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**GOVERNMENT OF INDIA  
MINISTRY OF RAILWAYS**



**Technical Specification  
for  
Cadmium Copper Conductors  
for  
Over Head Electric Traction**

**SPECIFICATION No. TI/SPC/OHE/CAT (Cu-Cd)/0971**

**ISSUED BY  
TRACTION INSTALLATION DIRECTORATE,  
RESEARCH DESIGNS & STANDARDS ORGANISATION,  
MANAK NAGAR, LUCKNOW – 226 011 (INDIA)**


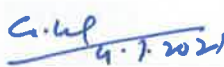
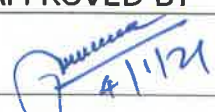
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Specification No. TI/SPC/OHE/CAT (Cu-Cd)/0971

Amendment Number	Amendment/ Revision	Total pages including-Annexure	Date of issue
0	1	24	06/1997

	PREPARED BY	CHECKED BY	APPROVED BY
SIGNATURES			
DATE	04.01.2021		
DESIGNATION	SSE/Conductor	JD(TI)	ED(TI)

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Following clauses will be effective from 3 months from date of issue/effective date of Specification :

Clause 9.1 : The Inspector shall check calibration certificate of counter meters of all available stranding machine, the accuracy and calibration of the counter meters by passing the wire of known length.

Clause 9.2(ix) : In case of wooden drums, 10% of the offered drums will be rewound for checking declared length and weight of conductor in drum.

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## Specification for Cadmium Copper Conductors for Overhead Railway Traction

### 1.0 SCOPE

This Specification covers the requirements and method of tests for stranded cadmium copper conductors for electric traction overhead lines. Old Specification no. ETI/OHE/50(6/97) is re-designated and updated to TI/SPC/OHE/CAT/0971 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.

### 2.0 GOVERNING SPECIFICATION

- 2.1 The cadmium copper conductor shall, unless otherwise specified, conform to the following standards specification (latest version) 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 wire.
iii.	IS:440-1964 or latest	Method of Chemical Analysis of Copper.
iv.	IS:6344-2006 or latest	Specification for cadmium metal
v.	NEMA WC 26-2008 or latest	Binational Wire and Cable Packaging Standard.

- 2.2 In case of any conflict or disparity between the contents of the above specifications and this specification, the latter shall prevail.
- 2.3 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 with justification thereof are furnished. In such a case, the manufacturer shall quote according to this specification and deviation, if any, proposed by him shall be quoted as an alternative(s).
- 2.4 For the purpose of this standard, the definitions given in IS: 1885 (Part -32) - 2019 or latest glossary of terms for electrical cables and conductors shall apply.

### 3.0 ENVIRONMENTAL CONDITIONS

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

TABLE - 1  
ENVIRONMENTAL CONDITIONS

SN	Environmental condition	Limits
i.	Ambient Air Temperature.	0° C to 50° 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 <sup>2</sup>
x.	Altitude	2500m above mean sea level.

4.0 CONDUCTOR4.1 COPPER

4.1.1 Copper used for fabrication of cadmium copper conductor, shall be Electrolytic Grade Copper cathodes/ Continuous Cast Copper Rods. Electrolytic Grade Copper cathodes conforming to the requirement of LME Grade 'A' copper as listed in the London Metal Exchange. Grade 'A' copper cathode conforming to the chemical composition of Cu-Cath-1 of IS 191: 2007 or latest. The chemical composition of Continuous Cast Copper Rods shall be as given in Table 2. Continuous Cast Copper Rods shall be manufactured using of LME Grade 'A' copper cathodes.

TABLE - 2  
CHEMICAL COMPOSITION OF CCC ROD

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

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4.1.2 The copper shall be alloyed with cadmium in manufacturer's works. The cadmium content shall be between 0.7% to 1.0% the presence of deoxidizing agent upto an extent which is not detrimental to the conductivity of the conductor may be permitted. The phosphorous content in cadmium copper shall not exceed 50 ppm.

#### 4.2 CADMIUM FOR ALLOYING

Cd 99.95 or Cd 99.99 grade cadmium conforming to IS: 6344-2006 or latest "Specification for Cadmium metal" shall be used for alloying copper.

#### 4.3 JOINTS IN WIRE BEFORE STRANDING

The wire shall be drawn in continuous lengths without joints except those made in original Rods before cold drawing.

#### 4.4 JOINTS IN STRANDED CONDUCTORS

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 15 meters. Joints shall be hard soldered or Butt Welded.

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

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

#### 4.5 RESISTIVITY

At a temperature of 20° C the maximum value of the resistivity of the hard drawn cadmium copper shall be 0.021769 ohm mm<sup>2</sup>/m

Note (1)  $R = (p \cdot l) / A$

Where

R= Resistance in ohm

l = length in meters

A=Area in mm<sup>2</sup>

p=Resistivity

Note(2) The above resistivity corresponds to a conductivity of 79.2% of that adopted by the international Electro-technical Commission for "Stranded Annealed Copper".

#### 4.6 DENSITY

At a temperature of 20°C the density of hard drawn cadmium copper shall be taken as 8.945 g/cm<sup>3</sup>.



**4.7 CO-EFFICIENT OF LINEAR EXPANSION**

At a temperature of 20°C the coefficient of linear expansion of hard drawn cadmium copper shall be taken as 0.000017 per°C. This coefficient may be used over a temperature range of 0°C to 150°C.

**4.8 CONSTANT MASS TEMPERATURE CO-EFFICIENT OF RESISTANCE**

At a temperature of 20°C, the coefficient of variation of the resistance with temperature of hard drawn cadmium copper, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, has been taken as 0.0031 per°C.

**4.9 FREEDOM FROM DEFECTS**

The wires shall be clean, smooth and free from harmful defects, such as peeling, scratches, abrasion etc.

**4.10 RESISTANCE, WEIGHT AND SIZE OF SOLID WIRE**

After drawing, the wire shall have the diameter, weight and the resistance as given in Table-3.

**4.11 TOLERANCE ON THE STANDARD WEIGHT, DIAMETER AND RESISTANCE OF WIRE**

A tolerance of +2% & -1% shall be permitted on the standard weight of solid wires.

4.11.1 The diameter of the wires shall fall within the maximum and minimum values given in Table 3 which are the maximum and minimum mean diameter permissible in order that the specified tolerance of +2% & -1% on the weight shall not exceed.

4.11.2 The cross section of any wire shall not depart from circularity by more than an amount corresponding to a tolerance of  $\pm 2\%$  on the nominal diameter.

4.11.3 The resistance of the wire when measured and corrected as described in Clause 8.3.5 shall not exceed the appropriate maximum values given in Table 3.

**4.12 STANDARD RESISTANCE, WEIGHT AND SIZE OF STRANDED CONDUCTOR**

The size, weight and resistance of stranded circular conductor shall be as given in Table-4 (also see Appendix B)

**4.13 TOLERANCE ON THE STANDARD WEIGHT OF CONDUCTOR**

A tolerance of +2% & -1% shall be permitted on the standard weight of stranded conductors.

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#### 4.14 MECHANICAL PROPERTIES

The mechanical properties of the wire shall be such that the tensile strength when tested in accordance with Clause 8.3.6 shall not be less than the appropriate value given in Table-3.

4.15 The wire shall comply with the requirement of wrapping test as given in Clause 8.3.7.

#### 5.0 STRANDING

5.1 The wire used in the construction of a stranded conductor shall satisfy all the requirements of this specification as indicated in TABLE-3 and the stranded conductor shall satisfy all the requirements of this specification as indicated in TABLE-4 of this specification.

5.2 The lay ratio of different layers shall be within the limits specified in TABLE-5.

5.3 In all constructions the successive layers shall have opposite direction of the lay, the outermost layer being right handed.

Note: 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.

TABLE - 3  
PROPERTIES OF SOLID CIRCULAR CADMIUM COPPER WIRES

DIAMETER			Calculated area of cadmium copper Wire	Nominal equivalent area of hard drawn copper Wire	Weight per km			Resistance per km at 20° C corrected to std Weight		Minimum Breaking Load on Diameter			Minimum Tensile Strength.
Std.	Max.	Min.			Std.	Max.	Min.	Std.	Max.	2.09 mm	2.10 mm	2.12 mm	
mm	mm	mm	mm <sup>2</sup>	mm <sup>2</sup>	Kg	Kg	Kg	Ohm	Ohm	Kgf	Kgf	Kgf	Kgf/mm <sup>2</sup>
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2.10	2.12	2.09	3.464	2.826	30.98	31.60	30.67	6.285	6.348	227	229	234	66.14

NOTE : 1 The values of breaking load specified in column 11 are minimum with which Single Wire shall comply before stranding.

NOTE : 2 The values specified in column 12 are the bases from which appropriate breaking load of the stranded conductors listed in Table-4 have been calculated.

**TABLE – 4**  
**PROPERTIES OF CADMIUM COPPER STRANDED CONDUCTOR**

Nominal equivalent Area of Hard Drawn Copper	No. of strands and diameter of Wire	Approx. overall Diameter	Weight Per Km.			Resistance per km at 20°C corrected to Standard Weight		Minimum breaking load of Conductor	Calculated area of Cadmium Copper.
			Std	Max	Min	Std	Max		
mm <sup>2</sup>	mm <sup>2</sup>	mm	Kg	Kg	Kg	Ohm	Ohm	Kgf	mm <sup>2</sup>
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
20	7/2.10	6.3	218.70	223.0	216.5	0.9051	0.9141	1443	24.04
53	19/2.10	10.5	597.30	609.2	591.3	0.3360	0.3390	3920	64.84
102	37/2.10	14.7	1169.20	1192.6	1157.5	0.1730	0.1750	7650	125.60

**TABLE – 5**

**LAY RATIO**

No. of wires	LAYER AND NUMBER OF WIRES					
	First Layer		Second Layer		Third layer	
	Max.	Min	Max.	Min	Max.	Min.
7	25	20	-	-	-	-
19	25	20	17.5	15	-	-
37	25	20	17.5	15	15	12.5

**6.0 TECHNICAL DATA**

- 6.1 The manufacturer shall furnish, along with the offer, the guaranteed performance data and other technical particulars of the conductor. All the guaranteed values have to be proved by tests in presence of RDSO representative.
- 6.2 The information furnished in the schedule of guaranteed technical performance data and other particulars shall be complete in all respect. If there is any entry like "shall be furnished later" or blanks are left against any item of schedule of guaranteed particulars, the tender is not likely to be considered as such omission cause delay in finalization of the tender.

**7.0 TESTS**

- 7.1 After a purchase order is placed for supply of cadmium copper conductor for overhead railway traction, the internal test results for all the tests specified in clauses-8.2 shall be furnished by the manufacturer to the Purchaser/Director General (TI)/RDSO, prior to take up the prototype testing.
- 7.2 Any changes required in the process of manufacture or the prototype as desired by the Purchaser/Director General (TI)/RDSO shall be carried out expeditiously by the manufacturer.
- 7.3 TYPE-TESTING SCHEDULE: Prior to giving a call to the Purchaser/Director General (Traction Installation)/ RDSO for inspection and testing of the prototype, the successful manufacturer shall submit a detailed test schedule consisting of



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schematic circuit diagrams/layout for each of the tests and the number of days required to complete all the tests at one stretch. Once the schedule is approved, the test shall invariably be done accordingly. However, during the process of type testing or even later, the purchaser 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 representative of the Director General (TI)/RDSO during the process of testing as regards the procedure for type tests and/or the interpretation and acceptability of the results of type test, it shall be brought to the notice of the Director General (TI)/RDSO, whose decision shall be final and binding.

- 7.4 All the tests specified in the specification shall be carried out at the manufacturer works. The manufacturer shall arrange all the necessary machinery, apparatus, labour and assistance required for conducting the tests without any extra cost.
- 7.5 In the event of the tests not being carried through to completion at one stretch for any reasons attributable to the manufacturer and it is required for the representative of the Purchaser/Director General (TI)/RDSO to go again or more number of 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 (TI)/RDSO the cost for the representative's visits to works or other place(s) for the tests more than once. The costs as claimed by the Purchaser/Director General (Traction Installation), Research Designs & Standards Organization, Lucknow shall be paid through a demand draft as advised to the manufacturer.

## 8.0 TYPE TESTS:

### 8.1 SAMPLING

- 8.1.1 For chemical analysis of electrolytic copper cathodes/continuous cast copper wire rods, sample shall be taken in accordance with IS:191-2007 or latest. After alloying the copper with cadmium in presence of the representative of DG(TI)/RDSO, first and last cadmium copper billets of the melt shall also be tested for chemical composition.
- 8.1.2 The cadmium copper billets shall be hot rolled into 8 to 10 mm diameter wire rods, these wire rods shall be pickled, drawn into wires of the required size and then stranded into the conductor in the presence of the representative of DG(TI)/RDSO. These wires and stranded conductor shall be type tested.
- 8.1.3 Three wires before stranding and three wires after stranding shall be taken at random for each type of tests.
- 8.1.4 In case of stranded conductor, three samples shall be taken at random for each type of tests.

8.2 **Type Tests:** The following type tests shall be carried out on the electrolytic copper cathodes/continuous cast copper wire rods/cadmium copper billets, conductor and wires at the works of the manufacturer in presence of the representative of DG(TI)/RDSO, in accordance with the relevant procedures laid down in this specification

- 8.2.1 Visual examination of electrolytic copper cathodes/continuous cast copper wire rods, wires and stranded conductor
- 8.2.2 Chemical composition of electrolytic copper cathodes/continuous cast copper wire rods, cadmium copper billets and 2.1 mm Cu-Cd wires.
- 8.2.3 Measurement of diameter of individual wire and stranded conductor
- 8.2.4 Measurement of weight of wire and conductor
- 8.2.5 Measurement of lay length and lay ratio of each layer of stranded conductor
- 8.2.6 Measurement of electrical resistance of wire and stranded conductor.
- 8.2.7 Tensile test on wires
- 8.2.8 Wrapping test on wires.

### 8.3 TEST METHODS

#### 8.3.1 VISUAL EXAMINATION

The electrolytic copper cathodes/continuous cast copper wire rods shall be substantially free from shrink holes, cold sets, pits, sloping edges, concave tops etc. When examined visually, the wires and conductor shall be smooth, free from harmful defects such as abrasions, peeling, rough surface, bird caging etc.

#### 8.3.2 MEASUREMENT OF DIAMETER OF WIRE & STRANDED CONDUCTOR:

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 wire as well as of the stranded conductor shall be taken at three sections and average of 6 readings shall be taken as diameter of the wire/stranded conductor. The diameter of wire shall be as per Table-3 and diameter of conductor shall be as per Table-4.

#### 8.3.3 MEASUREMENT OF WEIGHT OF WIRE & STRANDED CONDUCTOR

The weight of wire and stranded conductor per kilometer shall be measured by weighing three samples each of 50 cm (approx.) length by a balance of accuracy of  $\pm 1$  gm for conductor and  $\pm 0.1$  gm for wire. The weight of wire shall be as per Table-3 and weight of conductor shall be as per Table-4.

#### 8.3.4 MEASUREMENT OF LAY LENGTH & LAY RATIO OF EACH LAYER OF STRANDED CONDUCTOR

##### LAY RATIO

The ratio of the axial length of a complete turn of the helix, formed by the core of a cable or the wire of a stranded conductor, to the mean diameter of the helix. The values of lay ratio shall be as per Clause 5.2.

**LENGTH OF LAY(LAY)**

The axial length of one complete turn of the helix, formed by the core in the case of a cable, or the wire in the case of a stranded conductor

The lay length shall be measured for the complete conductor. Lay ratio of each layer shall be measured by a Vernier caliper or lay guage.

**8.3.5 MEASUREMENT OF ELECTRICAL RESISTANCE OF WIRE & STRANDED CONDUCTOR**

Electrical Resistance of the wire and Stranded Conductor shall be measured by Digital Micro-Ohm Meter or Double Kelvin's Bridge. The measurement shall be made on a sample length of not less than 50 cm. The **Inspecting Engineer** shall have the right to test the accuracy of the instrument by another wire of known resistance.

The Electrical Resistance per kilometer of the test sample (Wire/Stranded Conductor) multiplied by  $W \times C / K$  shall not exceed on appropriate maximum value given in TABLE - 3 and TABLE - 4.

Where  $K$  = Standard weight per km,

$W$  = Weight per km. of test sample (wire/stranded conductor) and

$C$  = multiplier constant for correction to 20° C

The multiplier constant shall be in accordance with TABLE 6.

The measurement of resistance shall be carried out to an accuracy of at least one part in thousand (.001)

**TABLE - 6**  
**MULTIPLIER CONSTANT FOR COVERION OF**  
**ELECTRICAL RESISTANCE TO 20°C.**

Multiplier constant for converting resistance of hard drawn cadmium Copper (wire/conductor) at any temperature between 5° C and 45° C to a temperature of 20° C is in column 2 and 5 and its reciprocal is in column 3 and 6 respectively for converting resistance at 20° C to that at any other temperature between 5° C and 45° C.

Temperature °C	Multiplier Constant	Reciprocal of Constant	Temperature <sup>0</sup> C	Multiplier Constant	Reciprocal of Constant
5	1.049	0.954	26	0.982	1.019
5.5	1.047	0.955	26.5	0.980	1.020
6	1.045	0.957	27	0.979	1.022
6.5	1.044	0.958	27.5	0.977	1.023
7	1.042	0.960	28	0.976	1.025
7.5	1.040	0.961	28.5	0.974	1.026
8	1.039	0.963	29	0.973	1.028
8.5	1.037	0.964	29.5	0.971	1.030

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9	1.035	0.966	30	0.970	1.031
9.5	1.033	0.968	30.5	0.9687	1.0323
10	1.032	0.969	31	0.9670	1.0341
10.5	1.030	0.971	31.5	0.9655	1.0357
11	1.039	0.972	32	0.9641	1.0372
11.5	1.027	0.974	32.5	0.9626	1.0388
12	1.025	0.975	33	0.9613	1.0403
12.5	1.024	0.977	33.5	0.9590	1.0419
13	1.022	0.978	34	0.9584	1.0434
13.5	1.021	0.980	34.5	0.9569	1.0450
14	1.019	0.981	35	0.9556	1.0465
14.5	1.017	0.983	35.5	0.9541	1.0481
15	1.016	0.985	36	0.9527	1.0496
15.5	1.014	0.986	36.5	0.9513	1.0512
16	1.013	0.988	37	0.9499	1.0527
16.5	1.011	0.989	37.5	0.9485	1.0543
17	1.009	0.991	38	0.9471	1.0558
17.5	1.008	0.992	38.5	0.9457	1.0574
18	1.006	0.994	39	0.9444	1.0589
18.5	1.005	0.995	39.5	0.9430	1.0605
19	1.003	0.997	40	0.9416	1.0620
19.5	1.002	0.999	40.5	0.9402	1.0636
20	1.000	1.000	41	0.9389	1.0651
20.5	0.998	1.002	41.5	0.9375	1.0667
21	0.997	1.003	42	0.9362	1.0682
21.5	0.995	1.005	42.5	0.9348	1.0698
22	0.994	1.006	43	0.9334	1.0713
22.5	0.992	1.008	43.5	0.9321	1.0729
23	0.991	1.009	44	0.9308	1.0744
23.5	0.989	1.011	44.5	0.9294	1.0760
24	0.988	1.012	45	0.9281	1.0775
24.5	0.986	1.014			
25	0.985	1.016			
25.5	0.983	1.017			

**NOTE - 1:** Given in resistance of wire/stranded conductor at T°C, the resistance at 20°C, the resistance at 20° C is found by multiplying the resistance at T°C by the constant for T°C given in Column 2 and 5 conversely, given the resistance at 20°C the corresponding resistance at T°C is found by multiplying the resistance at 20° C by the reciprocal against T°C given in Column 3 & 6.

**NOTE - 2 :** The temperature resistance co-efficient of large number of samples of cadmium copper complying with the requirements of this standard have been found to vary between 0.0031 and 0.0035 per °C. There is some evidence to suggest that the co-efficient of copper alloys in general are directly proportional to their conductivities. In this standard the value of 0.0031 has been adopted as it lies with the observed range and also



complies with the above theory if it be assumed that all cadmium copper has the maximum resistivity permitted.

### 8.3.6 TENSILE STRENGTH

This test shall apply to wires of all diameters before stranding and also to the wires taken from the stranded conductor. The tensile strength of a wire before stranding when tested in the manner as explained below, shall be not less than the appropriate value given in TABLE-3. If it is not possible to test the wires before stranding, the test may be made on wires taken from the stranded conductor. In such cases the tensile strength of any of the wire shall be not less than 92.5% of the value given in TABLE-3 and the average tensile strength of all the wires in a stranded conductor shall be not less than 94% of the value specified in TABLE-3.

The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall not be greater than 10 cm 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 is between 15 and 60 seconds.

NOTE :The strength of stranded conductor in terms of the sum of the strengths of the individual wires may be assumed to be not less than as indicated in TABLE- 7.

TABLE – 7

Number of Wires Stranded Conductor	Percentage strength based on the strength of wires when taken from the Stranded Conductor and tested	Percentage strength based on the strength of the wire before Stranding.
7	93	90
19	93	90
37	93	90

### 8.3.7 WRAPPING TEST ON INDIVIDUAL WIRE

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.

### 8.3.8 CHEMICAL COMPOSITION

The samples taken from electrolytic copper cathodes/continuous cast copper wire rods shall be tested for trace elements /impurities by Spectrometer. The copper content shall be determined in accordance with IS-440-1964 or latest. The chemical composition of electrolytic copper cathodes/continuous cast copper wire rods shall be as per Clause 4.1.1. Oxygen content shall be determined by Spectrometer or oxygen analyzer.



The samples taken from cadmium copper billet shall be tested for trace elements /impurities by Spectrometer. Oxygen content may be determined by Spectrometer or Oxygen analyzer. The chemical composition of cadmium copper billets shall be as given in Para 1(b) of Appendix-C.

The samples taken from copper cadmium wires (2.10 mm) shall be tested for trace elements /impurities, cadmium & phosphorous content by Spectrometer. The copper of copper cadmium wires (2.10 mm) shall be determined in accordance with IS 440-1964 or latest. Oxygen content may be determined by Spectrometer or Oxygen analyzer. The chemical composition of copper cadmium wires (2.10 mm) rods shall be as given in Para 1(b) of Appendix-C.

#### 8.4 ACCEPTANCE CRITERIA FOR PROTOTYPE

8.4.1 The samples offered for type tests in accordance with Clause 8.1 shall pass all the type tests stipulated in Clause 8.2 thereof.

8.4.2 Only after clear written approval of the results of the tests on the prototype is communicated by the Purchaser/Director General (TI)/RDSO to the manufacturer, manufacturer 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 material other than those adopted during the manufacture of prototype be used for bulk manufacture.

8.4.3 If the prototype of a 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 purchaser, provided that no changes whatsoever in the material or process of manufacture have been made. However, the purchaser reserves the right to test any conductor if he deems it necessary to do so in the light of experience gained from previous supplies.

#### 9.0 ACCEPTANCE TEST

9.1 Weighment of every empty drums (to be used for stranded cadmium copper conductor) for tare weight, either at the time of stage inspection or on call given by the manufacturer. Identification mark with Tare weight should be provided by Inspecting official on each drum. Record of the result of weighment shall be maintained.

The Inspector shall verify physical raw material purchased by the supplier with the copy of its invoice. Inspector shall check with copper cathode/copper rod, coil no./batch no. mentioned in raw material purchase invoice are actually matching with raw material. Record of the invoices shall be maintained.

The Inspector shall check calibration certificate of counter meters of all available stranding machine, the accuracy and calibration of the counter meters by passing the wire of known length.[Effective from 04.04.2021]

## 9.2 The following shall constitute the Acceptance Test

- 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 of Strands.
- vii) Wrapping Test on Wire
- viii) Verification of results of manufacturer's tests (see Clause 11.0)
- ix) Weighment of each offered Catenary Wire drums for acceptance test, for gross weight. The inspector shall verify the results of manufacturer's tests. In case of wooden drums, 10% of the offered drums will be rewound for checking declared length and weight of conductor in drum. .[Effective from 04.04.2021]
- x) Chemical Composition analysis of 2.1 mm Cu-Cd wire.

Note : Necessary arrangements shall be made for transferring the conductor from the sample drum to another empty drum after weighing the sample drum along with the conductor and at the same time measuring the length of the conductor so transferred by means of meters. Thereafter, the original sample drum without the conductor shall be weighted and the value shall be checked with the packing list. In case, any shortage of conductor is found in one or more drums, the maximum value of each shortage, in percent(s) shall be deducted from all the drums offered for inspection

## 9.3 The tests shall be conducted as laid down in the relevant Clauses thereof.

## 9.4 SAMPLING

The stranded conductor shall be offered for inspection in a batch of 6 drums at a time.

One sample of stranded conductor shall be taken from each drum for the tests prescribe in Clause 9.2. After visual examination, measurement of overall diameter, measurement of weight, measurement of resistance and measurement of lay ratio, three samples of wire shall be taken and subjected to test prescribed in clause 9.2(i), 9.2(ii), 9.2(iii), 9.2(v), 9.2(vi), 9.2(vii) & 9.2(x). For test prescribed in clause 9.2(x), three samples of wire from each drum, shall be tested for trace elements, cadmium and phosphorous content by spectrometer, after that one sample of wire from offered batch (6 drums) shall be tested for copper content by IS 440-1964 or latest.

## 9.5 CRITERIA FOR ACCEPTANCE

The sample of wire and Conductor taken from each Drum shall be subjected to all the tests prescribed in Clause 9.2. The Wire and Conductor in the Drum shall be deemed to have passed the tests if the samples pass all the tests. If a sample fails

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in more than one test, the Drum shall be rejected. If sample fail in anyone of the tests, two more samples shall be taken from the same drum and subjected to all the tests. If any sample fail in any tests out of two samples taken, the drum shall be rejected and the wires and conductor in the rejected drum shall be cut into lengths of less than 50 m.

#### 9.6 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/ Copper Rod and Test Certificate.
- b) For imported Copper Cathode/ Copper Rod the Supplier shall submit proof of import i.e.
  - i) Bill of Entry.
  - ii) Bill of Lading/Air way bill.
  - iii) Payment details to overseas Cathode/Copper Rod manufacturer.
  - iv) Declaration that he has and will not use these Documents for any other consignment or purpose.
- c) The Copper Cathode/Copper Rod, either Indigenous or imported, has to be procured directly from the manufacturer.
- d) Procurement of Copper cathode/Copper Rod from indigenous manufacturer is preferable.
- e) Procurement of Copper Cathode/Copper Rod from any distributor/trader/channel partner of manufacturer is not permitted to ensure quality of material.
- f) Inspecting Engineer shall verify the authenticity of proof of purchase from OEM.

#### 10.0 ROUTINE TESTS

- 10.1 The tests indicated in Clause 9.2 except chemical composition analysis shall constitute Routine Tests and shall be carried out on the samples from each drum and samples shall be taken as indicated in Clause 9.3. The tests shall be conducted as laid down in the relevant Clauses thereof.

#### 11.0 MANUFACTURER'S TEST

In addition to the tests prescribed above, the following tests shall be conducted by the manufacturer in the course of fabrication and the records maintained.

- 11.1 The manufacturer shall test every lot of copper wire rod for chemical composition. The samples shall be drawn in accordance with IS:191-2007 or latest.
- 11.2 The manufacturer shall test at least half the cadmium copper billets from each melt (these must include first and last billets of the melt) for cadmium content and phosphorous content. If the cadmium content in any of the billets is not within the specified limit of 0.7% to 1.0%, all the billets of the melt shall be rejected.

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Similarly, if phosphorous content in any of the billets of the melt is more than 50 ppm, all the billets of the melt shall be rejected. The rejected billets may be re-melted and alloyed to achieve the specified limits of cadmium and phosphorous.

- 11.3 The manufacturer shall test one of the cadmium copper billets from each melt for impurities listed in TABLE-2 (other than oxygen and silver) and none of them should exceed the corresponding value given in TABLE-2.
- 11.4 The manufacturer shall tests on each spool of 2.10 mm diameter wire for Tensile Strength, Wrapping Test, Measurement of Diameter, Weight and Electric Resistance. The spool shall be rejected if wire of the spool does not conform to the requirement of specification. The rejected wire may be re-melted with new wire bars in small quantity.
- 11.5 Records of these tests shall be maintained by the manufacturer and shall be produced to the Inspecting Engineer at the time of prototype testing /Re-assessment /Quality Audit and during Acceptance Tests.
- 11.6 The manufacturer shall weigh every Catenary Wire drum for tare weight and gross weight. Records of the results of weighment shall be checked by the Inspector at the time of acceptance test.

## 12.0 PACKING AND MARKING

### 12.1

- i) Cadmium Copper 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 Catenary Wire, 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 Catenary wire. After that cover it from Plastic sheet before final packing of drums with wooden lagging. "Any damage in Catenary wire 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

- 12.2 The exact manufacturing lengths of the conductor shall be specified by the purchaser. The length may vary between 500 m and 3200 m.

- 12.3 The labeling on drum shall include –

- The manufacturer's brand or mark.
- Size of the conductor.
- The actual length of the wire on the drum
- Weight of drum (net and gross)
- Number of joints provided during stranding with identification of joints.
- Drum number and
- Purchase Order no. and the name of the consignee.

- 13.0 All the provisions contained in RDSO's ISO procedure laid down in document no. **QO-D-8.1-11 dated 01.07.2020 or latest** (Title "Vendor-change in approved status") and subsequent versions/amendments thereof, shall be binding and applicable on the successful vendor/ vendors in the contracts floated by Railways to maintain quality of the products supplied to Railways.

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## Appendix – 'A'

### To the Specification No. TI/SPC/OHE/CAT (Cu-Cd)/0971

- A-1 The stranded cadmium copper conductors are used as Catenary, Bridle Wire and terminating wire in the traction overhead equipment and are very important components of the system. Any failure of the conductor in service has very serious repercussions. It is, therefore, essential that the manufacture of the conductors is to the highest standards of reliability, so as to achieve a maintenance free service of 40-50 years.
- A-2 The 8 mm - 10 mm diameter wire rods should preferably be jointed together so that the drawing of 2.10 mm diameter wire is continuous, during drawing, spools of lengths specified by the purchaser may be cut to obtain the wire of exact length and avoid the jointing of wire during stranding, except in the event of breakage.
- A-3 The manufacturers of Cadmium Copper Conductors should, therefore, be equipped with the following facilities. Measuring equipment should possess valid calibration certificate.
- Furnace for making cadmium copper alloy with suitable temperature measuring equipment.
  - Well equipped laboratory having facility of measuring quickly cadmium, phosphorous and other trace elements by spectroscopic method so as to maintain a close check on the quality of production.
  - Facility for chopping of the top of wire bars and scalping.
  - Rolling Mill\* for manufacture of 8-10 mm diameter
  - Pickling, wire drawing and stranding equipment.
  - 1-tonne Universal Tensile Testing Machine
  - Equipment for measurement of Electrical Resistance and instruments for measurement of diameter, weight and lay ratio etc.
- \* In case the manufacturers of the cadmium copper conductor does not having rolling mill of their own and intend to get the rolling done through some outside agency, it is essential that a joint application is submitted to DG(TI)/RDSO by both the parties for registration/approval. In such a case of joint registration, with-drawl of approval of one agency due to any reason what so-ever shall automatically lead to de-registration of other agency also.

Appendix – 'B' to  
Specification No. TI/SPC/OHE/CAT (Cu-Cd)/0971

NOTES ON THE CALCULATION ON TABLE-4

**B-1 DATA CONCERNING STRANDED CONDUCTORS**

**B-1.0** The values of TABLE-4 have been calculated on the following basis.

**B-1.1** When straightened out, each wire in any particular layer of the stranded conductor, except the central wire, is assumed to be longer than the stranded conductor by an amount depending on the mean lay ratio (See 5.2) of that layer as per TABLE - 5.

**TABLE-8**

**INCREASE IN LENGTH OF WIRE DUE TO STRANDING**

	FIRST LAYER	SECOND LAYER	THIRD LAYER
MEAN LAY RATIO	22.50	16.25	13.75
PERCENTAGE INCREASE IN LENGTH OF WIRE (Calculated)	0.97	1.85	2.50

**B 1.2** The weight of each wire in any particular layer of a stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the mean lay ratio of that layer as indicated in para B 1.1 above.

The area, weight and resistance of the wire have been calculated by multiplying the corresponding values for one of the single wire of which the conductor is composed by the constants given in TABLE - 9.

**TABLE-9**

**MULTIPLIER CONSTANTS FOR STRANDED CONDUCTOR**

No. of wires in stranded conductor	Constant		
	For Area	For Weight	For resistance
7	6.942	7.058	0.1440
19	18.720	19.280	0.0534
37	36.260	37.740	0.0276

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### B 1.3 CALCULATED AREA

This term denotes the area of a solid cadmium copper rod which would have the same resistance as the stranded conductor, assuming conductivity of both to be the same. This area, therefore, takes into account the assumed increase of resistance of each wire except the central wire and can be determined by multiplying the area of any one wire by a constant given in TABLE -9. This constant is the reciprocal of the constant for calculating the resistance.

### B 1.4 NOMINAL COPPER AREA

This term denotes in rounded figures the area of a solid Hard Drawn Copper Rod of resistance approximately equal to that of the Cadmium Copper stranded conductor.

### B 1.5 TABLE - 9 has been calculated for, and is only applicable to the standard constructions of stranded conductors specified in this standard.

## Appendix – 'C'

To the Specification No. TI/SPC/OHE/CAT (Cu-Cd)/0971

Schedule of guaranteed technical particulars for cadmium copper conductors for 25kV overhead railway traction on Indian Railways

SN	Item Description	Unit of measurement	Value as per RDSO's specification	Offered value by tenderer
1.	Chemical composition			
a	Copper Cathode/CC copper rod		CC copper rod	Copper Cathode
	i. Cu+Ag	%	99.95	99.99
	ii. Ag	ppm	-	25
	iii. Bi	ppm	<2	<2
	iv. Te	ppm	<2	<2
	v. Se	ppm	<2	<2
	vi. Bi+Te+Se	ppm	<3	<3
	vii. Pb	ppm	<5	<5
	viii. Sb	ppm	<4	<4
	ix. As	ppm	<5	<5
	x. Fe	ppm	<10	<10
	xi. S	ppm	<15	<15
	xii. Ni	ppm	-	<10
	xiii. Sn+Ni+Fe+Si+Zn+CO	ppm	<20	20
	xiv. Oxygen	ppm	<450	450
	xv. Total Impurities (Excluding oxygen)	ppm	<65	<65
b	Cadmium copper billets/ cadmium copper wire(2.10mm)			
	i. Cu+Ag	%	>or =98.90	
	ii. Cd	%	0.7 to 1.0	
	iii. P	ppm	<50	
	iv. Bi+Te+Se	ppm	<20	
	v. Pb	ppm	<5	
	vi. Sb	ppm	<4	
	vii. As	ppm	<5	
	viii. Sn+Ni+Fe+Si+Zn+CO	ppm	<50	
	ix. Oxygen	ppm	<450	
2.	Maximum value of resistivity of hard drawn Cd copper at 20°C	Ohm mm <sup>2</sup> /m	.021769	
3.	Density of hard drawn Cd copper	gm/c	8.945	

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	at 20°C	m <sup>3</sup>				
4.	Co-efficient of linear expansion of hard drawn Cd copper at 20°C	per <sup>0</sup> C	0.000017			
5.	Constant mass temperature co-efficient of resistance at 20°C	per <sup>0</sup> C	0.0031			
6.	Solid circular cadmium copper wire					
a.	Diameter	mm	2.09 to 2.12			
b.	Calculated area with respect to the diameter of the cadmium copper wire as given in 6(a)	mm <sup>2</sup>	3.464			
c.	Nominal equivalent area of hard drawn copper for std. dia. as per 6(a)	mm <sup>2</sup>	2.826			
d.	Weight per km for std., Max and Min.dia. as per 6(a)	Kg	Std.	Max.	Min	
			30.98	31.60	30.67	
e.	Resistance per km at 20°C corrected to standard weight for Std. & Max. dia. as per 6(a)	ohm	Std.	Max.		
			6.285	6.348		
f.	Minimum breaking load on diameter as per 6(a)	Kgf	2.09	2.10	2.12	
			227	229	234	
g.	Minimum tensile strength	Kgf/m m <sup>2</sup>	66.14			
7.	Standard Cadmium copper Stranded conductor					
a.	Standard equivalent area of hard drawn copper for std. dia. as per 6(a)	mm <sup>2</sup>	i) 20 ii) 53 iii) 102			
b.	No. of strands and std. diameter of wire	mm	i) 7/2.10 ii) 19/2.10 iii) 37/2.10			
c.	Approximate overall diameter as per 7(b)	mm	i) 6.3 ii) 10.5 iii) 14.7			
d.	Weight per km as per 7(b)	Kg		Std.	Max	Min
			i.	218.7	223.0	216.5
			ii.	597.3	609.2	591.3
			iii.	1169.2	1192.6	1157.5
e.	Resistance per km at 20°C corrected to standard weight as per 7(b)	Ohm		Std.	Max.	
			i.	0.9051	0.9141	
			ii.	0.3360	0.3390	
			iii.	0.1730	0.1750	
f.	Minimum breaking load of conductor as per 7(b)	Kgf	i. 1443 ii. 3920 iii. 7650			
g.	Calculated area of cadmium copper as per 7(b)	mm <sup>2</sup>	i. 24.04 ii. 64.84 iii. 125.60			



h.	Lay Ratio for stranded conductors of size	No.	Layer					
			I		II		III	
			Min	Max	Min	Max	Min	Max
	i. 7/2.10		25	20	-	-	-	-
	ii. 19/2.10		25	20	17.5	15	-	-
	iii. 37/2.10		25	20	17.5	15	15	12.5

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