requirements given in Table 5. The test shall be carried out in accordance with 8.2.

**Table 1 — Composition of unalloyed copper grades made from Cu-CATH-1 (CR001A)**

| Material designation | | Composition % (mass fraction) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ele-ment | Cu | Ag | As | Bi | Cd | Co | Cr | Fe | Mn | Ni | O | P | Pb | S | Sb | Se | Si | Sn | Te | Zn | Elements listed in this table other than copper | |
| Symbol | Number | | | | | | | | | | | | | | | | | | | | | | total | excl. |
| Cu-ETP1 | CR003A | min. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | max. | — | 0,002 5 | 0,000 5[a] | 0,000 20[b] | —[a] | —[c] | —[a] | 0,001 0[c] | —[a] | —[c] | 0,040 | —[a] | 0,000 5 | 0,001 5 | 0,000 4[a] | 0,000 20[b] | —[c] | —[c] | 0,000 20[b] | —[c] | 0,006 5 | O |
| Cu-OF1 | CR007A | min. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | | max. | — | 0,002 5 | 0,000 5[a] | 0,000 20[b] | —[a] | —[c] | —[a] | 0,001 0[c] | —[a] | —[c] | —[d] | —[a] | 0,000 5 | 0,001 5 | 0,000 4[a] | 0,000 20[b] | —[c] | —[c] | 0,000 20[b] | —[c] | 0,006 5 | O |
| Cu-OFE | CR009A | 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 | —[d] | 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 | CR022A | 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 | —[d] | 0,006 | 0,000 5 | 0,001 5 | 0,000 4 | 0,000 20 | — | 0,000 2 | 0,000 20 | 0,000 1 | — | — |

[a] (As + Cd + Cr + Mn + P + Sb) maximum 0,001 5 %.

[b] (Bi + Se + Te) maximum 0,000 3 %, of which (Se + Te) maximum 0,000 30 %.

[c] (Co + Fe + Ni + Si + Sn + Zn) maximum 0,002 0 %.

[d] The oxygen content shall be controlled by the manufacturer so that the material conforms to the hydrogen embrittlement requirements.

**Table 2 — Composition of unalloyed copper grades, other than those made from Cu-CATH-1 (CR001A)**

| **Material designation** | | **Composition** % (mass fraction) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Element | Cu[a] | Bi | O | Pb | Other elements (see note) | |
| Symbol | Number | | | | | | total | excluding |
| Cu-ETP | CR004A | min. | 99,90 | — | — | — | — | Ag, O |
| | | max. | — | 0,000 5 | 0,040[b] | 0,005 | 0,03 | |
| Cu-FRHC | CR005A | min. | 99,90 | — | — | — | — | Ag, O |
| | | max. | — | — | 0,040[b] | — | 0,06[d] | |
| Cu-FRTP | CR006A | min. | 99,90 | — | — | — | — | Ag, Ni, O |
| | | max. | — | — | 0,100 | — | 0,05 | |
| Cu-OF | CR008A | min. | 99,95 | — | — | — | — | Ag |
| | | max. | — | 0,000 5 | —[c] | 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 controlled by the manufacturer so that the material conforms to the hydrogen embrittlement requirements.

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

**Table 3 — Composition of phosphorus-containing copper grades**

| **Material designation** | | **Composition** % (mass fraction) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Element | Cu[a] | Bi | P | Pb | Other elements (see note) | |
| Symbol | Number | | | | | | total | excluding |
| Cu-PHC | CR020A | min. | 99,95 | — | 0,001 | — | — | Ag, P |
| | | max. | — | 0,000 5 | 0,006 | 0,005 | 0,03[b] | |
| Cu-HCP | CR021A | min. | 99,95 | — | 0,002 | — | — | Ag, P |
| | | max. | — | 0,000 5 | 0,007 | 0,005 | 0,03[b] | |
| Cu-DLP | CR023A | min. | 99,90 | — | 0,005 | — | — | Ag, Ni, P |
| | | max. | — | 0,000 5 | 0,013 | 0,005 | 0,03 | |
| Cu-DHP | CR024A | min. | 99,90 | — | 0,015 | — | — | — |
| | | max. | — | — | 0,040 | — | —[c] | |
| Cu-DXP | CR025A | min. | 99,90 | — | 0,04 | — | — | Ag, Ni, P |
| | | max. | — | 0,000 5 | 0,06 | 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] The oxygen content shall be controlled by the manufacturer so that the material conforms to the hydrogen embrittlement requirements.

[c] If required, the permitted total of elements, other than silver and phosphorus, should be agreed between the purchaser and the supplier.

**Table 4 — Composition of silver-containing copper grades (silver-bearing coppers)**

| **Material designation** | | **Composition** % (mass fraction) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Element | Cu | Ag | Bi | O | P | Other elements (see note) | |
| Symbol | Number | | | | | | | total | excluding |
| CuAg0,04 | CR011A | min. | Rem. | 0,03 | — | — | — | — | Ag, O |
| | | max. | — | 0,05 | 0,000 5 | 0,040 | — | 0,03 | |
| CuAg0,07 | CR012A | min. | Rem. | 0,06 | — | — | — | — | Ag, O |
| | | max. | — | 0,08 | 0,000 5 | 0,040 | — | 0,03 | |
| CuAg0,10 | CR013A | min. | Rem. | 0,08 | — | — | — | — | Ag, O |
| | | max. | — | 0,12 | 0,000 5 | 0,040 | — | 0,03 | |
| CuAg0,04P | CR014A | min. | Rem. | 0,03 | — | — | 0,001 | — | Ag, P |
| | | max. | — | 0,05 | 0,000 5 | —[a] | 0,007 | 0,03 | |
| CuAg0,07P | CR015A | min. | Rem. | 0,06 | — | — | 0,001 | — | Ag, P |
| | | max. | — | 0,08 | 0,000 5 | —[a] | 0,007 | 0,03 | |
| CuAg0,10P | CR016A | min. | Rem. | 0,08 | — | — | 0,001 | — | Ag, P |
| | | max. | — | 0,12 | 0,000 5 | —[a] | 0,007 | 0,03 | |
| CuAg0,04(OF) | CR017A | min. | Rem. | 0,03 | — | — | — | — | Ag, O |
| | | max. | — | 0,05 | 0,000 5 | —[a] | — | 0,006 5 | |
| CuAg0,07(OF) | CR018A | min. | Rem. | 0,06 | — | — | — | — | Ag, O |
| | | max. | — | 0,08 | 0,000 5 | —[a] | — | 0,006 5 | |
| CuAg0,10(OF) | CR019A | min. | Rem. | 0,08 | — | — | — | — | Ag, O |
| | | max. | — | 0,12 | 0,000 5 | —[a] | — | 0,006 5 | |

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] The oxygen content shall be controlled by the manufacturer so that the material conforms to the hydrogen embrittlement requirements.

**Table 5 — Electrical properties of grades of copper at 20 °C**

| Material designation | | Electrical properties | | | |
|---|---|---|---|---|---|
| Symbol | Number | Mass resistivity $\Omega \cdot g/m^2$ max. | Nominal volume resistivity $\mu\Omega \cdot m$ max. | Nominal conductivity MS/m min. | Nominal conductivity % IACS min. |
| Cu-ETP1 | CR003A | 0,151 76 | (0,017 07) | (58,58) | (101,0) |
| Cu-ETP | CR004A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| Cu-FRHC | CR005A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| Cu-FRTP | CR006A | — | — | — | — |
| Cu-OF1 | CR007A | 0,151 76 | (0,017 07) | (58,58) | (101,0) |
| Cu-OF | CR008A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| Cu-OFE | CR009A | 0,151 76 | (0,017 07) | (58,58) | (101,0) |
| Cu-PHC | CR020A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| Cu-HCP | CR021A | 0,155 96 | (0,017 54) | (57,00) | (98,3) |
| Cu-PHCE | CR022A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| Cu-DLP | CR023A | — | — | — | — |
| Cu-DHP | CR024A | — | — | — | — |
| Cu-DXP | CR025A | — | — | — | — |
| CuAg0,04 | CR011A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| CuAg0,07 | CR012A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| CuAg0,10 | CR013A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| CuAg0,04P | CR014A | 0,155 96 | (0,017 54) | (57,00) | (98,3) |
| CuAg0,07P | CR015A | 0,155 96 | (0,017 54) | (57,00) | (98,3) |
| CuAg0,10P | CR016A | 0,155 96 | (0,017 54) | (57,00) | (98,3) |
| CuAg0,04(OF) | CR017A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| CuAg0,07(OF) | CR018A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |
| CuAg0,10(OF) | CR019A | 0,153 28 | (0,017 24) | (58,00) | (100,0) |

NOTE 1 Figures in parentheses are not requirements of this standard but are given for guidance purposes only.

NOTE 2 For an explanation of “% IACS”, see B.2.

## 6.3 Hydrogen embrittlement

Samples taken from refinery shapes in copper grades Cu-OF (CR008A), Cu-OF1 (CR007A), Cu-OFE (CR009A), Cu-HCP (CR021A), Cu-PHC (CR020A), Cu-PHCE (CR022A), Cu-DLP (CR023A), Cu-DHP (CR024A), Cu-DXP (CR025A), CuAg0,04(OF) (CR017A), CuAg0,07(OF) (CR018A), CuAg0,10(OF) (CR019A), CuAg0,04P (CR014A), CuAg0,07P (CR015A) and CuAg0,10P (CR016A) shall show no evidence of cracking, when tested. The test shall be carried out in accordance with 8.2.2.

## 6.4 Scale adhesion

Samples taken from refinery shapes in copper grade Cu-OFE (CR009A) shall meet the requirements of the scale adhesion test. The test shall be carried out in accordance with 8.2.3.

**Table 6 — Tests for refinery shapes**

| Material designation | | Test appropriate to copper grade | | | |
|---|---|---|---|---|---|
| Symbol | Number | Analysis | Mass resistivity | Hydrogen embrittlement | Scale adhesion |
| Cu-ETP1 | CR003A | X | X | — | — |
| Cu-ETP | CR004A | X | X | — | — |
| Cu-FRHC | CR005A | X | X | — | — |
| Cu-FRTP | CR006A | X | — | — | — |
| Cu-OF1 | CR007A | X | X | X[a] | — |
| Cu-OF | CR008A | X | X | X[a] | — |
| Cu-OFE | CR009A | X | X | X[b] | X |
| Cu-PHC | CR020A | X | X | X[a] | — |
| Cu-HCP | CR021A | X | X | X[a] | — |
| Cu-PHCE | CR022A | X | X | X[b] | — |
| Cu-DLP | CR023A | X | — | X[a] | — |
| Cu-DHP | CR024A | X | — | X[a] | — |
| Cu-DXP | CR025A | X | — | X[a] | — |
| CuAg0,04 | CR011A | X | X | — | — |
| CuAg0,07 | CR012A | X | X | — | — |
| CuAg0,10 | CR013A | X | X | — | — |
| CuAg0,04P | CR014A | X | X | X[a] | — |
| CuAg0,07P | CR015A | X | X | X[a] | — |
| CuAg0,10P | CR016A | X | X | X[a] | — |
| CuAg0,04(OF) | CR017A | X | X | X[a] | — |
| CuAg0,07(OF) | CR018A | X | X | X[a] | — |
| CuAg0,10(OF) | CR019A | X | X | X[a] | — |

[a] The assessment criterion for hydrogen embrittlement shall be the close-bend test in accordance with EN ISO 2626.

[b] The assessment criterion for hydrogen embrittlement shall be the reverse bend test (10 reversals) in accordance with EN ISO 2626.

## 6.5 Dimensions, mass and tolerances

### 6.5.1 Horizontally cast wire bars

Horizontally cast wire bars of various nominal masses shall conform to the appropriate dimensions and tolerances given in Table 7 and Figure 1.

**Table 7 — Dimensions and tolerances for horizontally cast wire bars of various nominal masses**

| **Nominal mass** kg | **Dimensions and tolerances** (see Figure 1) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L$ mm | Tol. mm | $L_1$ mm | Tol. mm | $h$ mm | Tol. mm | $h_1$ mm | Tol. mm | $b$ mm | Tol. mm | $b_1$ mm | Tol. mm | $R$ mm | Tol. mm | $R_1$ mm | Tol. mm | $R_2$ mm | Tol. mm | $\alpha$ | Tol. | $\beta$ | Tol. | $\gamma$ | Tol. |
| 91 | 1370 | ± 14 | 150 | ± 5 | 90 | ± 6 | 25 | ± 6 | 100 | ± 6 | 90 | ± 6 | 16 | ± 6 | 16 | ± 6 | 40 | ± 6 | 10° | ± 2° | 10° | ± 2° | 3° | ± 1° |
| 102 | | | | | 100 | | | | 100 | | 90 | | 16 | | | | | | | | | | | |
| 113 | | | | | 100 | | | | 110 | | 100 | | 25 | | | | | | | | | | | |
| 120 | | | | | 110 | | | | 110 | | 100 | | 25 | | | | | | | | | | | |
| 125 | | | | | 110 | | | | 110 | | 100 | | 25 | | | | | | | | | | | |
| 136 | | | | | 120 | | | | 110 | | 100 | | 25 | | | | | | | | | | | |

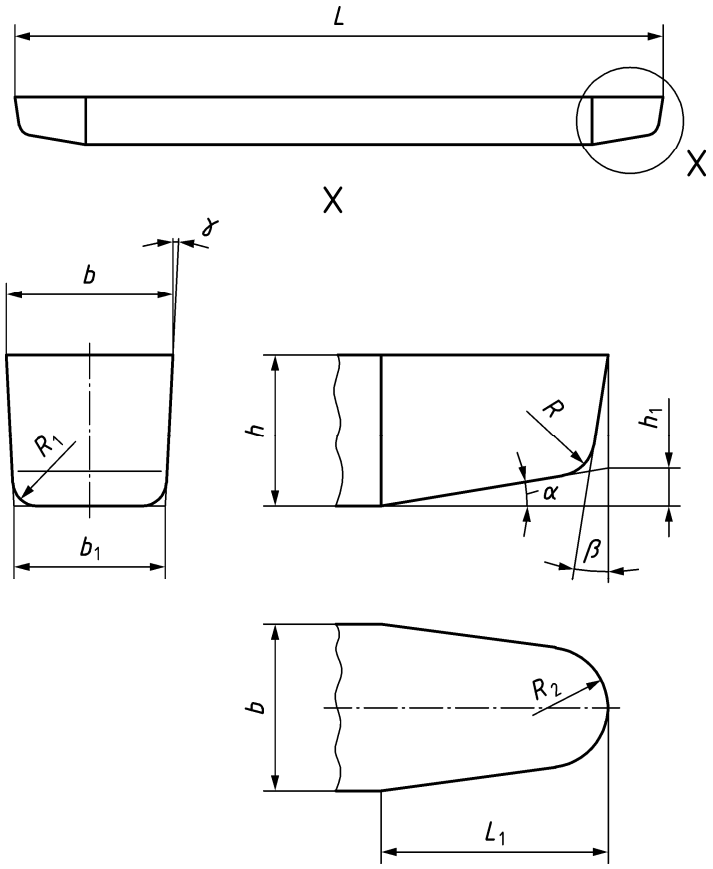


**Figure 1 — Dimensions of horizontally cast wire bars**

#### 6.5.2 Billets

Billets shall be of a cylindrical shape with both ends flat.

The mass, diameter and length and the maximum deviation from straightness shall conform to the tolerances given in Table 8.

#### 6.5.3 Other shapes

The mass, dimensions and straightness of vertically (either statically or continuously) cast wire bars, vertically and horizontally cast cakes and ingots, shall conform to the tolerances given in Table 8.

### 6.6 Physical condition of refinery shapes

Cakes, billets and wire bars shall be substantially free from shrinkage defects, gas holes, cracks, cold sets, pits, concave tops and other similar defects in set or casting.

NOTE No physical condition requirements are specified for ingots, as physical defects are generally of minor consequence.

**Table 8 — Tolerances on mass and dimensions for refinery shapes other than horizontally cast wire bars**

| Refinery shape | Tolerances | | | | | |
|---|---|---|---|---|---|---|
| | Mass<br>% | Diameter<br>mm | Length | Width and thickness<br>mm | Other dimensions<br>mm | Maximum deviation from straightness per 1 000 mm length<br>mm |
| **Billets** (all sizes) | ± 5 | ± 3 | ± 2 % of ordered length | — | — | 4 |
| **Cast wire bars**: | | | | | | |
| - vertically continuously | ± 5 | — | — | ± 3 | ± 6 | — |
| - vertically statically | ± 5 | — | — | ± 6 | ± 6 | — |
| **Cast cakes**, width, thickness: | | | | | | |
| - up to 200 mm | ± 5 | — | — | ± 3 | — | 4 |
| - over 200 mm | ± 5 | — | — | ± 6 | — | 4 |
| **Ingots** | ± 10 | — | — | — | — | — |

## 7 Sampling

### 7.1 Arrangement of lots for sampling purposes

For refinery shapes produced in a batch process, the manufacturer shall arrange lots for sampling purposes so that, as far as possible, each lot contains pieces from one furnace charge or production batch only.

For refinery shapes produced in a continuous process, the manufacturer shall arrange lots so that, as far as possible, each lot contains pieces produced consecutively from the process.

NOTE A lot is the number of, or aggregate mass of, individual refinery shapes, appropriate to the total amount ordered and to the means of shipment, which constitutes a unit for sampling purposes.

### 7.2 Inspection lots for analysis and physical testing

For the routine sampling of refinery shapes for analysis or for the routine determination of physical properties, the method and rate of sampling each inspection lot shall be at the discretion of the sampler, unless otherwise specified by the purchaser.

In cases of dispute concerning the analysis or physical properties, the method and rate of sampling each inspection lot shall be agreed between the supplier, the purchaser, and if necessary, any mutually accepted arbitrator.

# 8 Test methods

## 8.1 Analysis

Analysis shall be carried out on the sample(s) obtained in accordance with 7.2.

The copper content of Cu-OFE (CR009A) and Cu-PHCE (CR022A) shall be determined by subtracting the total percentage of the concentrations of the specified impurities present from 100 % (see Table 1).

For routine quality control purposes, the composition shall be determined using generally recognised analytical techniques.

In cases of dispute concerning the results of analysis, the method(s) of analysis to be used shall be agreed between the supplier, the purchaser and, if necessary, any mutually accepted arbitrator, and shall be for all the impurities for which limits are specified in Table 1.

For expression of results, the rounding rules given in 8.3 shall be used.

## 8.2 Physical tests

### 8.2.1 Mass resistivity

For the routine determination of the mass resistivity, the test methods used shall be left to the discretion of the tester.

In cases of dispute, the mass resistivity shall be determined on a representative sample from each inspection lot (see 7.2). External oxide shall be removed from the sample which shall then be rolled and/or drawn to a (2,00 ± 0,01) mm diameter wire.

The sample may be hot-worked initially, provided care is taken to avoid contamination or excessive oxidation.

The wire shall be degreased and annealed at (500 ± 10) °C for 30 min in an inert atmosphere and the mass resistivity test carried out in accordance with IEC 60468.

NOTE Information on the relationship between the mass resistivity and the corresponding values for volume resistivity and conductivity is given in Annex B.

### 8.2.2 Hydrogen embrittlement

When a hydrogen embrittlement test is carried out (see Table 6), the specimens prepared from a representative sample from each inspection lot (see 7.2) shall be forged, or hot rolled, and cold drawn into wire or strip (2,00 ± 0,05) mm diameter or thickness.

The hydrogen embrittlement test shall be carried out in accordance with EN ISO 2626.

The types of bend tests to be carried out at the conclusion of the procedure depend upon the copper grade and shall be in accordance with Table 6.

### 8.2.3 Scale adhesion test

When a scale adhesion test is carried out (see Table 6), the specimens of Cu-OFE (CR009A) copper prepared from a representative sample from each inspection lot (see 7.2) shall be tested in accordance with ISO 4746.

### 8.3 Rounding of results

For the purpose of determining conformity to the limits specified in this standard for composition or for electrical resistivity, 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 Annex B of ISO 80000-1:2009. It shall be rounded in one step to the same number of figures used to express the specified limit in this standard.

The following rules shall be used for rounding:

a) if the figure immediately after the last figure to be retained is less than 5, 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 5, 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 5 j)] and agreed with the supplier, the supplier shall issue for the product the appropriate declaration of conformity in accordance with EN 1655.

### 9.2 Inspection documentation

When requested by the purchaser [see 5 k)] and agreed with the supplier, the supplier shall issue for the product the appropriate inspection document, in accordance with EN 10204.

## 10 Marking

All refinery shapes, with the exception of ingots, shall be permanently marked with the manufacturer's brand and furnace charge mark or production number. Ingots shall have a brand stamped or cast-in, but need not have a furnace charge mark unless otherwise specified by the purchaser [see 5 h)].

# Annex A
(informative)

# Available products and grades

The refinery shapes in which each copper grade is normally available are shown, for information purposes, by a 'X' in Table A.1.

**Table A.1 — Available products and grades**

| Material designation | | Product | | | | |
|---|---|---|---|---|---|---|
| Symbol | Number | Wire bar | | Cake | Billet | Ingot |
| | | vertical | horizontal | | | |
| Cu-ETP1 | CR003A | X | X | X | X | X |
| Cu-ETP | CR004A | X | X | X | X | X |
| Cu-FRHC | CR005A | X | X | X | X | X |
| Cu-FRTP | CR006A | — | — | X | X | X |
| Cu-OF1 | CR007A | X | — | X | X | — |
| Cu-OF | CR008A | X | — | X | X | — |
| Cu-OFE | CR009A | X | — | X | X | — |
| Cu-PHC | CR020A | X | — | X | X | — |
| Cu-HCP | CR021A | X | — | X | X | — |
| Cu-PHCE | CR022A | X | — | X | X | — |
| Cu-DLP | CR023A | X | — | X | X | — |
| Cu-DHP | CR024A | X | — | X | X | — |
| Cu-DXP | CR025A | X | — | X | X | — |
| CuAg0,04 | CR011A | X | X | X | X | — |
| CuAg0,07 | CR012A | X | X | X | X | — |
| CuAg0,10 | CR013A | X | X | X | X | — |
| CuAg0,04P | CR014A | X | — | X | X | — |
| CuAg0,07P | CR015A | X | — | X | X | — |
| CuAg0,10P | CR016A | X | — | X | X | — |
| CuAg0,04(OF) | CR017A | X | — | X | X | — |
| CuAg0,07(OF) | CR018A | X | — | X | X | — |
| CuAg0,10(OF) | CR019A | X | — | X | X | — |

# Annex B
(informative)

# Information on electrical resistivity and conductivity relationships

## B.1 Mass resistivity

This standard is intended to prescribe a minimum quality for the coppers specified, including, for several grades, their electric current carrying suitabilities.

Determination of cross-sectional areas to the requisite degree of accuracy is difficult. Hence, in practice nearly all assessments of resistivity are made by measuring the resistance, mass and length of a representative sample. Mass resistivity can be calculated directly from these values and this gives a true measure of the quality of the copper for carrying electric current.

Mass resistivity is therefore the property specified in this standard.

## B.2 Standard annealed copper (IACS)

IEC 60028 uses evidence from earlier years (see USA National Bureau of Standards Circular 31, 1956, superseded by USA National Bureau of Standards Handbook 100, 1966) to establish a fixed value for the resistance to flow of an electric current within an imaginary “standard” annealed copper. This is based on a volume resistivity of 1/58 $\mu\Omega \cdot m$ or 0,017 241 $\mu\Omega \cdot m$ at 20 °C which is defined as corresponding to a conductivity of 100 % IACS at 20 °C. The introduction of the International ohm in 1948 altered the volume resistivity of standard annealed copper by only 0,049 %.

Also on this earlier evidence, the standard annealed copper is allotted a density of 8 890 kg/m$^3$ (8,89 g/cm$^3$).

Hence, as the mass resistivity is the product of the volume resistivity and the density, the mass resistivity of standard annealed copper is 0,153 28 $\Omega \cdot g/m^2$.

## B.3 Commercial annealed copper

IEC 60028 states that “the (electrical) conductivity of commercial annealed copper shall be expressed as a percentage, at 20 °C, of that of standard annealed copper given to approximately 0,1 %”, on the assumption that “the density of commercial annealed copper at 20 °C is 8,89 g/cm$^3$”.

## B.4 Nominal volume resistivity

The density of commercial copper varies with small changes in composition, particularly oxygen content. Thus, a true volume resistivity can only be calculated from a measured mass resistivity if the true density of the particular sample is known or is measured to the requisite degree of accuracy, i.e. better than 0,1 %.

For general purposes, however, a nominal volume resistivity may be calculated using the density of 8 890 kg/m$^3$, as referred to in B.2. (This practice has been adopted in Table 5 of this standard in presenting values for nominal volume resistivity and for nominal conductivity corresponding to the mandatory mass resistivity.)

## B.5 Differences between measured and nominal values

If true volume resistivity or true conductivity is required from measured mass resistivity and therefore actual density is used in calculation, differences of up to 0,6 % (for example for oxygen-free coppers) may result between these values and the corresponding nominal values.

Conductivity calculated from the ratio of the mass resistivity of standard annealed copper (0,153 28 $\Omega \cdot g/m^2$) to the derived mass resistivity may also exhibit a similar disparity.

# Bibliography

[1] EN 1412, *Copper and copper alloys — European numbering system*

[2] IEC 60028, *International standard of resistance for copper*

[3] ISO 197-2:1983, *Copper and copper alloys — Terms and definitions — Part 2: Unwrought products (Refinery shapes)*

[4] ISO 1190-1, *Copper and copper alloys — Code of designation — Part 1: Designation of materials*

[5] ISO 80000-1:2009, *Quantities and units — Part 1: General*

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