

SPECIFICATION NO. ETI/OHE/50(6/97)

**GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS**

**Technical Specification
For
Cadmium Copper Conductors
For
Over Head Railway Traction**

Issued by :-

**RESEARCH DESIGNS & STANDARDS ORGANISATION
MANAK NAGAR, LUCKNOW – 226 011**

(For Official Use Only)

SPECIFICATION FOR CADMIUM COPPER CONDUCTORS FOR OVERHEAD RAILWAY TRACTION.

1.0 SCOPE

1.1 This specification covers the requirements and method of tests for stranded cadmium copper conductors for electric traction overhead lines.

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 – 1980 : Specification for copper.
- ii) IS : 1778 – 1980 : Specification for reels and drums for bare wire.
- iii) IS : 440 – 1964 : Method of chemical analysis of copper.
- iv) IS : 6344-1971 : Specification for cadmium metal.

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 tenderer, intended to improve the performance, utility and efficiency of the conductor, will be given due consideration provided full particulars of the deviation with justification therefor are furnished. In such a case, the tenderer 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 XXXII)-1971 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

i)	Maximum ambient air temperature	50 ⁰ C
ii)	Average ambient air temperature Over a period of 24 hours.	35 ⁰ C
iii)	Maximum relative humidity	100%
iv)	Annual rainfall	Ranging from 1750 mm to 6250 mm.
v)	Maximum number of thunder storm days per annum	85
vi)	Maximum number of dust storm days per annum	35
vii)	Number of rainy days per annum.	120
viii)	Basic wind pressure	200 kgf/m ²
ix)	Altitude	Not exceeding 1000 m

4. **CONDUCTOR**

4.1 COPPER

4.1.1 Copper used for fabrication of cadmium copper conductor shall be electrolytic copper conforming to IS : 191-1980 “Specification for Copper”. The composition of copper shall be as given in TABLE – 2.

TABLE – 2
CHEMICAL COMPOSITION

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

4.1.2 The copper shall be alloyed with cadmium in manufacturer’s works. The cadmium content shall be between 0.7% and 1.0%. the presence of deoxidising 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 : 6344-1971 “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 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 20⁰ C the maximum value of the resistivity of the hard drawn cadmium copper shall be 0.021769 ohm mm²/m

Note : (1) $R = L/A$

Where R = Resistance in ohms
 L = Length in metre
 A = Area of cross section in mm²
= Resistivity.

Note : (2) The above resistivity corresponds to a conductivity of 79.2% of that adopted by the international Electrotechnical Commission for “Standard annealed copper”.

4.6 DENSITY

At a temperature of 20⁰ C, the density of hard drawn cadmium copper has been taken as 8.945 gm/cm³.

4.7 CO-EFFICIENT OF LINEAR EXPANSION

At a temperature of 20⁰ C the co-efficient of linear expansion of hard drawn cadmium copper has been taken as 0.000017 per⁰ C. This co-efficient may be used over a temperature range from 0⁰C to 150⁰C.

4.8 CONSTANT MASS TEMPERATURE CO-EFFICIENT OF RESISTANCE

At a temperature of 20⁰ C, the co-efficient 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 per⁰ C.

4.9 FREEDOM FROM DEFECTS

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

4.10 RESISTANCE ON THE STANDARD WHEIGHT, DIAMETER, AND RESISTANCE OF 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 $\pm 2\%$ shall be permitted on the standard weight of solid wires.

4.11.1 The diameter of the wire shall fall within the maximum and minimum values given in Table-3 which are the maximum and minimum mean diameters permissible in order that the specified tolerances of $\pm 2\%$ 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 (see also Appendix-B).

4.13 TOLERANCE ON THE STANDARD WEIGHT OF CONDUCTOR

A tolerance of $\pm 2\%$ shall be permitted on the standard weight of stranded conductors.

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 7.1.14.

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 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 outer most layer being right handed.

TABLE – 3
SOLID CIRCULAR CADMIUM COPPER WIRES

DIAMETER			Calculated area of cadmium copper	Nominal equivalent area of hard drawn copper	Weight per km			Resistance per km at 20° C corrected to std. Weight		Minimum Breaking Load on Diameter			Min tensile strength.
Nominal	Max	Min			Std.	Max	Min	Std.	Max	2.08 mm	2.10 mm	2.12 mm	
mm	mm	mm	mm ²	mm ²	Kg	Kg	Kg	Ohm	Ohm	Kgf	Kgf	Kgf	Kgf/mm ²
2.10	2.12	2.08	3.464	2.826	30.98	31.60	30.36	6.285	6.348	225	229	234	66.14

NOTE : 1 The values specified in column 11 are the minimum with which wire shall comply before stranding.

NOTE : 1 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
STANDARD 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 dg. C corrected to Std. Weight		Minimum breaking load of conductor	Calculated area of cadmium copper.
			Std	Max	Min	Std	Max		
mm ²	mm ²	Mm	Kg	Kg	Kg	Ohm	Ohm	Kgf	mm ²
20	7/2.10	6.3	218.7	223.0	214.3	0.9051	1443	1443	24.04
53	19.2.10	10.5	597.3	609.2	585.3	0.3360	3920	3920	64.84
102	37/2.10	14.7	1169.2	1192.6	1145.8	0.1730	7650	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

5. TECHNICAL DATA

6.1 The tenderer 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 omissions 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 Clause 7.1.7 shall be furnished by the successful tenderer to the Director General (Traction Installations)/Research Designs & Standards Organisation, Manak Nagar, Lucknow – 226 011, within the period stipulated for prototype approval in the order.

7.2 Any changes required in the process of manufacture or the prototype as desired by the Director (Traction Installation)/Research Designs & Standards Organisation (RDSO) shall be carried out expeditiously by the manufacturer

7.3 Type testing schedule :- Prior to giving a call to the Director General (Traction Installation) / Research Designs & Standards Organisation for inspection and testing of the prototype, the manufacturer shall submit a detailed test schedule consisting of schematic circuit diagrams 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 tests 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 (Traction Installations) / 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 (Traction Installation /RDSO as the case may be, whose decision shall be final and binding.

7.4 All the tests specified in the 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.

7.5 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 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 Installations)/ RDSO the cost for the representative's visits to works or other place(s) more than once. The cost as claimed by the Director General (Traction Installation) / RDSO 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 copper wire bars sample shall be taken in accordance with IS : 191 (Pt.III)-1980. After alloying the copper with cadmium in presence of the representative of Director General (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 Director General (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 test on wires.

8.1.2 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 copper wire bars, cadmium copper billets, conductor and wires at the works of the manufacturer in the presence of the representative of the Director General (TI)/RDSO, in accordance with the relevant procedures laid down in this specification.

- 8.2.1 Visual examination of copper wire bars, wires and stranded conductor.
- 8.2.2 Chemical composition of copper wire bar and cadmium copper billets.
- 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 copper wire bars 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, peelings, tough surface, bird caging etc.

8.3.2 MEASUREMENT OF DIAMETER OF WIRE & STRANDED CONDUCTOR.

The diameter shall be measured by means of ratchet micrometer or a dial micrometer between two flat circular studs of minimum diameter of 5 mm. 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.

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 (approximate) length by a balance of accuracy of +/- 1 gm for conductor and +/- 0.1 gm for wire.

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

8.3.4.1 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

8.3.4.2 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 of the wire in the case of a stranded conductor.

8.3.4.3 The lay length shall be measured for the complete conductor Lay ratio of each layer shall be measured by a vernier calliper or lay gauge.

8.3.5 MEASUREMENT OF ELECTRICAL RESISTANCE OF WIRE AND STRANDED CONDUCTOR

Electrical resistance of the wire and stranded conductor shall be measured by digital micro-ohm meter or Double Kelvin Bridge. The measurement shall be made on a

sample length of not less than 50 cm. The purchaser 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 CONVERSION 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 $^{\circ}\text{C}$	Multiplier constant	Reciprocal of constant	Temperature $^{\circ}\text{C}$	Multiplier constant	Reciprocal constant
5	1.049	0.954	24.5	0.986	1.014
5.5	1.047	0.955	25	0.985	1.016
6	1.045	0.957	25.5	0.983	1.017
6.5	1.044	0.958	26	0.982	1.019
7	1.042	0.960	26.5	0.980	1.020
7.5	1.040	0.961	27	0.979	1.022
8	1.039	0.963	27.5	0.977	1.023
8.5	1.037	0.964	28	0.976	1.025
9	1.035	0.966	28.5	0.974	1.026
9.5	1.033	0.968	29	0.973	1.028
10	1.032	0.969	29.5	0.971	1.030
10.5	1.030	0.971	30	0.970	1.031
11	1.029	0.972	30.5	0.9687	1.0323
11.5	1.027	0.974	31	0.9670	1.0341
12	1.025	0.975	31.5	0.9655	1.0357
12.5	1.024	0.977	32	0.9641	1.0372
13	1.022	0.978	32.5	0.9626	1.0388
13.5	1.021	0.980	33	0.9613	1.0403
14	1.019	0.981	33.5	0.9590	1.0419

14.5	1.017	0.983	34	0.9584	1.0434
15	1.016	0.985	34.5	0.9569	1.0450
15.5	1.014	0.986	35	0.9556	1.0465
16	1.013	0.988	35.5	0.9541	1.0481
16.5	1.011	0.989	36	0.9527	1.0496
17	1.009	0.991	36.5	0.9513	1.0512
17.5	1.008	0.992	37	0.9499	1.0527
18	1.006	0.994	37.5	0.9485	1.0543
18.5	1.005	0.995	38	0.9471	1.0558
19	1.003	0.997	38.5	0.9457	1.0574
19.5	1.002	0.999	39	0.9444	1.0589
20	1.000	1.000	39.5	0.9430	1.0605
20.5	0.998	1.002	40	0.9416	1.0620
21	0.997	1.003	40.5	0.9402	1.0636
21.5	0.995	1.005	41	0.9389	1.0651
22	0.994	1.006	41.5	0.9375	1.0667
22.5	0.992	1.008	42	0.9362	1.0682
23	0.991	1.009	42.5	0.9348	1.0698
23.5	0.989	1.011	43	0.9334	1.0713
24	0.988	1.012	43.5	0.9321	1.0729
			44	0.9308	1.0744
			44.5	0.9294	1.0760
			45	0.9281	1.0775

NOTE –1 : Given in resistance of wire/stranded conductor at T^0 C, the resistance at 20^0 C, the resistance at 20^0 C is found by multiplying the resistance at T^0 C by the constant for T^0 C given in Column 2 and 5 conversely, given the resistance at 20^0 C the corresponding resistance at T^0 C is found by multiplying the resistance at 20^0 C by the reciprocal against T^0 C given in Column 3 & 6.

NOTE –2 : The temperature resistance co-efficients of a 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 0 C. There is some evidence to suggest that the co-efficients 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 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.

8.3.6.1 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 in strand	Percentage strength based on the strength of the 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 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 the copper wire bar/cadmium copper billet shall be tested for trace elements/impurities by spectrometer. The copper of copper wire bars shall be determined in accordance with IS : 440-1964. The chemical composition of copper wire bar shall be as given in TABLE-2. For oxygen content of copper wire bars, certificate from the manufacturer of copper shall be furnished. The cadmium content and phosphorous content in the cadmium copper billet shall be as per Clause 4.1.2. The trace elements/impurities in the cadmium copper billet shall not exceed the values given in TABLE – 2.

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 Director General (TI), RDSO to the manufacturer, he shall take up bulk manufacture of the conductor which shall be strictly with the same materials 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 an 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 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
- iv) Measurement of lay length and lay ratio of each layer of stranded conductor.
- v) Measurement of electrical resistance of wire.
- 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)

9.2 The tests shall be conducted as laid down in the relevant Clauses hereof.

9.3 SAMPLING

One sample of stranded conductor shall be taken from each drum for the tests prescribed in Clause 9.1. After visual examination, measurement of overall diameter, measurement of weight, and measurement of lay ratio of each layer, three samples of the wires shall be taken and subjected to the visual examination, measurement of diameter, measurement of weight, measurement of electrical resistance, tensile test and wrapping test.

9.4 CRITERIA FOR ACCEPTANCE.

The sample of wire and conductor taken from each drum shall be subjected to all the tests prescribed in Clause 9.1. 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 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 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.

10.0 **ROUTINE TESTS**

10.1 The tests indicated in Clause 9.1 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 rods for chemical composition. The samples will be drawn in accordance with IS : 191 (Pt. III) – 1980.

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. Similarly, if phosphorous content in any of the billets of the melt is more than 50 ppm, all the billets 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 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 test 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 produced to the Inspecting Engineer at the time of prototype testing and during Acceptance Tests.

12.0 PACKING AND MARKING

12.1 The cadmium copper stranded conductor shall be delivered to the purchaser properly wound on drums. 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. 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 manufacturing process.

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

12.3 The labelling 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 during stranding with identification of joints.
- f) Drum number and
- g) Purchase Order no. and the name of the consignee.

**Appendix - 'A' to
Specification No.ETI/OHE/50(6/97)**

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 :

- i) Furnaces for making cadmium copper alloy with suitable temperature measuring equipment.
 - ii) 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.
 - iii) Facility for chopping of the top of wire bars and scalping.
 - iv) Rolling Mill* for manufacture of 8 – 10 mm diameter wire rods.
 - v) Pickling, wire drawing and stranding equipment.
 - vi) 1-tonne Universal Tensile Testing Machine.
 - vii) 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 have 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 Director General (TI), RDSO by both the parties for registration/approval. In such a case of joint registration, withdrawal 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.ETI/OHE/50(6/97)**

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 (Sec 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	10.25	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	0.144.0
19	18.720	19.280	0.53.4
37	36.260	17.740	0.027.6

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.

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Specification No.ETI/OHE/50(6/97)

for

**Cadmium Copper Conductors
for Overhead Railway Traction.**

Addendum & Corrigendum Slip No. 1.

1. The following new Clause shall be added after the clause – 9.1(viii) :

Clause – 9.1(ix) “Weighment of 3 or 1/5th of offered catenary wire drums for acceptance test, whichever is higher, for gross weight. The inspector shall verify the results of manufacturer’s tests.”

2. The following new Clause shall be added after the clause – 11.5 :

Clause – 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.”
