International Standard 431

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Copper refinery shapes

Formes brutes d'affinage du cuivre

Second edition — 1981-12-15

UDC 669.3-4 **Ref. No. ISO 431-1981 (E)**

Descriptors : copper, refining, shape, designations, chemical composition, electrical properties, impurities, mass, tolerances, dimensions, chemical analysis, physical tests, defects.

Price based on 7 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 431 was developed by Technical Committee ISO/TC 26, *Copper and copper alloys*, and was circulated to the member bodies in November 1979.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	South Africa, Rep. of
Belgium	Hungary	Spain
Bulgaria	India	Sweden
Canada	Korea, Rep. of	Switzerland
China	Mexico	Turkey
Czechoslovakia	Netherlands	USA
Egypt, Arab Rep. of	Poland	USSR
Finland	Portugal	Yugoslavia
France	Romania	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Chile
United Kingdom

This second edition cancels and replaces the first edition (i.e. ISO 431-1972), ISO Recommendations R 1428, R 1429 and R 1430 and International Standard ISO 2311.

Copper refinery shapes

1 Scope and field of application

This International Standard specifies the requirements of refined copper listed in table 1, in the form of refinery shapes (unwrought products). The refinery shapes included are cathodes, horizontally, vertically and continuously cast wire bars, cakes, billets and ingots.

Table 1 — Designation and terms of refined copper

Designation	Term
Cu-CATH	Cathode copper
Cu-ETP	Electrolytically refined tough pitch copper
Cu-FRHC	Fire-refined high-conductivity copper
Cu-CRTP	Chemically refined tough-pitch copper
Cu-FRTP	Fire-refined tough-pitch copper
Cu-HCP	High-conductivity phosphorus-containing copper
Cu-PHC	High-conductivity phosphorus-containing copper
Cu-PHCE	High-conductivity phosphorus-containing copper (electronic grade)
Cu-DLP	Phosphorus-deoxidized copper — Low residual phosphorus
Cu-DHP	Phosphorus-deoxidized copper — High residual phosphorus
Cu-OF	Oxygen-free electrolytically refined copper
Cu-OFE	Oxygen-free electrolytically refined copper (electronic grade)
Cu-Ag (OF)	Oxygen-free copper-silver
Cu-Ag	Tough-pitch copper-silver
Cu-Ag (P)	Phosphorus-deoxidized copper-silver

2 References

ISO 197, *Copper and copper alloys — Terms and definitions.*

— *Part 1 : Materials.* [1)]

— *Part 2 : Unwrought products.* [2)]

ISO 1190/1, *Copper and copper alloys — Code of designation — Part 1 : Designation of materials.* [3)]

ISO 1553, *Unalloyed copper containing not less than* 99,90 % *of copper — Determination of copper content — Electrolytic method.*

ISO 1554, *Wrought and cast copper alloys — Determination of copper content — Electrolytic method.*

ISO/R 1811, *Chemical analysis of copper and copper alloys — Sampling of copper refinery shapes.* [4)]

ISO 2626, *Copper — Hydrogen embrittlement test.*

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

IEC Publication 28, *International standard of resistance for copper.*

IEC Publication 468, *Method of measurement for resistivity of metallic materials.*

3 Definitions

For the purpose of this International Standard, the definitions for refined copper in ISO/TR 197/1 and for refinery shapes in ISO/TR 197/2, as well as the principles for the designation of copper in ISO 1190/1, apply.

4 Requirements

4.1 Composition and properties

The copper in each refinery shape shall conform to the requirements for composition and physical properties specified in tables 2 and 3 as appropriate.

4.2 Refinery shapes

The shapes in which each grade is available are shown in table 2.

Wire bars, cakes and billets are intended for fabricating into wrought products; ingots are intended for alloying in wrought and cast copper alloys.

1) At present at the stage of draft. (Revision of ISO/TR 197/1.)

2) At present at the stage of draft. (Revision of ISO/TR 197/2.)

3) At present at the stage of draft. (Revision of ISO/R 1190/1.)

4) Under revision.

Table 2 — Requirements

Designation[1]	Chemical composition		Refinery shapes					Electrical properties				Methods of test			
	Copper plus silver % min.	Other elements %	Vertical wire bar	Horizonal wire bar	Cake	Billet	Ingot and ingot bar	Mandatory value: Mass resistivity Ωg/m² max.	Equivalent values for guidance only[7]: Volume resistivity[8] Ωmm²/m max.	Conductivity MS/m min.	Conductivity % IACS min.	Chemical analysis	Resistivity test	Scale adhesion test	Hydrogen im-brittlement test
Cu-CATH	99,90		Cathodes only					0,153 28	0,017 24	58,00	100,0	x	x		
Cu-ETP	99,90		x	x	x	x	x	0,153 28[4] 0,155 96[5]	0,017 24[4] 0,017 54[5]	58,00[4] 57,00[5]	100,0[4] 98,3[5]	x	x		
Cu-FRHC	99,90		x	x	x	x	x	0,153 28[4] 0,155 96[5]	0,017 24[4] 0,017 54[5]	58,00[4] 57,00[5]	100,0[4] 98,3[5]	x	x		
Cu-CRTP	99,90			x	x	x	x	0,153 28[4] 0,155 96[5]	0,017 24[4] 0,017 54[5]	58,00[4] 57,00[5]	100,0[4] 98,3[5]	x	x		
Cu-FRTP	99,85				x	x	x					x			
Cu-HCP	99,95	P 0,001-0,005[9]	x		x	x		0,156 14			98,16	x	x		Close bend
Cu-PHC	99,95	P 0,003	x		x	x		0,153 28	0,017 24	58,00	100,0	x	x		Close bend
Cu-PHCE	99,99 (excl. Ag)	[2]	x		x	x		0,151 76	0,017 07	58,58	101,0	x	x		10 reverse bends
Cu-DLP	99,90	P 0,005-0,012			x	x		[6]				x	[6]		Close bend
Cu-DHP	99,85	P 0,013-0,04			x	x						x			Close bend
Cu-OF	99,95		x		x	x		0,153 28	0,017 24	58,00	100,0	x	x		Close bend
Cu-OFE	99,99 (excl. Ag)	[2]	x		x	x		0,151 76	0,017 07	58,58	101,0	x	x	x	10 reverse bends
Cu-Ag (OF)	99,95	[3]	x		x	x		0,153 28	0,017 24	58,00	100,0	x	x		Close bend
Cu-Ag	99,90	[3]	x	x	x	x		0,153 28	0,017 24	58,00	100,0	x	x		
Cu-Ag (P)	99,90	[3]			x	x		0,155 96[5]	0,017 54	57,00	98,3	x	x		Close bend

1) According to ISO 1190/1.

2) See table 3.

3) Specific ranges of silver content between 0,01 and 0,25 % by agreement between the interested parties.

4) When copper is for electrical purposes.

5) When copper is for non-electrical purposes.

6) May be agreed between the interested parties.

7) See annex A.

8) The precise value is found in IEC Publication 28.

9) When made from an oxygen-free base copper, the oxygen content of HCP copper shall be less than 0,001 %.

Table 3 — Maximum impurity limits

Values as a percentage by mass

Element \ Copper	Cu-OFE	Cu-PHCE
Arsenic	1)	1)
Antimony	1)	1)
Bismuth	0,001 1)	0,001 1)
Cadmium	0,000 1	0,000 1 1)
Iron	2)	2)
Lead	0,001	0,001
Manganese	1) 2)	1) 2)
Mercury	0,000 1	0,000 1
Nickel	2)	2)
Oxygen	0,001	0,003 3)
Phosphorus	0,000 3	0,003 3)
Selenium	0,001 1)	0,001 1)
Silver	2)	2)
Sulphur	0,001 8	0,001 8
Tellurium	0,001 1)	0,001 1)
Tin	1)	1)
Zinc	0,000 1	0,000 1

1) Total of these seven elements not to exceed 0,004 %.

2) Analysis required. No limit established.

3) Approximate values.

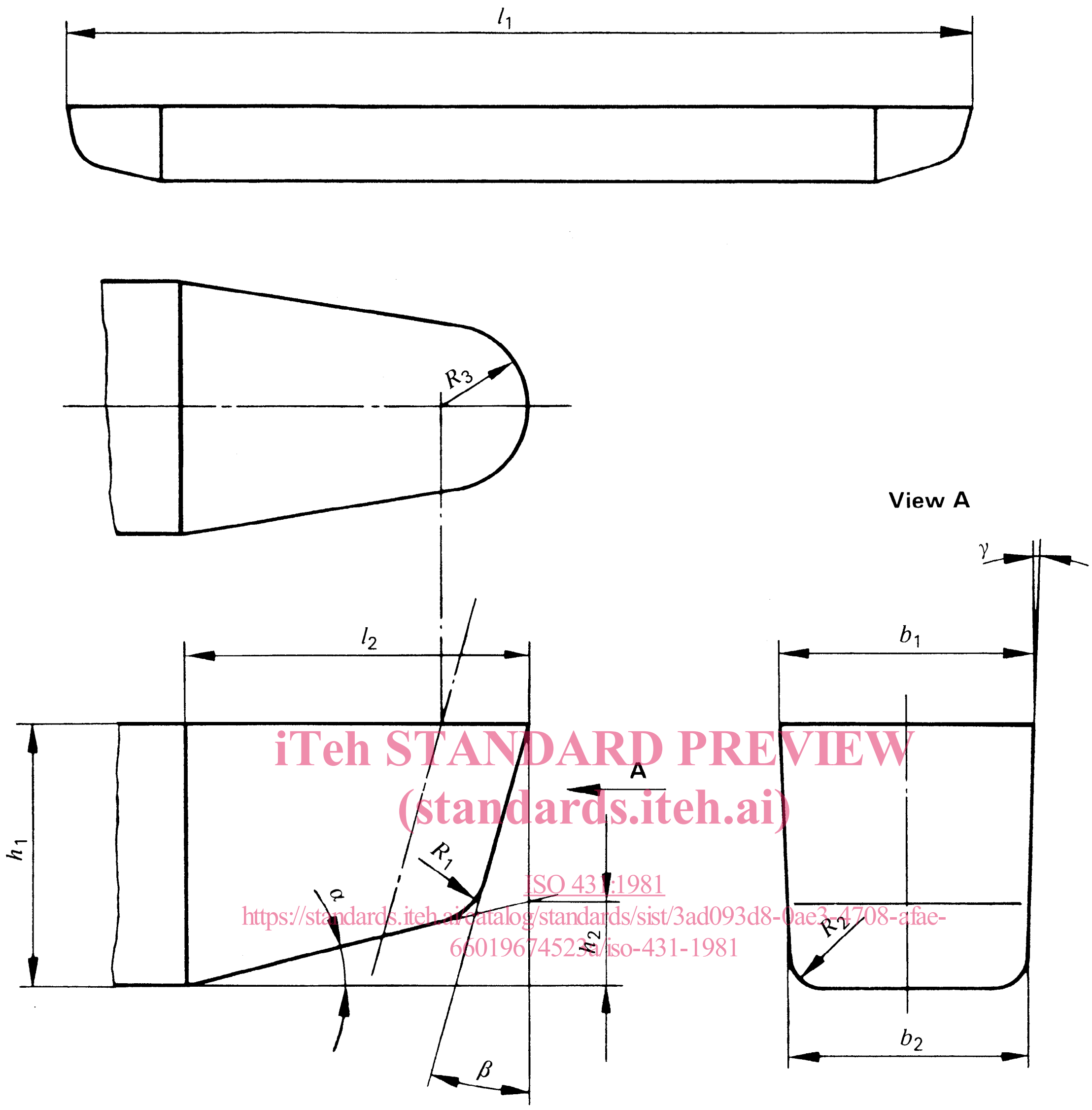

Figure — Shapes and sizes of horizontally cast wire bars

Table 4 — Masses and dimensions of horizontally cast wire bars (see the figure)

Dimensions in millimetres for masses in kilograms (pounds)							
Symbol	Tolerance	91 (200)	102 (225)	113 (250)	120 (265)	125 (275)	136 (300)
l_1	± 1 %	1 370	1 370	1 370	1 370	1 370	1 370
l_2	± 6 mm	150	150	150	150	150	150
h_1	± 6 mm	90	100	100	110	110	120
h_2	± 6 mm	25	25	25	25	25	25
b_1	± 6 mm	100	100	110	110	110	110
b_2	± 6 mm	90	90	100	100	100	100
R_1	± 6 mm	16	16	25	25	25	25
R_2	± 6 mm	16	16	16	16	16	16
R_3	± 6 mm	40	40	40	40	40	40
α	± 2°	10°	10°	10°	10°	10°	10°
β	± 2°	10°	10°	10°	10°	10°	10°
γ	± 1°	3°	3°	3°	3°	3°	3°

4.3 Dimensions, masses and tolerances

4.3.1 Cathodes

Whole cathodes or cathodes cut to size may be supplied as agreed between the interested parties.

4.3.2 Wire bars (horizontally cast)

Wire bars shall have masses, dimensions and tolerances as selected from table 4 and the figure.

4.3.3 Billets

Billets shall be ordered by diameter and length. For diameters of billets up to and including 200 mm, a variation of ± 3 mm is permissible. If closer tolerances on diameters are required, they shall be agreed between the interested parties. For diameters of billets over 200 mm tolerances on diameter shall be as agreed between the interested parties. Billets may vary in length by ± 2 % from the specified length unless otherwise agreed, and shall be straight within 4 mm per metre length. Unless otherwise specified, billets of phosphorus-deoxidized copper less than or equal to 100 mm in diameter may be supplied sheared at one end. The other end shall be flat.

Billets over 100 mm in diameter shall be supplied with both ends flat. Billets shall not be cupped except by specific agreement at the time of purchase.

4.3.4 Other shapes

Other shapes not dealt with in 4.3.1 to 4.3.3 are static and continuously vertically cast wire bars, vertically and horizontally cast cakes and ingots. Variation from ordered size is permissible within the limits shown in table 5.

4.4 Physical condition

4.4.1 Cathodes shall withstand ordinary handling without excessive breakage or excessive separation of nodules and shall be reasonably free from all foreign material such as copper sulphate, dirt, grease and oil.

4.4.2 Cakes, billets and wire bars shall be substantially free from shrink holes, cracks, cold sets, pits, sloppy edges, concave tops and other similar defects in set or casting. These requirements do not apply to ingots and ingot bars in which physical defects are of minor consequence.

5 Marking

All shapes intended for fabrication 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.

6 Lots

The manufacturers should endeavour to arrange lots so that, as far as possible, each lot contains pieces from one furnace charge or production lot only.

7 Chemical analysis

7.1 Sampling for chemical analysis

Sampling shall be done in accordance with ISO/R 1811, where such procedures apply.

7.2 Methods of analysis

The methods used for determining the copper content of coppers of 99,90 % purity or greater shall be in accordance with ISO 1553, and for coppers of less than 99,90 % purity the test method shall be in accordance with ISO 1554.

The copper content of Cu-OFE and Cu-PHCE shall be determined by subtracting the total of the concentrations of impurities determined from 100 %. The impurity total is defined as the sum of the seventeen elements in table 3. The analytical methods for determining the impurities in Cu-OFE and Cu-PHCE shall, in all cases of disagreement, be as agreed between the supplier, the purchaser and any mutually acceptable arbitrator.

Table 5 — Other shapes — Permissible variations from ordered size

Shape	Mass	Width and thickness	Other dimensions
Vertically continuously cast wire bars	± 5 %	± 3 mm	± 6 mm
Vertically static cast wire bars	± 5 %	± 6 mm	± 6 mm
Vertically and horizontally cast cakes	± 5 %	⩽ 200 mm ± 6 mm > 200 mm ± 3 %	⩽ 200 mm ± 6 mm > 200 mm ± 3 %
Ingots	+ 10 %		

8 Physical testing

8.1 Resistivity test

For electrolytic cathode copper, Cu-CATH, the resistivity shall be determined from a representative sample of each batch of less than 50 t or from each 50 t lot. Samples shall be melted under charcoal in a pure graphite crucible and then chill cast to a form suitable for working.

For shapes other than cathode copper, samples may be taken either while still molten or by cutting from representative portions of the cast shape.

The sample may be hot-worked initially, if required, provided that care is taken to avoid contamination or excessive oxidation. External oxide shall be removed and the sample then rolled or drawn to 2 mm diameter, degreased and annealed at 500 °C for a minimum time of 30 min in an inert atmosphere.

The resistivity test shall be made in accordance with IEC publication 468.

Notes on the relationship between mandatory mass resistivity and the corresponding volume resistivity and conductivity are given in the annex.

8.2 Embrittlement test

Test specimens prepared from representative samples shall normally be forged or hot-rolled and cold-drawn into wire or strip of approximately 2,0 mm in diameter or thickness.

As a routine test, samples cut from cast copper may be used and the results accepted if satisfactory. In the event of failure, further tests shall be carried out on wrought specimens.

The hydrogen embrittlement test shall be carried out in accordance with ISO 2626. The types of tests to be carried out are detailed in table 2.

After bending, the stressed surface of the bent portion shall be visually inspected. No significant cracks shall be apparent to the unaided eye, corrected to normal vision.

8.3 Scale adhesion test

Cu-OFE copper shall be tested in accordance with ISO 4746.

Annex

Notes on resistivity and conductivity relationships

(This annex forms part of the Standard.)

A.1 Mass resistivity

This International Standard is intended to prescribe a minimum quality for the copper specified including, for several grades, their electric current carrying suitability.

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

Mass resistivity has therefore been taken as the mandatory property in this International Standard.

A.2 Standard annealed copper

IEC Publication No. 28-1925, first published in 1914, 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 or 0,017 241... Ωmm²/m* at 20 °C.

Also on this earlier evidence the standard annealed copper is allotted a density of 8,89 g/cm³ (8 890 kg/m³ in SI units).

A.3 Commercial annealed copper

In addition IEC publication 28 states that "the (electrical) conductivity of commercial annealed copper shall be expressed as a percentage at 20 °C, of that of standard annealed copper... to... 0,1 %... on the assumption (that) the density of commercial annealed copper is (also) 8,89 grams per cubic centimetre".**

A.4 Nominal volume resistivity

In fact, the density of commercial copper varies with small changes in composition, particularly oxygen content (see ISO 197). 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/m³, as referred to in clause A.2. This practice has been adopted in table 2 of this International Standard in presenting values for nominal volume resistivity and for nominal conductivity corresponding to the mandatory mass resistivity.

A.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...) to the observed mass resistivity may also exhibit similar disparities.

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* Microhm metre in SI units; the introduction of the International ohm in 1948 altered the volume resistivity of standard annealed copper by only 0,049 %.

** No underlining is used in IEC Publication 28.