Draft Indian Standard
COPPER WIRE RODS FOR ELECTRICAL APPLICATIONS – SPECIFICATION

(*Second Revision)*

1 SCOPE

This standard covers the requirements of copper wire rods for electrical applications having nominal cross-sectional diameter over 6 mm to 35 mm. The requirements of Electrolytic Tough Pitch (ETP), Oxygen Free Copper (OFC) and Fire Refined High Conductivity (FRHC) types of copper wire rods are covered in this standard.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards:

IS No.	*Title*
IS 440 : 1964	Methods of chemical analysis of copper (*first revision*)
IS 1387 : 1993	General requirements for the supply of metallurgical materials (*second revision*)
IS 1608 (Part 1) : 2022/ ISO 6892-1 : 2019	Metallic Materials — Tensile Testing Part 1 Method of Test at Room Temperature (*fifth revision*)
3288 (Part 3) : 1986	Glossary of terms relating to copper and copper alloys: Part 3 Wrought forms
IS 3635 : 1966	Methods of test for resistance of metallic electrical resistance material

3 TERMINOLOGY

For the purpose of this standard definitions as given in IS 3288 (Part 3) shall apply.

4 SUPPLY OF MATERIAL

General requirements relating to the supply of material shall conform to IS 1387.

5 CHEMICAL COMPOSITION

5.1 The material shall have chemical composition as given in Table 1.

Table 1 Chemical Composition
(*Clause* 5.1)

Element	**Grade of the material**		
Copper, *Min*	**Cu-ETP** 99.90% (by difference)	**Cu-OF** 99.95% (by difference)	**Cu-FRHC** 99.90 percent (by difference)
(1)	(2)	(3)	(4)
Tellurium, *Max*	2 ppm	2 ppm	10 ppm
Selenium, *Max*	2 ppm	2 ppm	10 ppm
Bismuth, *Max*	1.0 ppm	1.0 ppm	5 ppm
Group total, (Se+Te+Bi), *Max*	3 ppm	3 ppm	-
Antimony, *Max*	4 ppm	4 ppm	50 ppm
Arsenic, *Max*	5 ppm	5 ppm	10 ppm
Tin, *Max*	5 ppm	5 ppm	150 ppm
Lead, *Max*	5 ppm	5 ppm	150-450 ppm
Iron, *Max*	5 ppm	5 ppm	20 ppm
Nickel, *Max*	10 ppm	10 ppm	150 ppm
Sulphur, *Max*	15 ppm	15 ppm	20 ppm
Silver, *Max*	25 ppm	25 ppm	150 ppm
Oxygen	150-450 ppm	10 ppm (max)	0.040
Maximum allowable total impurities	65 ppm (not including oxygen)	65 ppm (not including oxygen)	750 ppm (not including oxygen)
			ASTM B49

5.2 The chemical composition shall be determined either by the method specified in IS 440 or any other established instrumental/chemical method. In case of dispute the procedure specified in IS 440 for chemical analysis, shall be the referee method. However, when the method is not given in 1S 440, the referee method shall be as agreed to between the purchaser and the manufacturer. The method for determination of oxygen shall be as agreed to between the supplier and the purchaser.

5.3 Alternatively the test method specified in relevant ISO/IEC Standard maybe used.

6 DIMENSION AND TOLERANCES

6.1 Dimension

The diameter of the wire rod that can be supplied under this specification is over 6 mm and up to and including 35 mm. The diameter shall be determined by ratchet thimble micrometer or suitable measuring device with least count of at least 0.01 mm.

The diameter is to be measured after discarding approximately 2.5 m length from the end of the coil.

6.2 Tolerances

6.2.1 The wire rod shall have nominal diameter from 6 mm to 35 mm within the permissible variation as given in Table 2. Three measurements at 60º angular displacement shall be made around circumference at two places 4 meters apart. An average of six readings shall be considered as the diameter of the wire rod. No individual reading should exceed the tolerance limit.

Table 2 Tolerance of Diameter
(*Clause* 6.2.1)
(All values in mm)

Diameter		Diameter Tolerance	Maximum Ovality
Over	Up to Including		
(1)	(2)	(3)	(4)
6	9	± 0.38	0.38
9	12.5	± 0.50	0.50
12.5	21	± 0.60	0.60
21	35	± 0.80	0.80

6.2.2 Ovality of the Wire Rod

The measurement shall be carried out in accordance with **6.1**. Measurement shall be done at two places 4 meters apart, and at each point, 4 readings at 45º to each other shall be taken. Ovality shall be measured by obtaining the difference in a pair of readings taken at 90º to each other.

7 FREEDOM FROM SURFACE DEFECTS

7.1 The surface of the wire rod shall be fairly smooth, untarnished, free from inclusions or foreign particles, indentation, twists, entanglements, etc.

7.2 Surface oxide

The oxide on rod surface (surface oxide) shall not be more than 600 Angstrom when determined by Surface Oxide Determinator or any equivalent measuring equipment, working on the principle of electrolytic reduction method. This test shall be performed by reducing the surface oxide(s) to copper in an electrolytic cell containing 0.1 M Na_2CO_3 solution as electrolyte at a current density of 0.30 mA/cm^2. Thus, the current to be applied depends upon the total surface area of the rod immersed in the solution. Accordingly, calculate and apply required current as per the rod diameter and height of the test sample immersed in the electrolyte. Current shall be supplied from a dc power supply.

Take a clean rod as a test sample and make it cathodic with respect to an anode (either a platinum wire or an equivalent inert electrode). Ensure that the sample is straightened and has no physical mark & is free from oil, grease and dust. Each of the oxides found on copper, namely cuprous and cupric, are reduced sequentially to copper at different reduction potentials. When the

reactions between the oxides and hydrogen ions are complete, gaseous hydrogen is evolved from the surface of the copper rod sample and may be seen visually.

Surface oxide shall be calculated as follows:-

$$T = I \times t \times M /(S \times d \times F \times n)$$

where,
T = Oxide thickness, in cm;
I = Current, A
t = Time of reaction, in sec
M = Molecular weight of oxide, gm
S = Surface area of the immersed sample, cm^2
d = Oxide density, g/cm^3 (6.0 g/cm^3 for Cu_2O and 6.4 g/cm^3 for CuO)
F = Faraday constant, 96500 C; and
n = Hydrogen equivalent = 2

8 MECHANICAL PROPERTIES

8.1 Tensile Test

When tested in accordance with IS 1608 (Part 1) for tensile strength and elongation, the material shall meet the requirements as given in Table 3.

Table 3 Tensile Properties
(*Clause* 8.1)

Diameter (mm)		Tensile Strength (MPa, *Min*)			Elongation on Gauge Length of 250 mm, percent, *Min*		
Over	Up to and including	ETP	OFC	FRHC	ETP	OFC	FRHC
(1)	(2)	(3)	(4)		(5)	(6)	
6	9	210	170	210	35	35	35
9	12.5	205	165	205	40	38	40
12.5	21	200	160	200	42	40	40
21	35	195	155	195	44	40	40

NOTES :
1. 1 MPa = 1 MN/m^2 = 1 N/mm^2 = 0.102 kgf/mm^2
2. Gauge length 250 mm and Speed of the machine should not be more than 300 mm/ min.

8.2 Surface Test (Compression Test)

This test shall be carried out if requested by the purchaser. A sample of wire rod, from a rolled coil, of length twice the diameter of the wire rod is to be cut and then hammered till its length becomes half of the original length. The curved surface *for example*, periphery after test, shall not show any crack or defect on the surface when viewed with normal vision. For OFC rod, test

sample to be annealed (at 275 ± 1 deg C for 15 minutes at constant temperature and quenched immediately into water at ambient temperature).

9 ELECTRICAL PROPERTIES

9.1 Copper wire rods shall have electrical properties at 20^0C as mentioned in Table 4.

Table 4 Electrical Properties
(*Clause* 9.1)

Copper at 20^0C	Volume resistivity, μΩ.m *Max.*	Mass Resistivity, Ω g/m^2 *Max.*	Electrical conductivity, % IACS *Min.*
(1)	(2)	(3)	(4)
OFC	0.01707	0.15176	101
ETP	0.01724	0.15328	100
FRHC	0.01724	0.15328	100

9.2 Resistivity Test

9.2.1 Resistance measurements may be determined by direct measurement on specimens of the rod after cleaning, but without further processing and annealing. Resistance shall be measured with the instrument that has a resistance measurement capability of ± 0.15 percent accuracy. The length of sample selected for the test shall be sufficient to give the accuracy required and shall be suitable for the method of testing employed. In the case of dispute refer to **9.2.2.**

9.2.1.1 Testing of copper wire rod for volume resistivity requirements shall be done as per IS 3635.

9.2.1.2 Mass Resistivity

For mass resistivity measure resistance of the test sample as per IS 3635. Measure the weight of the test sample and calculate mass resistivity as follows:

Mass resistivity (Y cal) = $(W/ L_1 L_2) \times R_T$ Ohm.gms/m^2

W = weight of the test specimen, in gms;
L_1 = Length of the test specimen, in m;
L_2 = Length of the test specimen between potential points, in m;
R_T = Measured resistance at 20°C, in Ω;

$R_{T=}$ $R_t / [1+0.00393(t-20)]$;

R_t = Resistance as measured at temperature t;
t = temperature at which measurement is made.

9.2.1.3 Electrical conductivity is calculated as follows:

% Electrical Conductivity = Std. mass resistivity (Y Std) × 100 = ... % IACS

$$\frac{\text{Standard mass resistivity (Y std)}}{\text{Calculated mass resistivity (Y cal)}}$$

where, Standard mass resistivity (Y std) of copper at 20°C = 0.15328.

9.2.2 In case of dispute, samples for the resistivity test shall be prepared in the form of wire of approximately 2.0 mm diameter, which shall be annealed at a temperature of 500 ± 10°C for not less than 30 min.

10 SAMPLING AND CRITERIA FOR CONFORMITY

10.1 Unless otherwise agreed between the purchaser and the supplier, following sampling plan (as given in Table 5) to be followed:

Table 5 Sampling Plan for Test
(*Clause* 10.1)

Test	Sampling plan Weight of Copper Wire Rod (Metric Ton) to be considered as one lot	
	ETP	OFC, FRHC
Oxygen	35	30
Surface Oxide	35	30
Chemical	300	100
Electrical	300	100
Mechanical	300	100

10.1.1 In any consignment, all the coils of wire rod of same size, manufactured from same raw material under similar condition of production at the same place, shall be grouped together to constitute a lot.

10.1.2 Each coil of wire rod shall be examined for freedom from defects and for tolerance on diameter. Any coil found defective shall be rejected.

10.1.3 If the test result of chemical analysis as obtained for each of the elements satisfy the corresponding requirements, the coil shall be considered as conforming to the chemical composition requirements of this specification.

10.1.4 The coil shall be considered as conforming to the requirements of 'Test' parameters if the test results of samples satisfy the corresponding requirements.

10.2 Retest

10.2.1 If the test result of chemical analysis fails to satisfy the requirement for any element, two more tests for that element, shall be done on the same sample in order to confirm that the analysis has been done properly. If both the test results satisfy the relevant requirements, the coil shall be considered as conforming to the chemical composition requirements of this specification, otherwise not.

10.2.2 If the test result on any sample fail in the requirements of any of the chemical, mechanical or electrical properties, two more tests shall be done on samples taken from the same coil. If both

the test results satisfy the relevant requirements, the coil shall be considered as conforming to the corresponding requirements of this specification, otherwise not.

11 PACKING

11.1 The material shall be packed in coils. The weight of each coil shall be as agreed upon between the manufacturer and the purchaser.

11.2 The coils shall be wrapped with suitable wrapping sheet. The quality and application of the wrapping material shall be adequate to protect the wire rod coils from damage, rain, incidental to normal handling and shipment.

12 TEST CERTIFICATE

The manufacturer/ supplier shall provide test certificate for each consignment giving information like coil number, dimension, freedom from surface defects, surface oxide layer thickness, chemical composition, tensile test and conductivity test results. Any additional requirement by the buyer shall be provided by the manufacturer as per the agreed terms and conditions.

13 MARKING

13.1 Suitable tags with marking made on them to show the grade of material, the name of the manufacturer, size and type of the wire rod, coil number and coil weight shall be attached with each coil of the material.

13.2 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act, 2016* and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.