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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION
FOR
Hard Drawn Stranded Copper Conductor

Issued by :-

RESEARCH DESIGNS & STANDARDS ORGANISATION
MANAK NAGAR, LUCKNOW-226011

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TECHNICAL SPECIFICATION
FOR
Hard Drawn Stranded Copper Conductor

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**TECHNICAL SPECIFICATION
FOR
Hard Drawn Stranded Copper Conductor**

1. SCOPE

This specification covers the requirements and methods of tests for Hard Drawn Stranded Copper Conductor used in 25 kV ac traction. Old Specification no. TI/SPC/OHE/HDCSCF/0030 is re-designated and updated to TI/SPC/OHE/HDCSCF/0031 in-line with TI document no. TI-WI-7.5.1- 1 ver 1.0.

The “Make in India” Policy of Government of India shall be applicable.

2. REFERENCE SPECIFICATIONS

2.1 The following specifications have been referred which shall be applied in the manner altered, amended or supplemented by this specification.

i.	IS: 191-2007 or latest	Specification for copper
ii.	IS: 1778-1980 or latest	Specification for reels and drums for bare wires.
iii.	IS: 440-1964 or latest	Indian standard methods of chemical analysis of copper.
iv.	IS: 1885(Part 32)-2019 or latest	Electro-technical vocabulary – electric cables.
v.	DIN 48200-Part 1-1981 or latest	Wires for stranded conductor, copper wire
vi.	DIN 48201-Part 1-1981 or latest	Stranded conductors Copper Cables
vii.	DIN 48203-Part 1-1984 or latest	Copper wires and copper stranded conductors- Technical delivery conditions.

2.2 In case of any conflict or disparity between the contents of the above specifications and this specification, the later shall prevail.

3. DEVIATIONS

3.1 Any deviation from this specification proposed by the manufacturer intended to improve the performance, utility and efficiency of the conductor, will be given due consideration provided full particulars of the deviation(s) with justification thereof are furnished. In such a case, the manufacturer shall quote according to this specification and deviation(s), if any, proposed by him shall be quoted as an alternative(s).

4. ENVIRONMENTAL CONDITIONS

- 4.1 The conductor shall be suitable for outdoor use in moist tropical climate and in areas subject to heavy rainfall, polluted due to industrial and marine atmosphere and severe lighting. The limiting weather conditions which the conductor has to withstand in service are indicated in TABLE-1

TABLE - 1

ENVIRONMENTAL CONDITIONS

i)	Ambient air temperature	:	0°C to 65°C
ii)	Maximum temperature of metallic object under sun.	:	70°C
iii)	Minimum temperature	:	-10°C
iv)	Maximum relative humidity	:	100%
v)	Annual rainfall	:	Ranging from 1750mm to 6250mm
vi)	Maximum number of thunder storm Days per annum	:	85
vii)	Maximum number of dust storm days Per annum	:	35
viii)	Number of rainy days per annum.	:	120
ix)	Basic wind pressure	:	216 kgf/m ²
x)	Altitude	:	2500m above mean sea level

5. MATERIAL

- 5.1 ~~The wire shall be made out of the ETP copper conforming to IS:191-2007 or latest (pt.V) or out of cathode copper conforming to IS:191-2007 or latest (Pt.IV) or out of continuous cast copper wire rods which shall have the following chemical composition-~~

Element	:	%/ppm
Cu+Ag	:	99.90%Min
Bi+Te+Se	:	<20ppm
Pb	:	<5ppm
Sb	:	<4ppm
As	:	<5ppm
Sn+Ni+Fe+Si+Zn+Co	:	<50ppm
Oxygen	:	<450ppm

~~The wire shall be drawn from Continuous Cast Copper Rods. Continuous Cast Copper Rods shall be manufactured using of LME Grade 'A' copper cathodes. The chemical composition of Continuous Cast Copper Rods shall be as given below. Grade 'A' copper cathode conforming to the chemical composition of Cu-Cath-1 of IS 191: 2007 or latest~~

Element	% ppm
Cu+Ag	99.95% min
Bi	< 2 ppm
Te	< 2 ppm
Se	< 2 ppm
Bi+Te+Se	< 3 ppm
Pb	< 5 ppm
Sb	< 4 ppm
As	< 5 ppm
Fe	< 10 ppm
S	< 15 ppm
Sn+Ni+Fe+Si+Zn+Co	< 20 ppm
Cr+Mn+Sb+Cd+As+P	< 15 ppm
Oxygen	<450 ppm
Total impurities (Excluding oxygen)	<65 ppm

6. FREEDOM FROM DEFECTS

6.1 The wire shall be smooth and free from all imperfections such as spills and spurns.

7. JOINTS IN WIRE BEFORE STRANDING

7.1 The wire shall be drawn in continuous lengths without joints except those made in the drawing stock prior to drawing.

8. JOINTS IN STRANDED CONDUCTORS

8.1 Normally joints in the wires during stranding are not permitted. However, in the event of breakage of a wire during stranding, a joint in any wire shall be so permitted that distance between two joints in the stranded conductor shall not be less than 15m. joints shall be hard soldered orbuttwelded.

NOTE : Joints during stranding can be avoided by judiciously selecting the length of wires in the spools.

8.2 Not more than four joints during stranding in 1525m length of the stranded conductor shall be permitted. Each joint shall be painted to enable the operator to identify the joint easily.

9. STRANDING

9.1 The conductor shall have right hand ordinary concentric lay. The successive layers shall be twisted in opposite directions. The wires in each layer shall be evenly and closely stranded around the underlying wire(s). The lay ratio shall be in accordance with TABLE-4

Note : For right hand lay, the wires conform to the direction of the central part of the letter 'Z' when the conductor is held vertically and viewed from the side. For left hand lay, the wires conform to the central part of the letter 'S' when the conductor is held vertically and viewed from the side.

10. STANDARD RESISTANCE, WEIGHT, AND SIZE OF SOLID WIRE AND STRANDED CONDUCTOR.

10.1 After drawing, the wire shall have the diameter, weight and the resistance as given in TABLE-2. The size, weight and resistance of stranded conductor shall be in accordance with the values given in TABLE-3.

11. TOLERANCE ON DIMENSIONS AND WEIGHT

11.1 Solid Wire : After drawing, the diameter of the wire shall fall within the appropriate maximum and minimum values specified in TABLE-2. The weight shall be in accordance with the values specified in TABLE-2 with a permitted tolerance of $\pm 2\%$. The cross section of any wire after drawing shall not depart from circularity by more than an amount corresponding to 2% on the standard diameter.

11.2 Stranded Conductor: The dimensions of stranded circular conductor shall comply with requirement laid down in TABLE-3. The weight shall be in accordance with the values specified in TABLE-3 with a permitted tolerance of $\pm 2\%$.

12. MECHANICAL PROPERTIES

12.1 The mechanical properties of the solid wire before stranding shall be such that the tensile strength when tested in accordance with Clause No.18.6 shall not be less than the value given in TABLE-2.

12.2 The wire shall comply with the requirements of wrapping test as given in sub Clause No. 18.7.

**TABLE -2
SOLID CIRCULAR COPPER WIRE**

Diameter			Weight/Km	Resistance per Km at 20°C corrected to std. weight		Minimum Breaking load after drawing		Min tensile strength
Std.	Max.	Min.	Std.	Std.	Max.	On Min.dia	On Std. dia	
mm	mm	mm	Kg	Ohm	Ohm	Kgf	Kgf	Kgf/mm ²
2.25	2.272	2.227	35.36	4.461	4.563	179	183	46.0

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2.89	2.92	2.86	58.38	2.668	2.723	277	283	43.0
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TABLE -3
STRANDED COPPER CONDUCTOR

No. of strands and diameter of wire	Approx, overall diameter	Strandard weight	Resistance per km at 20 ⁰ C corrected to std. weight		Approximate breaking load of conductor	Calculated area on standard diameter
			Std.	Max.		
mm	mm	Kg/Km	Ohm	Ohm	Kgf	mm ²
37/2.25	15.75	1326	0.1222	0.1248	6080	147.20
61/2.89	26.00	3640	.0448	0.0457	16358.29	400.14

TABLE -4
LAY RATIO

No. of wires in conductor	LAYERS (NUMBER OF WIRES)							
	First Layer (six)		Second layer (twelve)		Third Layer (eighteen)		Fourth Layer (twenty four)	
	Max	Min	Max	Min	Max	Min	Max	Min
37	25	20	17.5	15	15	12.5	-	-
61	17	10	16	10	15	10	14	10

13. TESTS

- 13.1 After a purchase order is placed, the internal test results for all the tests specified in clause 14 shall be furnished by the successful manufacturer to the Director General (Traction Installation), Research Designs & Standards Organization, Manak Nagar, Lucknow-226011, or to the Purchaser, as the case may be, within the period stipulated for prototype approval in the purchase order.
- 13.2 Any changes required in the process of manufacture or the prototype as desired by the Director General (Traction Installation), Research Designs & Standards Organization, , or by the Purchaser, as the case may be, shall be carried out expeditiously by the manufacturer.
- 13.3 Type testing schedule : Prior to giving a call to the Director General (Traction Installation), Research Designs & Standards Organization, or to the Purchaser, as the case may be, for inspection and testing of the prototype, the manufacturer shall submit a detailed test schedule consisting of number of days required to complete all the tests at one stretch. Once the schedule is approved, the tests shall invariably be done accordingly. However, during the process of type testing or even later, the

Director General/TI/RDSO or the purchaser, as the case may be, reserves the right to conduct any additional test(s) besides those specified herein, to his satisfaction or for gaining additional information and knowledge. In case any dispute or disagreement arises between the manufacturer and the representative of the Director General (Traction Installation), RDSO, or the Purchaser, as the case may be, during the process of testing as regards the procedure for type tests and/or the interpretation and acceptability of the results of type tests, it shall be brought to the notice of the Director General (Traction Installation), RDSO or of the Purchaser, as the case may be, whose decision shall be final and binding.

13.4 All the tests specified in this specification shall be carried out at the manufacturer's works. The manufacturer shall arrange all the necessary machinery, apparatus, labour and assistance required for conducting the tests without any extra cost.

13.5 In the event of the tests not being carried through to completion at one stretch for any reason attributable to the manufacturer and it is required for the representative of the Director General (Traction Installation), RDSO, or of the Purchaser, as the case may be, to go once or several times to the works of the manufacturer or other place(s) for continuing and/or completing the tests on the prototype(s), the manufacturer shall reimburse to the Director General (Traction Installation), RDSO, or to the Purchaser, as the case may be, the cost for the representative's visit(s) to works or other places(s) more than once. The cost as claimed shall be paid through a demand draft as advised to the manufacturer.

14. TYPE TESTS

14.1 The manufacturer shall manufacture at least 500m length of stranded conductor and offer for type tests. The type tests shall be conducted on the stranded conductor and on the wires taken from stranded conductor. For carrying out the tests on wire, the samples of stranded conductor selected shall be opened and mixed and then three wires at random shall be selected. The following shall constitute the type tests:

- i) Visual examination.
- ii) Measurement of diameter of individual wire and stranded conductor
- iii) Measurement of weight of wire and stranded conductor
- iv) Measurement of lay length and lay ratio of each layer of stranded conductor,
- v) Measurement of electrical resistance of wire and stranded conductor,
- vi) Tensile test on individual wire,
- vii) Wrapping test on individual wires,
- viii) Chemical composition of material.

Three samples of adequate length from the manufactured length offered shall be cut and type tests carried out on these samples.

Note: 1. The entire manufacturing process upto the finished conductor shall be witnessed by the representative of the Director General (Traction Installation), RDSO, Lucknow or by the Purchaser, as the case may be. In such a case the prototype tests on the wires shall be conducted before and after stranding. For chemical composition, the Cu+Ag content shall be determined as per IS:440-1964 or latest on one composite sample taken from stranded conductor. The trace elements of the material of ~~wire bar~~, cathode copper or continuous cast copper wire rod shall be determined by spectrometer. The oxygen content shall be verified from the supplier's certificate.

Note:2. If prototype of the conductor conforming to this specification has already been approved in connection with previous supplies to Indian Railways, fresh testing of prototype of the conductor may be waived at the discretion of the Director General (Traction Installation), RDSO, or of the Purchaser, as the case may be, provided that no changes whatsoever in the material or process of manufacture have been made. However, the Director General (Traction Installation), RDSO, or the Purchaser, as the case may be, reserves the right to test the conductor if he deems it necessary to do so in the light of experience gained from previous supplies.

15. ACCEPTANCE TESTS

15.1 The following shall constitute the acceptance tests:

- i) Visual examination
- ii) Measurement of diameter of individual wire and stranded conductor,
- iii) Measurement of weight of individual wire and stranded conductor
- iv) Measurement of lay length and lay ratio of each layer of stranded conductor,
- v) Measurement of electrical resistance of individual wire and stranded conductor.
- vi) Tensile test on individual wire taken from stranded conductor,
- vii) Wrapping test on wire,
- viii) Chemical composition,
- ix) Weightment of drums.

15.2 Only after clear written approval of the results of the tests on the prototype is communicated by Director General (TI), RDSO or by the Purchaser, as the case may be, to the manufacture, he shall take up bulk manufacture of the conductor which shall be strictly with the same material and process of manufacture as adopted for the prototype. In no circumstances shall be material other than that adopted during the manufacture of prototype be used for bulk manufacture.

15.3 Sampling:

Weightment of three or one fifth of offered drums whichever is higher shall be made for gross weight .

One sample of stranded conductor shall be taken from each drum offered for the tests prescribed in Clause 15.1(i, ii, iii, iv, v).Three samples of wires from each sample of stranded conductor shall be subjected to the tests of individual wire prescribed in Clause 15.1(i, ii, iii, v, vi, vii, viii) .

After chemical composition analysis by Spectrometer, one sample(one wire) per 6 drums or minimum one sample for less than 6 drums, shall be subjected to Electrolysis Test (IS: 440-1964 or latest) for determination of copper content.

15.4 Criteria for acceptance :

The sample of conductor taken from each drum shall be subjected to all the tests prescribed in Clause 15.1. The wire and conductor in the drum shall be deemed to have passed the tests if the sample passes all the tests. If a sample fails in more than one test, the drum shall be rejected. Should the sample fail in any one of the tests, two more samples shall be taken from the same drum and subjected to all the tests. Should any sample fail in any test(s) out of two samples taken, the drum shall be rejected and the conductor in the rejected drum shall be cut into lengths of less than 50m.

15.5 PROOF OF PURCHASE OF RAW MATERIAL

Supplier shall be required to submit following documents at the time of Acceptance Test which shall be part of Inspection Certificate.

- a) Proof of purchase(Invoice) of Copper Cathode/Continuous Cast Copper Rod.
- b) For imported Copper Cathode/Continuous Cast Copper Rod the Supplier shall submit proof of import i.e.
 - i) Bill of Entry.
 - ii) Bill of Lading/Air way bill.
 - iii) Test Certificate
 - iv) Payment details to overseas Cathode/Rod manufacturer.
- c) The Cathode/Rod, either Indigenous or imported, has to be procured directly from the manufacturer.
- d) Procurement of Rod on Job Work Basis is not allowed
- e) Procurement of Cathode/Rod from indigenous manufacturer is preferable.
- f) Procurement of Cathode/Rod from any distributor/trader/channel partner of manufacturer is not permitted to ensure quality of material.

16. ROUTINE TESTS:

16.1 The tests indicated in Clause 15.1 **except chemical composition test** shall constitute routine tests and shall be carried out by the manufacturer and records maintained on the samples from each drum.

17. MANUFACTURER'S TESTS:

17.1 In addition to the tests prescribed in clause No. 16.1, the following tests shall be conducted by the manufacturer in the course of fabrication and the records should be maintained.

- i) The chemical composition including trace elements of every lot of ~~wire-bars~~, cathodes and/or continuous cast copper wire rods for chemical composition. The chemical composition shall meet the requirement laid down in clause 5.1.
- ii) Tests on each spool of wire after drawing for tensile strength, wrapping test, measurement of diameter, weight and electric resistance. The spool shall be rejected if wire in the spool does conform to the requirements of specification. The rejected wire may be re-melted with new stock in small quantity.
- iii) Weightment of every drum for tare weight and gross weight.

17.2 Records of these tests shall be maintained by the manufacturer and produced to the Inspecting Engineer at the time of prototype tests and during acceptance tests wherever applicable.

18. TEST METHODS :

18.1 Visual examination.

18.1.1 The wire and stranded conductor shall be visually examined. The wire shall be clean, smooth and free from harmful defects. The strands in the conductor shall be evenly laid without any loose wires. The construction shall be checked for laying of strands of different layers and for the total number of wires. The construction shall be as per Clause No.9 of this specification.

18.2 Measurement of diameter of wire & stranded conductor.

18.2.1 The diameter of wire shall be measured by means of Ratchet Micrometer or a Dial Micrometer between two flat circular studs of minimum diameter of 5 mm. The diameter of conductor shall be measured by means of Vernier caliper. Two measurements at right angles of the stranded conductor shall be taken at three sections and average of 6 readings shall be taken as diameter of the stranded conductor. For measurement of the diameter of individual wire two measurements at right angles at three sections shall be done the average of six readings shall be taken as the diameter of individual wire.

- 18.3 Measurement of weight of wire & stranded conductor
- 18.3.1 The weight of wire and stranded conductor shall be measured by weighing the sample of 50cm(approximate) length by a balance of accuracy of ± 1 gm for stranded conductor and ± 0.1 gm for wire.
- 18.4 Measurement of lay length & lay ratio of each layer of stranded conductor
- 18.4.1 The lay length, i.e. the axial length of complete turn of the helix formed by the wire in a layer of the stranded conductor, of each layer shall be measured by a vernier caliper or by any other method. The measured lay length when divided by the **mean diameter** of helix will be the lay ratio of that layer in case of 37/2.25 conductor. The measured lay length when divided by the **outside diameter of the layer** will be the lay ratio of that layer in case of 61/2.89 conductor.
- 18.5 Measurement of electrical resistance of wire and stranded conductor.
- 18.5.1 The D.C. electrical resistance of the wire and stranded conductor shall be measured by digital micro-ohm meter or Double Kelvin's Bridge at room temperature. The conductor shall be in the test room which shall be at a reasonably constant temperature for sufficient time. The measurement shall be carried out on a sample length of not less than 50cm to an accuracy of one part per thousand. The purchaser shall have the right to test the accuracy of the instrument by another wire of known resistance.
- 18.5.2 The electrical resistance per kilometer of the test sample when multiplied by WxC/K shall not exceed appropriate maximum value given in Table-2 and Table-3.
Where,
K = Standard weight per Km,
W = Weight per km of test sample and
C = Multiplier constant for correction to 20°C
- 18.5.3 The multiplier constant for correction to 20°C

TABLE- 5
MULTIPLIER CONSTANTS (C)

Temperature°C	Multiplier constant
5	1.0606
5.5	1.0585
6.0	1.0563
6.5	1.0542
7.0	1.0521
7.5	1.0500
8.0	1.0479
8.5	1.0458
9.0	1.0437

9.5	1.0417
10.0	1.0396
10.5	1.0376
11.0	1.0355
11.5	1.0335
12.0	1.0314
12.5	1.0294
13.0	1.0274
13.5	1.0254
14.0	1.0234
14.5	1.0214
15.0	1.0194
15.5	1.0174
16.0	1.0155
16.5	1.0135
17.0	1.0116
17.5	1.0096
18.0	1.0077
18.5	1.0057
19.0	1.0038
19.5	1.0019
20.0	1.0000
20.5	0.9981
21.0	0.9962
21.5	0.9943
22.0	0.9924
22.5	0.9906
23.0	0.9887
23.5	0.9868
24.0	0.9850
24.5	0.9831
25.0	0.9813
25.5	0.9795
26.0	0.9777
26.5	0.9758
27.0	0.9740
27.5	0.9722
28.0	0.9704
28.5	0.9686
29.0	0.9668
29.5	0.9651
30.0	0.9633
35.0	0.9459
40.0	0.9292
45.0	0.9130
50.0	0.8974

18.6 Tensile test on individual wire:

18.6.1 The load on the wire shall be applied gradually and the rate of separation of the jaws of the tensile testing machine shall not be greater than 10cm per minute and shall be so adjusted that the total time of the testing from the moment of the application of the load till fracture of wire is between 15 and 60 seconds.

Note : The strength of stranded conductor in terms of the sum of strengths of the individual wires may be assumed to be not less than as indicated in TABLE-6

TABLE-6

Number of wires in stranded conductor	Percentage strength based on the strength of the wires when taken from the stranded conductor and tested	Percentage strength based on the strength at the wire before stranding
37	93	90
61	-	95

The tensile strength of any of the wire after stranding shall be not less than 93% of the value given in TABLE-2 and average tensile strength of all the wires in a stranded conductor shall not be less than 94% of the value specified in TABLE-2.

18.7 Wrapping test on wire:

18.7.1 The wire shall be wrapped round a wire of its own diameter to form a close helix of 8 turns. Six turns shall then be unwrapped and then closely re-wrapped in the same direction as the first wrapping. Wire shall not break during the test.

18.8 Chemical composition:

18.8.1 The trace elements shall be determined by spectrometer. The oxygen content shall be verified from supplier's certificate. Copper content shall be chemically analysed as per IS:440-1964 or latest. The chemical composition shall be as given in Clause No.5 of this specification.

18.9 Weightment of drums :

18.9.1 Weightment of three or one fifth of offered drums whichever is higher shall be made for gross weight and recorded.

19. LENGTH OF CONDUCTOR

19.1 The conductor shall be ordered in specified lengths and shall be supplied as per the following tolerances:

Length under 750m	:	+10.0m -0.0m
Length of 750m & above	:	+20.0 m -0.0m

20. PACKING AND MARKING

20.1

- i) The stranded conductor shall be delivered to the purchaser properly wound on either wooden drums or corrugated steel drums 2.5 MT capacity (type of drum required whether wooden or

steel to be specified by the purchaser in his purchase order).

- ii) In case of wooden drum, the spindle plates of the drums shall have a square hole 105 mm x 105 mm to permit the passage of a square axle of maximum size 100 mm x 100 mm. The use of spindle plates with the hole of any other shape or size shall be subjected to agreement between the purchaser and the manufacturer.
- iii) A drum shall carry only one continuous length of stranded conductor. Paper shall be provided between each layer of conductor while winding on the drum during manufacturing process.
- iv) In order to avoid any damage to conductor, corrugated paper sheet of min. 3.00 mm thickness shall be provided on the outer diameter of barrel, on the inner side of each flanges of the wooden drum and also on the top layer of conductor. After that cover it from Plastic sheet before final packing of drums with wooden lagging. "Any damage in conductor shall be to the suppliers account".
- v) The wooden drum shall comply with IS: 1778-1980 "Specification for Reels and Drums for bare conductors".
- vi) Corrugated Steel drums shall be of maximum capacity 2321 Kg as per Table 2.3 type RM of NEMA WC 26. Size of the selected drum is as per table below:

Flange	Barrel Dia	Traverse
48 inch	24 inch	24 inch
1219.2 mm	609.6 mm	609.6 mm

20.2 The exact manufacturing lengths/weight of the conductor shall be specified by the Purchaser.

20.2.1 The marking on the drum shall include-

- a) The manufacturer's brand or mark.
- b) Size of the conductor.
- c) The actual length of the wire on the drum
- d) Weight of drum (Net and gross)
- e) Number of joints provided in wire during stranding with identification of joints.
- f) Drum number and
- g) Purchase Order no. and the name of the consignee.

