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**Continuously Transposed Conductor (CTC) Copper Winding Wires**

ICS 29.060.10

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भारतीय मानक ब्यूरो

BUREAU OF INDIAN STANDARDS

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Winding Wire Sectional Committee, ETD 33

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Winding Wires Sectional Committee and has been approved by the Electrotechnical Division Council.

This standard has been prepared to cover the requirements of continuously transposed conductor (CTC) copper winding wires which are growing in popularity in India due to their ability to reduce eddy current loss. They are increasingly being used in transformer winding of the power and locomotive transformers. Tests to ascertain conformity in this regard have also been stipulated in the standard.

Continuously Transposed Conductor (CTC) copper winding wires are a specialized type of conductor used primarily in power transformers, consisting of multiple thin, rectangular copper strips stacked and twisted together along their length. This continuous transposition ensures each strip occupies every position within the conductor cross-section, offering several advantages:

1. Reduced eddy current losses — Transposition minimizes circulating currents induced by alternating magnetic fields, leading to lower energy losses and improved transformer efficiency;
2. Even current distribution — Each strip carries its share of current, preventing hot spots and improving conductor utilization;
3. Enhanced heat dissipation — The arrangement promotes better heat transfer, aiding cooling efficiency and potentially reducing transformer size;
4. Increased mechanical strength — CTCs, especially self-bonding types, offer improved mechanical strength to withstand operational stresses;
5. Easier winding — They're generally easier to wind than traditional conductors, saving production time and cost; and
6. Space efficiency — Their compact structure and thin insulation enable more efficient use of space within the transformer.

The composition of the Committee responsible for the formulation of this standard is given in Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

CONTINUOUSLY TRANSPOSED CONDUCTORS (CTC) COPPER WINDING WIRES

**1 SCOPE**

**1.1** This standard specifies the requirement of the continuously transposed conductors with type, product variety structure, technical requirements, acceptance rules and packaging marking.

**1.2** Continuously transposed conductors are generally used in the electrical windings of a variety of transformers including oil-immersed, dry-type, and reactors etc.

**2 REFERENCES**

The standards listed in Annex A 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 editions of the standards.

**3 TERMINOLOGY**

For the purpose of this standardthe following definitions, in addition to those given shall comply.

**3.1 Bonding Layer** — Material (generally epoxy or any other bond coat) that is deposited on an enamelled wire in which has the specific function of bonding wire together.

**3.2 Butt Lapping** — It refers to the lapping form that the edges of the adjacent paper lap of the same lapping layer are lapped edge to edge with overlap up to 0.5 mm or gap up to 2 mm.

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Fig. 1 Butt Lapping

**3.3 Class** ­­­— Thermal performance of a wire expressed by the temperature index and the heat shock temperature.

**3.4 Coating** — Material which is deposited on the conductor by a suitable means and then dried and/or cured.

**3.5 Coincidence of Butt Gaps** — It refers to the coincidence of the adjacent lapping layer gaps during open lapping. This shall not be applicable in case of change of taping head from one layer to another.

**3.6 Conductor** — Bare metal after removal of insulation.

**3.7 Conductor/Material Code** — The following are relevant:

1. Continuously transposed conductor (CTC);
2. 0 - annealed-copper conductor; and
3. CPR - Controlled proof-stress copper conductor (recommended for CTC).

**3.8 Continuously Transposed Conductor** — It refers to the winding conductors formed by two rows of a certain number of enamelled copper rectangular wires mutually contacted at wide surfaces, transposed in same direction along the narrow surface of the top and bottom of the two rows of enamelled rectangular wires, and lapped continuously by electrical insulated paper, netting tape etc.

**3.9 Controlled Proof-Stress Copper Conductor** — It refers to the copper conductors for which the specified non-proportional elongation strength Rp0.2 is between (80 to 220) N/mm2.

**3.10 Enamelled Rectangular Wire** — Rectangular wire coated with an insulation of cured resin such as the following:

1. 105/120 class, polyvinyl acetal (PVA) enamelled copper rectangular wire;
2. 180 class, polyester imide enamel enamelled (PEI) copper rectangular wire;
3. 200 class, polyester imide over coated with polyamide-imide enamelled (PEI + PAI) copper rectangular wire;
4. 220 class, polyamide-imide enamelled (PAI) copper rectangular wire and
5. 105/120/180/200 class, enamelled copper rectangular wire overcoated with epoxy or another suitable bond coat.

**3.11 Enamelled Wire** — Wire coated with insulation of cured resins (for example, PVA, PEI and PAI).

**3.12 Factory Acceptance Test** — Tests carried out on samples taken from a lot for the purpose of factory acceptance of the lot before dispatch in presence of purchaser or third-party inspection agency as agreed between CTC manufacturer and purchaser.

**3.13 Half Overlapping** — It refers to the lapping form with the width of overlapping in 40 percent to 60 percent .



Fig. 2 Half Overlapping

**3.14 Insulation Paper Tape and Binding Rope (Tape) Material** — Referred to IS 9335 (Part 3/Sec 5)/IEC 60554-3-5 Specification for cellulosic papers for electrical purposes.

1. *Special papers* —General purpose electrical grade kraft paper winding wire and conductor wrapping.

NOTE — It is referred to all the temperature class;

1. *Crepe paper* — As per relevant standards IS 9335 (Part 3/Sec 3)/IEC 60554-3-3 and as per agreement between CTC manufacturer and purchaser; and
2. *Netting tape* — As per agreement between CTC manufacturer and purchaser.

**3.15 Interlocked Lapping** — It refers to the lapping form that the two layers of paper tapes which are mutually overlapped (40 to 60) percent are subjected to half overlapping along the same direction.



Fig. 3 Interlocked Lapping

**3.16 One Third Overlapping** — It refers to the lapping form with the width of overlapping in 25 percent to 35 percent.



Fig. 4 One Third Overlapping

**3.17 Open Lapping (Gap Lapping)** — It refers to the lapping form that the edges of the adjacent paper lap of the same lapping layer are not mutually overlapped but have a gap up to 2 mm.

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Fig. 5 Gap Lapping

**3.18 Optional Tests** — Special tests to be carried out, when required, by agreement between CTC manufacturer and purchaser.

**3.19 Overlapping** — It refers to the lapping form that the edges of the adjacent paper tape of the same lapping layer are mutually overlapped.

**3.20 Routine Test** — Tests performed by the CTC manufacturer on the CTC, during manufacturing of the given product to demonstrate integrity and quality control.

**3.21 Staggering in Lapping** — It refers to the distance between the edges of the adjacent paper tapes. The distance shall be approx 25 percent to 40 percent of the width of the tape. This range shall not be applicable in case of change of taping head from one layer to another.



Fig. 6 Staggering In Lapping

**3.22 Symbols** — The dimensional symbols of the continuously transposed conductor are as shown in Fig. 7.

where

|  |  |  |
| --- | --- | --- |
| A*Max* | : | Maximum dimension of the narrow edge (thickness), in mm, of enamelled rectangular wire; |
| a | : | Nominal dimension of the narrow edge (thickness), in mm, of bare rectangular wire; |
| B | : | Wide edge nominal dimension (width), in mm, of enamelled rectangular wire;  |
| B*Max* | : | Maximum dimension of the wide edge (width), in mm, of enamelled rectangular wire; |
| b | : | Nominal dimension of the wide edge (width), in mm, of bare rectangular wire; |
| Ck | : | Inter leaving/inter column paper width, in mm; |
| Cz  | : | Inter leaving/inter column paper thickness, in mm; |
| H2 | : | Nominal height, in mm, of continuously transposed conductor; |
| H2*Max*  | : | Maximum height, in mm, of continuously transposed conductor; |
| Kh | : | Tolerance in height, in mm, of continuously transposed conductor; |
| Kw | : | Tolerance in width of continuously transposed conductor, in mm; |
| k1 | : | Height correction factor of continuously transposed conductor. |
| n | : | Number of transposed enamelled rectangular wire; |
| S | : | Transposition pitch; and |
| Tape | : | Narrow edge nominal dimension (thickness), in mm, of enamelled rectangular wire; |
| W2 | : | Nominal width, in mm, of continuously transposed conductor; |
| W2*Max* | : | Maximum width, in mm, of continuously transposed conductor; |
| Δ | : | Nominal thickness, in mm, of paper insulation layer (both sides) of continuously transposed conductor (or bundle and paper thickness); |
| δ | : | Enamel film thickness (both sides), in mm, of enamelled rectangular wire; |
| δn | : | Self-adhesive epoxy layer thickness (both sides), in mm, of enamelled rectangular wire; |
| ε | : | Allowable tolerance, in mm, of bare rectangular wire conductor dimension; |
|  |  |  |



Fig.7 Dimensional Symbols Of The Continuously Transposed Conductor

**3.23 Transposed Core** — It refers to the combination of the enamelled rectangular wire after transposition.

**3.24 Transposition Pitch** — It refers to the axial length of a certain enamelled rectangular wire in the continuously transposed conductor after subjected to a complete transposition cycle divided by the number of enamelled rectangular wires of the continuously transposed conductor, that is, the axial length between two adjacent transpositions.

**3.25 Type Test** — In case any type tests are required, the same may be as per mutual agreement between the CTC manufacturer and purchaser.

**3.26 Width of Overlapping** — It refers to the width of the paper tape edge overlapped portion during overlapping.

**3.27 Winding Wire** — Wire used for construction/winding of a coil in electrical/electronic components that generate the component’s electro-magnetic field.

**4 TECHNICAL REQUIREMENTS**

**4.1** **Copper for Manufacturing CTC Conductor**

Copper shall comply as per IS 191, IS 12444.

**4.2** **Enamelled Rectangular Wire for CTC Copper Winding Wires**

**4.2.1** Copper conductor specified non-proportional extension strength (proof strength). Rp0.2 of the semi-hard enamelled rectangular wire conductor is divided in Table 1.

**Table 1 Proof Strength**

(*Clause* 4.2.1)

|  |
| --- |
| **Proof Strength Rp0.2** |
| **Sl No.** | **Type** | **Nominal** | **Tolerance** |
| (1) | (2) | (3) | (4) |
|  | Soft/Annealed | 80 | - 0/+ 40 |
|  | Semi-hard-1 | 120 | - 0/+ 30 |
|  | Semi-hard-2 | 150 | - 0/+ 30 |
|  | Semi-hard-3 | 180 | - 0/+ 40 |
|  | Semi-hard-4 | 220 | - 0/+ 44 |
| NOTE — Other than the above, if any nominal values are provided, a tolerance of 30 MPa or 20 percent of nominal whichever is higher shall apply, or higher if applicable, as agreed between CTC manufacturer and purchaser. |

The recommended dimensions in millimetres (width × thickness) for the enamelled rectangular wire of the CTC copper winding wires are:

1. Width from 3.00 mm up to and including 12.00 mm;
2. Thickness from 1.20 mm up to and including 2.50 mm; and
3. Ratio of width to thickness shall be greater than or equal to 2.5 : 1 and shall not exceed 7 : 1.

**4.2.2** Dimensions tolerance in enamelled rectangular wire conductor is given in Table 2.

**Table 2 Tolerance**

(*Clause* 4.2.2)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Nominal Width or Thickness of the Conductor (mm)** | **Tolerance ± mm** |
| Over | Up to and including |
| (1) | (2) | (3) | (4) |
|  | - | 3.15 | 0.030 |
|  | 3.15 | 6.30 | 0.050 |
|  | 6.30 | 12.50 | 0.070 |

**4.2.3** *Corner Radii*

The arc shall merge smoothly into the flat surfaces of the conductor and the strip shall be free from sharp, rough and projecting edges. The conductor shall have radius corner complying with below Table 3. The specified radii shall be maintained within ± 25 percent.

**Table 3 Corner Radii**

(*Clause* 4.2.3)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Nominal Thickness of Conductor, in mm** | **Corner Radius, in mm** |
|  | Over | Up to and including |
| (1) | (2) | (3) | (4) |
|  | - | 1.00 | 0.5 × Nominal thickness |
|  | 1.00 | 1.60 | 0.50 \* |
|  | 1.60 | 2.24 | 0.65 \*\* |
|  | 2.24 | 3.55 | 0.80 |
| NOTES **1** If agreed between CTC manufacturer and purchase. The corner radii for the wire with a width greater than 4.8 mm may be.**2** \* 0.5 mm × t, where t is the nominal thickness of the conductor.**3** \*\* 0.80 mm. |

**4.2.4** *Increase in Dimensions Due to the Enamel Insulation*

The increase in width or thickness due to the enamel insulation shall be as given in Table 3a.

**Table 3a Increase in Dimensions Due to the Enamel Insulation**

(*Clause* 4.2.4)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Grade** | **Increase in Dimensions, mm** |
| Minimum | Nominal | Maximum |
| (1) | (2) | (3) | (4) | (5) |
|  | 1 | 0.06 | 0.085 | 0.11 |
|  | 2 | 0.12 | 0.145 | 0.17 |

**4.2.5** *Increase in Dimensions Over Enamel Insulation Wire with Bonding Layer Epoxy*

Bonding layer epoxy film thickness for grade 1 or 2 Enamelled wire which is determined by the CTC Manufacturer and the purchaser during ordering. The recommended self-adhesive layer of epoxy film thickness and tolerance of 0.040 mm +/- 0.010 mm. In case of any other self-adhesive layer, the thickness and tolerance shall be mutually agreed between CTC Manufacturer and purchaser.

**4.3** **Transposed Core Structure**

**4.3.1** *Number of Transposed Core*

The number of transposed core is as follows:

1. Odd column: 5 to 83.
2. Even column: in consideration.

**4.3.2** *Transposed Core Dimension Range*

The dimension range of the transposed core is as follows:

1. W2 - Δ ≤ 26 mm;
2. H2 - Δ ≤ 76 mm; and
3. Height to width ratio H/W ≤ 6.

When it is needed to exceed the above range, it shall be as specified by the CTC manufacturer and the purchaser through negotiation.

**4.3.3** *Inter leaving/Inter Column Paper*

Inter leaving/inter column paper nominal thickness Cz. As for the inter leaving/inter column paperfor the acetal enamelled continuously transposed conductor, it is recommended to use the nominal thickness 0.10 mm special paper for cellulosic papers for electrical purposes insulation paper (press paper or kraft paper).

As for the Inter leaving/inter column paper for the 180 class polyester imide enamelled continuously transposed conductor and the 200 class polyester imide/polyamide imide composite enamelled continuously transposed conductor, it is recommended to use the nominal thickness 0.05 mm aromatic polyamide paper. It may also use the inter leaving/inter column paperof other types and thicknesses as negotiated by the CTC manufacturer and the purchaser.

**4.3.4** *Inter Leaving/Inter Column Paper Width Ck*

The inter leaving/inter column paper widthCk is calculated using the below equation, taking the even integer value downwards and with the deviation of - 1 mm.

$$C\_{k}= \frac{1}{2}\left(n-3\right)A$$

When Ck ≥ 10 mm, it shall add one layer of Inter leaving/inter column paperbetween the two rows of enamelled rectangular wires; when Ck < 10 mm, it may not be necessary to add Inter leaving/inter column paper.

**4.3.5** *Transposition Pitch S*

The transposition pitch S shall not exceed π/n times the minimum diameter D*Min* of the coil winding.

$$S\leq π\frac{D\_{min}}{n}$$

Generally: 6b ≤ S ≤ 18b.

The user (CTC manufacturer) shall propose the S value and the allowable deviation when ordering.

**4.4** **Insulation Paper**

Insulation paper for paper insulated continuously transposed conductors has the following types:

1. Special papers, general purpose electrical grade kraft paper shall comply with the mutual agreement of CTC manufacturer supplier and purchaser with relevant reference standard IS 9335 (Part 3/Sec 5)/IEC 60554-3-5;
2. The specifications, thickness and technical requirements for special papers, general purpose electrical grade kraft paper shall comply with the mutual agreement of CTC manufacturer and purchaser with relevant standard reference;
3. The technical requirements for other high density crepe paper shall be specified by the CTC manufacturer and the purchaser through negotiation with relevant reference standard IS 9335-3-3/IEC 60554-3-3 and
4. Other insulation paper as agreed by the CTC manufacturer and the purchaser.

**4.5** **Binding Rope or Tape**

The technical requirements for netting tape shall be specified by the CTC manufacturer and the purchaser through negotiation.

**4.6** **Lapping of Insulation Layer**

The nominal thickness and allowable tolerance of the paper insulation layer of the continuously transposed conductor shall comply with the requirements of Table 4. If the dimension of the continuously transposed conductor is within the specified range, it is allowed for the insulation thickness to exceed the values as specified in Table 4.

**Table 4 Lapping of Insulation Layer**

(*Clause* 4.6)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Increase in Diameters Due to Lapping Insulation Layer (Paper Covering)** | **Allowable Tolerance in %** |
|  | Over | Up to and Including |
| (1) | (2) | (3) | (4) |
|  | - | 0.50 | - 10.0/+ 0 |
|  | 0.50 | 1.25 | - 7.5/+ 0 |
|  | 1.25 | - | - 5.0/+ 0 |

The paper insulation layer of the continuously transposed conductor shall be composed of three or more than three layers of paper tape through lapping, and the structural composition and lapping method of the paper tape are generally determined by the manufacturer. For example, the insulation paper layer of the paper-insulated acetal enamelled continuously transposed conductor has the following structures:

1. All the insulation paper is electrical grade insulation paper;
2. The innermost layer or the outermost layer and the middle layer insulation paper grade shall be agreed between purchaser and CTC manufacturer and
3. When users make other requests for paper varieties, the number of lapping layers and the thickness of each layer, it is allowed for the CTC manufacturer and the purchaser to determine through negotiation the insulation layer thickness deviation and the maximum dimension.

The paper tape shall be of appropriate density and evenly and smoothly lapped around the transposed core and the paper tape shall be free from such defects as missing layer, wrinkles or cracking.

For paperless binding type continuously transposed conductor, the CTC manufacturer and the purchaser shall define the protection paper thickness and its location.

Paper lapping method can be as per **3.2**, **3.13**, **3.15**, **3.16**, **3.17**, **3.21**, and **3.26**.

Generally, all lapping layers will be in same direction. In case of specific requirement, lapping direction may be changed after group of maximum 8 layers. While lapping staggering within the group to be maintained as per **3.5**.

It is allowed for paper tape joint or repairing, but the joints shall be staggered from each other.

**4.7** **Maximum Dimensions of Continuously Transposed Conductors**

The maximum dimensions of continuously transposed conductors H2max and W2max shall not be greater than the value as calculated from the below equations

Nominal CTC covered height H2 = ½ k1 (n+1) (a + δ + δn) + Δ

 = ½ k1 (n +1) A + Δ --- (1)

Nominal CTC covered width W2 = 2(b + δ+ δn) + Δ+ Cz

 = 2 (B + Δ)+ Cz ---(2)

where

Kw, Kh and k1 are depending on the structure of the transposed core, including semi-hard wires, various papers and other factors, with the specific value as specified in the product standards.

k1 shall conform to the provisions of Table 5; Kw shall conform to the provisions of Table 6.

**Table 5 Factor k1**

(*Clause* 4.7)

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl No.** | **Conductor Thickness** | **Proof Stress < 220 MPa** | **Proof Stress > 220 MPa** |
| s/b > 7 | s/b < 7 | s/b > 7 | s/b < 7 |
| (1) | (2) | (3) | (4) | (5) | (6) |
|  | a < 1.60 | 1.01 | 1.02 | 1.01 | 1.02 |
|  | 1.60 < a < 1.90 | 1.02 | 1.025 | 1.02 | 1.025 |
|  | 1.90 < a < 2.20 |  1.025 | 1.035 | 1.03 | 1.035 |
|  | a > 2.20 | 1.03 | 1.035 | 1.03 | 1.035 |

Factor k1: Table 5.

Kh and Kw as per Table 6.

**Table 6 Factor Kh and Kw**

(*Clause* 4.7)

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl No.** | **Number of Conductors in CTC Stack** | **Tolerance on Radial Height (mm)** | **Tolerance on Axial Width****(mm)** |
| (1) | (2) | (3) | (4) |
|  | > 5 to < 21 | + 0.30 /- 0.30 | + 0.10 / - 0.15 |
|  | > 23 to < 37 | + 0.70 /- 0.30 | + 0.15 / - 0.10 |
|  | > 39 to < 55 | + 0.90 /- 0.30 | + 0.20 / - 0.10 |
|  | > 57 | + 1.20 /- 0.30 | + 0.20 / - 0.10 |

In case of specific designs which are critical to produce, the CTC manufacturer may propose higher tolerances which can be mutually agreed with the customer.

When the maximum dimension of the continuously transposed conductor does not exceed H2*Max* and W2*Max*, the positive tolerance of the insulation thickness is allowed to exceed the requirements of~~.~~ enamel, epoxy and paper insulation mention in **4.2.4**, **4.2.5** and **4.7**.

**4.8** **Welding**

It is allowed to weld the enamelled rectangular wires in the continuously transposed conductor, and the welding points shall be solid and reliable. The distance between the welding points of the two adjacent enamelled rectangular wires shall be not less than 500 mm. The weld shall be covered with heat-resistant self-adhesive electrical insulation tape (polyester or polyamide tape) compatible with transformer oil. Alternatively, or as an additional insulation based on customer specific need, one layer of 0.075 mm of crepe paper can also be applied with overlap of 40 percent to 60 percent width of the paper. The welding can be a butt weld or overlap weld. The dimension of weld should not be more than 1.5 times of ‘a’ and ‘b’ as defined in **3.22** Symbols above. Welds shall be so clearly identified as not effect onto the performance. If the user needs products without welding, it shall be mutually agreed between CTC manufacturer and purchaser at the time of ordering the CTC.

**4.9 Bond Strength**

1. The thermal bond strength of the enamelled rectangular wire in the self-adhesive continuously transposed conductors shall not be less than 7 N/mm² at room temperature.
2. The self-adhesive enamelled continuously transposed conductors shall, after thermal bonding, be able to withstand the specified bending test, with the bending force and bending deformation under consideration.

**4.10** **Delivery Length**

Delivery shall be made using the delivery wire coil and delivery length as agreed between the CTC manufacturer and the purchaser, and the length error shall not exceed the followings unless otherwise the user has special requirements which need to be agreed between the CTC manufacturer and the purchaser:

1. + 0.5 percent if the delivery length ≥ 400 m; and
2. + 1.0 percent if the delivery length < 400 m.

Nominal cross-sectional areas (informative only) for preferred and intermediate sizes of rectangular copper bare conductors, from which the user may select intermediate sizes only for technical reasons is given in Annex B.

**5 TEST METHODS**

**5.1** **General**

Unless otherwise specified, all tests shall be conducted at the temperature of 15 °C to 40 °C and the relative humidity of 30 percent to 75 percent. Before measurement, the specimen shall be pre-conditioned under these atmospheric conditions for a sufficient period to make the sample reach stable state.

When the tested sample is removed from the package, it shall not be subjected to tension or unnecessary bending. Prior to each test, it shall remove sufficient sample to ensure that the sample under test has no damage.

**5.2** **Dimensional Measurements**

**5.2.1** *Continuously Transposed Conductor Insulation Thickness Measurement*

Take a sample with a length of not less than 100 mm; use a sharp blade to cut the insulation layer of the sample, remove the transposed core under the conditions of not affecting the inter-layer mutual positions of the insulation layers, press the insulation sleeve flat, use the measurement tool of the least count shall not be more than 0.01 mm, measurement pressure of (8 to 14) N, and measurement rod and measurement seat diameter of (5 to 8) mm to measure the insulation layer thickness Δ; measure three points, and take the average value as the measurement result.

**5.2.2** *Continuously Transposed Conductor Dimension Measurement*

Take a straight sample of length about 300 mm to 400 mm use a suitable instrument for measurement, having precision of at least 0.02 mm, measurement pressure of about 100 N/cm2, and measurement range of (0 to 300) mm to measure at least three points and take the average value as the measurement result.

**5.2.3** *Transposition Pitch Measurement*

From one end of a whole coil of continuously transposed conductor, remove the insulation layer of sufficient length; use the steel ruler of a precision 1 mm to continuously measure five transposition pitches; and take the average value, accurate to 1 mm.

**5.2.4** Measurement of width of open (gap) lapping, width of overlapping and lapping pitch.

Take a sample of about 500 mm length; use the steel ruler of a precision not less than 0.5 mm to directly measure the width of gap lapping, width of overlapping, and lapping pitch, one measurement at each layer, accurate to 1 mm.

**5.3** **Electrical Resistance**

The copper rod being used shall comply with at least one of IS 12444 , IS 2378 or ISO 1190-1.

Resistivity of a material is the resistance of a wire of that material of unit length and unit cross- sectional area. The standard value of resistivity of high conductivity annealed copper wire which shall be used for calculation is to be considered as 0.017 24 Ω.mm2/m at 20 °C. The measurement accuracy shall be within 0.5 percent. The resistivity of the finished product (CTC) shall be as per Table 7 below:

**Table 7 Electrical Resistance**

(*Clause* 5.3)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl No.** | **Type** | **Nominal Proof Strength** | **Tolerance** | ***Max* Resistivity** (Ω.mm2/m-1) |
| (1) | (2) | (3) | (4) | (5) |
|  | Soft/Annealed | 80 | -0/+40 | 1/58 |
|  | Semi-hard-1 | 120 | -0/+30 | 1/58 |
|  | Semi-hard-2 | 150 | -0/+30 | 1/58 |
|  | Semi-hard-3 | 180 | -0/+40 | 1/57.5 |
|  | Semi-hard-4 | 220 | -0/+44 | 1/56.5 |

**5.4** **Elongation**

The percentage elongation after fracture shall be measured according to **20** of IS 1608 (Part 1)/ISO 6892-1 and IS 13730 (Part 0/Sec 2)/IEC 60317-0-2 proof strength Rp0.2. when the nominal proof strength, plastic extension is not specified or a nominal proof strength, plastic extension of 80 N/mm2 is required. The limit of Table 8 applies otherwise, the measurement is performed for reference only. The test method shall be as per IS 13778 (Part 3)/IEC 60851-3.

**Table 8 Percentage Elongation after Fracture**

(*Clause* 5.4)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Nominal Thickness of the Conductor****mm** | **Minimum Elongation Percent** |
|  | Over | Up to and Including |
| (1) | (2) | (3) | (4) |
|  | ~~-~~ | 2.50 | 30 |

**5.5** **Breakdown Voltage**

When tested at room temperature, at least four of the five specimens tested shall not break down at a voltage less than or equal to that of given Table 9 and fifth shall not break down at less than 50 percent of the valued specified. The test shall be carried out as per IS 13778 (Part 5)/IEC 60851-5.

**Table 9 Breakdown Voltage**

(*Clause* 5.5)

|  |  |  |
| --- | --- | --- |
| **Sl No.** | **Grade** | **Minimum Breakdown Voltage (RMS) V** |
| Without Bonding Layer | With Bonding Layer |
| Room Temperature | Elevated Temperature  | Room Temperature | Elevated Temperature  |
| (1) | (2) | (3) | (4) | (5) | (6) |
|  | 1 | 1 000 | 750 | 1 500 | 1 000 |
|  | 2 | 2 000 | 1 500 | 2 500 | 2 000 |

**5.6 Interstrand Continuity/Short Circuit Test**

Interstrand continuity/short circuit test should be carried out from one strand to all other strands at a minimum voltage of 300 V d.c. and there should not be any short.

**5.7 Flexibility and Adherence**

**5.7.1** *Mandrel Winding Test*

The coating shall not crack after the wire has been bent flat wise and edgewise on a mandrel. The test shall be carried out as stated in IS 13730 (Part 0/Sec 2)/IEC 60317-0-2 and IS 13778 (Part 3)/IEC 60851-3.

**5.7.2** *Adherence Test*

The wire shall be stretched and the distance of loss of adherence shall be measured. The test shall be carried out as stated in IS 13730 (Part 0/Sec 2)/IEC 60317-0-2 and IS 13778 (Part 3)/IEC 60851-3.

**5.8** **Conductor Path (Continuity)**

Use a multimeter to measure each enamelled rectangular wire of the continuously transposed conductors, and there shall be no open circuit.

**5.9** **Bond Strength Test**

The thermal bond strength of the enamelled rectangular wire in the self-adhesive continuously transposed conductors shall not be less than 7 N/mm².

From the continuously transposed conductor sample, take two straight enamelled rectangular wires of length about 110 mm, 5 groups in total; as shown in Fig. 8, overlap the wide edges of the samples, with the bonding length (that is, length of overlapping) of 25 mm and the bonding area pressure of 1 MPa. Place the pressed sample in the oven of (120 ± 3) °C for treatment for 24 h; cool it to room temperature to conduct tensile test, and the tensile speed shall be not greater than 20 mm/min and the bond strength shall be not less than 7 N/mm². Conduct five tests in total and take the average value as the test result.



Fig. 8 Bond Strength Test

**5.10** **Resistance to Solvent**

Using a pencil of hardness ‘H’ and standard solvent, coating shall not be removed. The test shall be carried out as stated in IS 13730 (Part 0/Sec 2)/IEC 60317-0-2 and IS 13778 (Part 4)/IEC 60851-4.

**5.11 Temperature Index**

The test shall be carried out on a rectangular wire in accordance with IS 5825/IEC 60172, unless otherwise agreed between CTC Manufacturer and purchaser.

When required by a purchaser, CTC manufacturer of the enamelled wire shall supply evidence that the wire meets the requirement for the temperature index.

NOTES

**1** The temperature index requirement based on an extrapolated life of 20 000 h related to enamelled wire tested unvarnished and not as part of an insulation system.

**2** Temperature in degree celsius corresponding to the temperature index is not necessarily that at which it is recommended that the wire be operated and this will depend on many factors including the type of equipment involved.

**5.12 Test of Specified Non-Proportional Extension Strength Rp0.2**

It shall follow the provisions of IS 1608 (Part 1)/ISO 6892-1 to conduct the tests.

**6 PACKAGING**

The CTC copper winding wire shall be delivered in packaged coil, the finished products shall be tightly, uniformly and neatly around the wire coil, layers shall be separated by the application of protective paper, and the distance from the outermost layer to the cable coil edge shall be not less than 30 mm.

The wire coil with finished products shall be wrapped by moisture-proof and anti-bump material, and both ends of the continuously transposed conductors shall be fastened to the wire coil.

**7 MARKING**

Each coil of finished product shall have label, indicating:

1. Manufacturer name, trademark or certification mark;
2. Product model, specifications, number, nominal thickness of insulation layer, product dimensions;
3. Customer reference number/job number;
4. Length, in metres;
5. Net weight and gross weight, in kg; and
6. Drum number.

**8 STORAGE**

The finished product shall be stored in a clean, dry, and well-ventilated covered warehouse with a temperature of (15 to 40) °C away from direct sunlight and moisture.

The mechanical properties of this product such as electrical performance and bond strength etc, are related to the surroundings, and all the products shall from the date of exit-factory have a storage period of six months.

**ANNEX A**

(*Clause* 2)
**LIST OF REFERRED STANDARDS**

|  |  |
| --- | --- |
| *IS No.* | *Title* |
| IS 191 : 2007 | Copper — Specification (*fourth revision*) |
| ISO 1190-1:1982 | Copper and copper alloys — Code of designation Part 1: Designation of materials |
| IS 2378:1974 | Code for designation of copper and copper alloys |
| IS 1608 (Part 1) : 2022/ISO 6892-1 : 2019 | Metallic materials — Tensile testing: Part 1 Method of test at room temperature (*fifth revision*) |
| IS 5825 : 2024/IEC 60172 : 2020 | Test procedure for the determination of the temperature index of enamelled and tape wrapped winding wires (*third revision*) |
| IS 9335 (Part 3/Sec 3): 1984/IEC 60554-3-3:1980 | Specification for cellulosic papers for electrical purposes: Part 3 specifications for individual materials, Sec 3 Crepe paper |
| IS 9335 (Part 3/Sec 5): 1985/IEC 60554-3-5:1984 | Specification for cellulosic papers for electrical purposes: Part 3 specifications for individual materials, Sec 5 Special papers |
| IS 12444 : 2020 | Copper wire rods for electrical applications — Specification (*first revision*) |
| IS 13730 (Part 0/ Sec 2) : 2024/ IEC 60317-0-2 : 2020 | Specifications for particular types of winding wires: Part 0 General requirements, Sec 2 Enamelled rectangular copper wire |
| IS 13778 (Part 3) : 2012/IEC 60851-3 : 2009 | Winding wires — Test methods: Part 3 Mechanical properties (*first revision*) |
| IS 13778 (Part 4) : 2018/IEC 60851-4 : 2016 | Winding wires — Test methods: Part 4 Chemical properties (*Second revision*) |
| IS 13778 (Part 5) : 2012/IEC 60851-5 : 2008 | Winding wires — Test methods: Part 5 Electrical properties (*first revision*) |

**ANNEX B**

(*Clause* 4.10)

**NOMINAL CROSS-SECTIONAL AREAS FOR PREFERRED AND INTERMEDIATE SIZES**

**B-1** Table 10 provides nominal cross-sectional areas for preferred and intermediate sizes of rectangular copper bare conductors, from which the user may select intermediate sizes only for technical reasons.

**Table 10 Nominal Cross-Sectional Areas**

| **Sl No.** | **Nominal** **Width** | **Nominal** **Thickness** | **Corner** **Radius** | **Nominal Cross-** **Section Area** |
| --- | --- | --- | --- | --- |
| (mm) | (mm) | (mm) | (mm²) |
| (1) | (2) | (3) | (4) | (5) |
|  | 3.00 | 1.20 | 0.50 | 3.385 |
| 1.25 | 0.50 | 3.535 |
| 1.40 | 0.50 | 3.985 |
| 1.60 | 0.50 | 4.585 |
| 1.80 | 0.65 | 5.037 |
| 2.00 | 0.65 | 5.637 |
|  | 3.15 | 1.20 | 0.50 | 3.565 |
| 1.25 | 0.50 | 3.723 |
| 1.32 | 0.50 | 3.943 |
| 1.40 | 0.50 | 4.195 |
| 1.50 | 0.50 | 4.510 |
| 1.60 | 0.50 | 4.825 |
| 1.70 | 0.65 | 4.992 |
| 1.80 | 0.65 | 5.307 |
| 1.90 | 0.65 | 5.622 |
| 2.00 | 0.65 | 5.937 |
| 2.12 | 0.65 | 6.315 |
| 2.24 | 0.65 | 6.693 |
|  | 3.35 | 1.20 | 0.50 | 3.805 |
| 1.25 | 0.50 | 3.973 |
| 1.40 | 0.50 | 4.475 |
| 1.60 | 0.50 | 5.145 |
| 1.80 | 0.65 | 5.667 |
| 2.00 | 0.65 | 6.337 |
| 2.24 | 0.65 | 7.141 |
|  | 3.55 | 1.20 | 0.50 | 4.045 |
| 1.25 | 0.50 | 4.223 |
| 1.32 | 0.50 | 4.471 |
| 1.40 | 0.50 | 4.755 |
| 1.50 | 0.50 | 5.110 |
| 1.60 | 0.50 | 5.465 |
| 1.70 | 0.65 | 5.672 |
| 1.80 | 0.65 | 6.027 |
| 1.90 | 0.65 | 6.382 |
| 2.00 | 0.65 | 6.737 |
| 2.12 | 0.65 | 7.163 |
| 2.24 | 0.65 | 7.589 |
| 2.36 | 0.80 | 7.828 |
| 2.50 | 0.80 | 8.325 |
|  | 3.75 | 1.20 | 0.50 | 4.285 |
| 1.25 | 0.50 | 4.473 |
| 1.32 | 0.50 | 4.735 |
| 1.40 | 0.50 | 5.035 |
| 1.60 | 0.50 | 5.785 |
| 1.80 | 0.65 | 6.387 |
| 2.00 | 0.65 | 7.137 |
| 2.24 | 0.65 | 8.037 |
| 2.50 | 0.80 | 8.825 |
|  | 4.00 | 1.20 | 0.50 | 4.585 |
| 1.25 | 0.50 | 4.785 |
| 1.32 | 0.50 | 5.065 |
| 1.40 | 0.50 | 5.385 |
| 1.50 | 0.50 | 5.785 |
| 1.60 | 0.50 | 6.185 |
| 1.70 | 0.65 | 6.437 |
| 1.80 | 0.65 | 6.837 |
| 1.90 | 0.65 | 7.237 |
| 2.00 | 0.65 | 7.637 |
| 2.12 | 0.65 | 8.117 |
| 2.24 | 0.65 | 8.597 |
| 2.36 | 0.80 | 8.890 |
| 2.50 | 0.80 | 9.450 |
|  | 4.25 | 1.20 | 0.50 | 4.885 |
| 1.25 | 0.50 | 5.098 |
| 1.40 | 0.50 | 5.735 |
| 1.60 | 0.50 | 6.585 |
| 1.80 | 0.65 | 7.287 |
| 2.00 | 0.65 | 8.137 |
| 2.24 | 0.65 | 9.157 |
| 2.50 | 0.80 | 10.075 |
|  | 4.50 | 1.20 | 0.50 | 5.185 |
| 1.25 | 0.50 |  5.410 |
| 1.32 | 0.50 | 5.725 |
| 1.40 | 0.50 | 6.085 |
| 1.50 | 0.50 | 6.535 |
| 1.60 | 0.50 | 6.985 |
| 1.70 | 0.65 | 7.287 |
| 1.80 | 0.65 | 7.737 |
| 1.90 | 0.65 | 8.187 |
| 2.00 | 0.65 | 8.637 |
| 2.12 | 0.65 | 9.177 |
| 2.24 | 0.65 | 9.717 |
| 2.36 | 0.80 | 10.070 |
| 2.50 | 0.80 | 10.700 |
|  | 4.75 | 1.20 | 0.50 | 5.485 |
| 1.25 | 0.50 | 5.723 |
| 1.32 | 0.50 | 6.055 |
| 1.40 | 0.50 | 6.435 |
| 1.50 | 0.50 | 6.910 |
| 1.60 | 0.50 | 7.385 |
| 1.70 | 0.65 | 7.712 |
| 1.80 | 0.65 | 8.187 |
| 1.90 | 0.65 | 8.662 |
| 2.00 | 0.65 | 9.137 |
| 2.12 | 0.65 | 9.707 |
| 2.24 | 0.65 | 10.277 |
| 2.36 | 0.80 | 10.660 |
| 2.50 | 0.80 | 11.325 |
|  | 5.00 | 1.20 | 0.50 | 5.785 |
| 1.25 | 0.50 | 6.035 |
| 1.32 | 0.50 | 6.385 |
| 1.40 | 0.50 | 6.785 |
| 1.50 | 0.50 | 7.285 |
| 1.60 | 0.50 | 7.785 |
| 1.70 | 0.65 | 8.137 |
| 1.80 | 0.65 | 8.637 |
| 1.90 | 0.65 | 9.137 |
| 2.00 | 0.65 | 9.637 |
| 2.12 | 0.65 | 10.237 |
| 2.24 | 0.65 | 10.837 |
| 2.36 | 0.80 | 11.250 |
| 2.50 | 0.80 | 11.950 |
|  | 5.30 | 1.20 | 0.50 | 6.145 |
| 1.25 | 0.50 | 6.410 |
| 1.32 | 0.50 | 6.781 |
| 1.40 | 0.50 | 7.205 |
| 1.50 | 0.50 | 7.735 |
| 1.60 | 0.50 | 8.265 |
| 1.70 | 0.65 | 8.647 |
| 1.80 | 0.65 | 9.177 |
| 1.90 | 0.65 | 9.707 |
| 2.00 | 0.65 | 10.237 |
| 2.12 | 0.65 | 10.873 |
| 2.24 | 0.65 | 11.509 |
| 2.36 | 0.80 | 11.958 |
| 2.50 | 0.80 | 12.700 |
|  | 5.60 | 1.20 | 0.50 | 6.505 |
| 1.25 | 0.50 | 6.785 |
| 1.32 | 0.50 | 7.177 |
| 1.40 | 0.50 | 7.625 |
| 1.50 | 0.50 | 8.185 |
| 1.60 | 0.50 | 8.745 |
| 1.70 | 0.65 | 9.157 |
| 1.80 | 0.65 | 9.717 |
| 1.90 | 0.65 | 10.277 |
| 2.00 | 0.65 | 10.837 |
| 2.12 | 0.65 | 11.509 |
| 2.24 | 0.65 | 12.181 |
| 2.36 | 0.80 | 12.666 |
| 2.50 | 0.80 | 13.450 |
|  | 6.00 | 1.20 | 0.50 | 6.985 |
| 1.25 | 0.50 | 7.285 |
| 1.32 | 0.50 | 7.705 |
| 1.40 | 0.50 | 8.185 |
|  | 6.00 | 1.50 | 0.50 | 8.785 |
| 1.60 | 0.50 | 9.385 |
| 1.70 | 0.65 | 9.837 |
| 1.80 | 0.65 | 10.437 |
| 1.90 | 0.65 | 11.037 |
| 2.00 | 0.65 | 11.637 |
| 2.12 | 0.65 | 12.357 |
| 2.24 | 0.65 | 13.077 |
| 2.36 | 0.80 | 13.610 |
| 2.50 | 0.80 | 14.450 |
|  | 6.30 | 1.20 | 0.50 | 7.345 |
| 1.25 | 0.50 | 7.660 |
| 1.32 | 0.50 | 8.101 |
| 1.40 | 0.50 | 8.605 |
| 1.50 | 0.50 | 9.235 |
| 1.60 | 0.50 | 9.865 |
| 1.70 | 0.65 | 10.347 |
| 1.80 | 0.65 | 10.977 |
| 1.90 | 0.65 | 11.607 |
| 2.00 | 0.65 | 12.237 |
| 2.12 | 0.65 | 12.993 |
| 2.24 | 0.65 | 13.749 |
| 2.36 | 0.80 | 14.318 |
| 2.50 | 0.80 | 15.200 |
|  | 6.70 | 1.20 | 0.50 | 7.825 |
| 1.25 | 0.50 | 8.160 |
| 1.32 | 0.50 | 8.629 |
| 1.40 | 0.50 | 9.165 |
| 1.50 | 0.50 | 9.835 |
| 1.60 | 0.50 | 10.505 |
| 1.70 | 0.65 | 11.027 |
| 1.80 | 0.65 | 11.697 |
| 1.90 | 0.65 | 12.367 |
| 2.00 | 0.65 | 13.037 |
| 2.12 | 0.65 | 13.841 |
| 2.24 | 0.65 | 14.645 |
| 2.36 | 0.80 | 15.262 |
| 2.50 | 0.80 | 16.200 |
|  | 7.10 | 1.20 | 0.50 | 8.305 |
| 1.25 | 0.50 | 8.660 |
| 1.32 | 0.50 | 9.157 |
| 1.40 | 0.50 | 9.725 |
| 1.50 | 0.50 | 10.435 |
| 1.60 | 0.50 | 11.145 |
| 1.70 | 0.65 | 11.707 |
| 1.80 | 0.65 | 12.417 |
|  | 7.10 | 1.90 | 0.65 | 13.127 |
| 2.00 | 0.65 | 13.837 |
| 2.12 | 0.65 | 14.689 |
| 2.24 | 0.65 | 15.541 |
| 2.36 | 0.80 | 16.206 |
| 2.50 | 0.80 | 17.200 |
|  | 7.50 | 1.20 | 0.50 | 8.785 |
| 1.25 | 0.50 | 9.160 |
| 1.32 | 0.50 | 9.685 |
| 1.40 | 0.50 | 10.285 |
| 1.50 | 0.50 | 11.035 |
| 1.60 | 0.50 | 11.785 |
| 1.70 | 0.65 | 12.387 |
| 1.80 | 0.65 | 13.137 |
| 1.90 | 0.65 | 13.887 |
| 2.00 | 0.65 | 14.637 |
| 2.12 | 0.65 | 15.537 |
| 2.24 | 0.65 | 16.437 |
| 2.36 | 0.80 | 17.150 |
| 2.50 | 0.80 | 18.200 |
|  | 8.00 | 1.20 | 0.50 | 9.385 |
| 1.25 | 0.50 | 9.785 |
| 1.32 | 0.50 | 10.345 |
| 1.40 | 0.50 | 10.985 |
| 1.50 | 0.50 | 11.785 |
| 1.60 | 0.50 | 12.585 |
| 1.70 | 0.65 | 13.237 |
| 1.80 | 0.65 | 14.037 |
| 1.90 | 0.65 | 14.837 |
| 2.00 | 0.65 | 15.637 |
| 2.12 | 0.65 | 16.597 |
| 2.24 | 0.65 | 17.557 |
| 2.36 | 0.80 | 18.330 |
| 2.50 | 0.80 | 19.450 |
|  | 8.50 | 1.20 | 0.50 | 9.985 |
| 1.25 | 0.50 | 10.410 |
| 1.32 | 0.50 | 11.005 |
| 1.40 | 0.50 | 11.685 |
| 1.50 | 0.50 | 12.535 |
| 1.60 | 0.50 | 13.385 |
| 1.70 | 0.65 | 14.087 |
| 1.80 | 0.65 | 14.937 |
| 1.90 | 0.65 | 15.787 |
| 2.00 | 0.65 | 16.637 |
| 2.12 | 0.65 | 17.657 |
| 2.24 | 0.65 | 18.677 |
| 2.36 | 0.80 | 19.510 |
| 2.50 | 0.80 | 20.700 |
|  | 9.00 | 1.20 | 0.50 | 10.585 |
| 1.25 | 0.50 | 11.035 |
| 1.32 | 0.50 | 11.665 |
| 1.40 | 0.50 | 12.385 |
| 1.50 | 0.50 | 13.285 |
| 1.60 | 0.50 | 14.185 |
| 1.70 | 0.65 | 14.937 |
| 1.80 | 0.65 | 15.837 |
| 1.90 | 0.65 | 16.737 |
| 2.00 | 0.65 | 17.637 |
| 2.12 | 0.65 | 18.717 |
| 2.24 | 0.65 | 19.797 |
| 2.36 | 0.80 | 20.690 |
| 2.50 | 0.80 | 21.950 |
|  | 9.50 | 1.20 | 0.50 | 11.185 |
| 1.25 | 0.50 | 11.660 |
| 1.32 | 0.50 | 12.325 |
| 1.40 | 0.50 | 13.085 |
| 1.50 | 0.50 | 14.035 |
| 1.60 | 0.50 | 14.985 |
| 1.70 | 0.65 | 15.787 |
| 1.80 | 0.65 | 16.737 |
| 1.90 | 0.65 | 17.687 |
| 2.00 | 0.65 | 18.637 |
| 2.12 | 0.65 | 19.777 |
| 2.24 | 0.65 | 20.917 |
| 2.36 | 0.80 | 21.870 |
| 2.50 | 0.80 | 23.200 |
|  | 10.00 | 1.25 | 0.50 | 12.285 |
| 1.32 | 0.50 | 12.985 |
| 1.40 | 0.50 | 13.785 |
| 1.50 | 0.50 | 14.785 |
| 1.60 | 0.50 | 15.785 |
| 1.70 | 0.65 | 16.637 |
| 1.80 | 0.65 | 17.637 |
| 1.90 | 0.65 | 18.637 |
| 2.00 | 0.65 | 19.637 |
| 2.12 | 0.65 | 20.837 |
| 2.24 | 0.65 | 22.037 |
| 2.36 | 0.80 | 23.050 |
| 2.50 | 0.80 | 24.450 |
|  | 10.60 | 1.40 | 0.50 | 14.625 |
| 1.50 | 0.50 | 15.685 |
| 1.60 | 0.50 | 16.745 |
| 1.70 | 0.65 | 17.657 |
| 1.80 | 0.65 | 18.717 |
| 1.90 | 0.65 | 19.777 |
| 2.00 | 0.65 | 20.837 |
| 2.12 | 0.65 | 22.109 |
| 2.24 | 0.65 | 23.381 |
| 2.36 | 0.80 | 24.466 |
| 2.50 | 0.80 | 25.950 |
|  | 11.20 | 1.40 | 0.50 | 15.465 |
| 1.50 | 0.50 | 16.585 |
| 1.60 | 0.50 | 17.705 |
| 1.70 | 0.65 | 18.677 |
| 1.80 | 0.65 | 19.797 |
| 1.90 | 0.65 | 20.917 |
| 2.00 | 0.65 | 22.037 |
| 2.12 | 0.65 | 23.381 |
| 2.24 | 0.65 | 24.725 |
| 2.36 | 0.80 | 25.882 |
| 2.50 | 0.80 | 27.450 |
|  | 11.80 | 1.60 | 0.50 | 18.665 |
| 1.70 | 0.65 | 19.697 |
| 1.80 | 0.65 | 20.877 |
| 1.90 | 0.65 | 22.057 |
| 2.00 | 0.65 | 23.237 |
| 2.12 | 0.65 | 24.653 |
| 2.24 | 0.65 | 26.069 |
| 2.36 | 0.80 | 27.298 |
| 2.50 | 0.80 | 28.950 |
|  | 12.00 | 1.60 | 0.50 | 18.985 |
| 1.70 | 0.65 | 20.037 |
| 1.80 | 0.65 | 21.237 |
| 1.90 | 0.65 | 22.437 |
| 2.00 | 0.65 | 23.637 |
| 2.12 | 0.65 | 25.077 |
| 2.24 | 0.65 | 26.517 |
| 2.36 | 0.80 | 27.770 |
| 2.50 | 0.80 | 29.450 |

**ANNEX C**

(*Foreword*)

**COMMITTEE COMPOSITION**

Winding Wire Sectional Committee, ETD 33

| *Organization* | *Representative(s)* |
| --- | --- |
| Bharat Heavy Electricals Limited, New Delhi | Shri Ratnanav Acharya **(*Chairperson*)** |
| Apar Industries Limited, Silvassa | Shri Yogesh KharatShri Siddhartha Sankar Maiti (*Alternate*) |
| BEICO Industries Private Limited, Mumbai | Shri Suhrid Singhvi  |
| Bharat Heavy Electrical Limited, New Delhi | Shri Laxmi Rajam M. |
| Bharat Insulation Company India Private Limited, Thane | Shri Dhiren Mehta  |
| Central Electricity Authority, New Delhi | Shri Abhishek Kumar Shri Faraz (*Alternate*) |
| Central Power Research Institute, Bengaluru | Dr Moumita Naskar  |
| Development Commissioner Micro-Small and Medium Enterprises | Dr S. K. SahooShri S. Dharmaselvan (*Alternate*) |
| Elantas Beck India Limited, New Delhi | Shri Bapu GawadeMiss Rakhee Telkar (*Alternate*) |
| Electrical Research and Development Association, Vadodara | Shri Shailesh PatelShrimati Sheetal Panchal (*Alternate*) |
| Indian Electrical and Electronics Manufacturers Association, New Delhi | Shri Ashutosh VasishtShri Navdeep Singh (*Alternate*) |
| International Copper Association India, Mumbai | Shri K. N. Hemanth KumarShri Jyotish Pande(*Alternate*) |
| Precision Wires India Limited, Mumbai | Shri Milan M. Mehta Shri Nirbhay Mehta (*Alternate*) |
| Siemens Limited, Mumbai | Shri Nagabhushan Bhat Shri Ashish Shere (*Alternate*) |
| Slimlites Electricals Private Limited, Mumbai | Shri Vimal Jalan |
| Southern India Engineering Manufacturers Association, Coimbatore | Shri Keshavarajulu R. G.Shri G. Rajendran (*Alternate*) |
| Steel Authority of India Limited (SAIL), New Delhi | Shri Gulshan Kumar |
| Vidya Wires Private Limited, Anand | Shri Shailesh Rathi  |
| Winding Wires Manufacturers' Association of India, Greater Noida | Shri Sudhir AgarwalShri Anant Loya (*Alternate*) |
| BIS Directorate General | Shri Asit Kumar Maharana Scientist ‘E’/ Director and Head (Electrotechnical) [Representing Director General (*Ex-officio*)] |

*Member Secretary*

Jatin Tiwari

Scientist ‘C’/Deputy Director

(Electrotechnical), BIS