Indian Standard

CONDUCTORS FOR INSULATED ELECTRIC CABLES AND FLEXIBLE CORDS — SPECIFICATION

(Second Revision)

1 SCOPE

1.1 This standard specifies the properties and construction of copper and aluminium conductors for insulated electric cables and flexible cords.

1.2 This standard does not apply to,

a) conductors for use in coils of machines or apparatus;
b) conductors without insulation, for use in aerial lines;
c) conductors for telecommunication purposes; and
d) conductors of special design, for example, hollow-core conductors.

2 REFERENCES

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

IS No.	*Title*
613 : 2000	Copper rods and bars for electrical purposes
1885 (Part 32) : 1993/IEC 50-461 : 1984	Electrotechnical vocabulary: Part 32 Electric cables
10810	Method of test for cables:
(Part 1) : 1984	Annealing test for wires used in conductors
(Part 2) : 1984	Tensile test for aluminium wires
(Part 3) : 1984	Wrapping test for aluminium wires
(Part 4) : 1984	Persulphate test of conductor
(Part 5) : 1984	Conductor resistance test

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 1885 (Part 32) and the following shall apply.

3.1 Metal Coated — Coated with a thin layer of suitable metal, such as tin or tin alloy.

3.2 Nominal Cross-Sectional Area — Value that identifies a particular size of conductor but is not subject to direct measurement.

3.3 Segmental Conductor — Circular conductor consisting of number of shaped or segment conductor and each separated by suitable separator. The number of segments or sector shaped conductor can be 4, 5 or 6.

NOTE — Each particular size of conductor in this standard is required to meet a maximum resistance value.

4 MATERIAL

4.1 Aluminium

The material for conductor shall consist of plain aluminium. It shall be one of the following grades with the corresponding tensile strength limits:

Grade	*Tensile Strength,* N /mm^2
0	Up to and including 100
H2	Above 100 and up to and including 150
H4	Above 150

a) For shaped solid conductors and the welding cable conductors, only Grade 0 aluminium shall be used;
b) For conductors of cross-sectional area up to and including 10 mm^2, H2 or H4 Grade aluminium shall be used; and
c) For the remaining conductors, aluminium of Grade 0, H2 or H4 may be used.

4.2 Copper

The conductors shall be made from high conductivity copper rods complying with IS 613. The conductors shall consist of tinned or untinned annealed copper as may be specified.

4.3 Form of Conductor

The conductors shall be solid, circular, shaped, compacted, stranded or bunched as required by the appropriate cable specification. The conductor shall be clean, reasonably uniform in size and shape, smooth and free from harmful defects.

4.4 Joints in Conductor

4.4.1 *Stranded Conductors*

Joints shall be permitted in the individual wires of which the conductor is formed, but no joint shall be within 300 mm of any other joint within the same layer. The joints shall be made by resistance butt welding, fusion welding, cold pressure welding, electric welding, gas welding, brazing or silver soldering.

4.4.2 *Solid Conductors (Aluminium Conductors only)*

No joints shall be made in the finished solid conductor.

5 CLASSIFICATION

5.1 The conductors have been divided into four classes as follows :

a) Cables for fixed installations — Classes 1 and 2
b) The flexibles — Classes 5 and 6
c) Copper welding cables — Class 6

5.2 Aluminium conductors for welding cables have not been assigned any class number.

6 CONSTRUCTION

6.1 Solid Conductor (Class 1)

6.1.1 The conductor shall consist of single wire of plain or tinned annealed copper or plain aluminium in accordance with Table 1.

6.1.2 Solid copper conductor shall be of circular cross-section.

6.1.3 Solid aluminium conductor of sizes from 10 mm^2 up to and including 35 mm^2 shall be of circular cross-section. Sizes 35 mm^2 and above may be of either circular or shaped cross-section.

6.2 Stranded Circular Non-compacted Conductors (Class 2)

6.2.1 Conductor shall consist of plain or tinned annealed copper or plain aluminium.

6.2.2 The wires in the conductor shall have the same nominal diameter before stranding.

6.2.3 The number of wires in the conductor shall be not less than the appropriate minimum number gives in Table 2.

6.3 Stranded Compacted Circular Conductors and Shaped Conductors (Class 2)

6.3.1 Conductor shall consist of plain or tinned annealed copper or plain aluminium.

6.3.2 The ratio of the diameters of two wires before stranding in the same conductor shall not exceed 2.

6.3.3 The number of wires in the conductor shall be not less than appropriate minimum number given in Table 2.

6.4 Flexible Conductors (Classes 5 and 6)

6.4.1 Conductor shall consist of plain or tinned annealed copper.

6.4.2 The wires in the conductor shall have same nominal diameter before bunching.

6.4.3 The diameter of the wires in any conductor shall not exceed the appropriate maximum value given in Table 3 for Class 5 and Table 4 for Class 6 conductors.

6.5 Flexible Aluminium Conductors for Welding Cables

6.5.1 Conductor shall consist of plain aluminium.

6.5.2 The wires in the conductor shall have same nominal diameter before stranding.

6.5.3 The diameter of wires in any conductor shall not exceed the appropriate maximum value given in Table 5.

7 TESTS

7.1 Tests for Copper Conductors

7.1.1 *Persulphate Test (for Tinned Copper only)*

This test shall be carried out in accordance with Method B given in IS 10810 (Part 4). The mass of copper dissolved shall not exceed the appropriate value given below:

Wire Diameter mm	*Permissible Mass of Copper Dissolved, Max* g/m^2
Up to and including 0.41	5
Above 0.41	3

7.1.2 *Annealing Test*

7.1.2.1 *Before standing*

This test shall be carried out in accordance with IS 10810 (Part 1). The elongation shall be not less than the appropriate value given below:

Wire Diameter		*Elongation, Min*
Over mm	Up to and Including mm	Percent
—	0.21	9.0
0.21	0.41	13.5
0.41	1.36	18.0
1.36	—	22.5

7.1.2.2 *After stranding*

Under consideration.

7.2 Tests for Aluminium Conductors

7.2.1 *Tensile Test*

This test shall be carried out in accordance with IS 10810 (Part 2). The sample shall meet the following requirements:

a) *Before stranding* — The tensile strength of any of the wires shall comply with the values given in **3.1**.

b) *After stranding* — The tensile strength of any of the wires shall be not less than 95 percent of the minimum values given in **3.1**.

NOTE — This test for wires taken from stranded conductors is not applicable in the case of compacted circular conductors or shaped conductors.

7.2.2 *Wrapping Test*

This test shall be done in accordance with IS 10810 (Part 3). The criteria for passing is that the wire shall not break.

NOTE — This test is not applicable to shaped solid conductors, wires taken from stranded conductors in case of compacted circular or shaped conductors and wires used for welding cable conductors.

7.2.3 *Annealing Test*

This test is applicable to shaped solid conductor and wires of conductor (before stranding) for welding cables only. The test shall be carried out in accordance with IS 10810 (Part 1). Shaped solid conductors shall have a minimum of 25 percent and wires of conductor for welding cables shall have a minimum of 12 percent elongation.

7.3 Resistance Test (for Both Copper and Aluminium)

This test shall be done on the finished conductors in accordance with IS 10810 (Part 5). The dc resistance of the conductor shall be measured at room temperature and corrected to 20°C by means of the appropriate factors given in Table 6.

7.3.1 The corrected dc resistance shall not exceed the values given in the appropriate Table 1 to Table 5.

8 PACKING AND MARKING

8.1 The conductor shall either be wound on reels or drums or supplied in coils packed and labelled. The label shall contain the name of the manufacturer, trade name, if any; size and length of the conductor.

NOTE — The requirements of packing and marking are not applicable when the processing of the conductor forms part of the manufacturing of complete cable.

8.2 BIS Certification Marking

The conductor (reel, drum or label) may also be marked with the Standard Mark.

8.2.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which a license for the use of the Standard Mark may be granted to the manufacturers or producers may be obtained from the Bureau of Indian Standards.

Table 1 Solid Conductors for Single Core and Multicore Cables (Class 1)

(*Clauses* 6.1.1 *and* 7.3.1)

Sl No.	Nominal Cross-Sectional Area	Maximum Resistance of Conductor at 20° C		
		Circular Copper Conductors		Aluminium Conductors Circular or Shaped
		Plain	Tinned	
	mm^2	Ω/km	Ω/km	Ω/km
(1)	(2)	(3)	(4)	(5)
i)	0.5	36.0	36.7	—
ii)	0.75	24.5	24.8	—
iii)	1	18.1	18.2	—
iv)	1.5	12.1	12.2	—
v)	2.5	7.41	7.56	—
vi)	4	4.61	4.70	—
vii)	6	3.08	3.11	—
viii)	10	1.83	1.84	3.08[2)]
ix)	16	1.15	1.16	1.91[2)]
x)	25	0.727[1)]	—	1.20[2)]
xi)	35	0.524[1)]	—	0.868[2)]
xii)	50	0.387[1)]	—	0.641
xiii)	70	0.268[1)]	—	0.443
xiv)	95	0.193[1)]	—	0.320[3)]
xv)	120	0.153[1)]	—	0.253[3)]
xvi)	150	0.124 [1)]	—	0.206[3)]
xvii)	185	—	—	0.164[3)]
xviii)	240	—	—	0.125[3)]
xix)	300	—	—	0.100[3)]

[1)] The solid copper conductors having nominal cross-sectional areas of 25 mm^2 and above are intended for particular types of cables only and not for general purpose.

[2)] Aluminium conductors 10 mm^2 to 35 mm^2 circular only.

[3)] For single core cables, four sectoral shaped conductor may be assembled into a single circular conductor.

Table 2 Stranded Conductors for Single Core and Multicore Cables (Class 2)

(*Clauses* 6.2.3, 6.3.3 *and* 7.3.1)

Sl No.	Nominal Cross-Sectional Area	Minimum Number of Wires in the Conductor				Maximum Resistance of Conductor at 20°C		
		Circular Conductor (Non-Compacted)		Circular Compacted or Shaped Conductor		Copper Conductor		Aluminium Conductor
						Plain Wires	Tinned Wires	
	mm^2	Cu	Al	Cu	Al	Ω/km	Ω/km	Ω/km
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	1	3	—	—	—	18.1	18.2	—
ii)	1.5	3	3	—	—	12.1	12.2	18.1
iii)	2.5	3	3	—	—	7.41	7.56	12.1
iv)	4	7	3	—	—	4.61	4.70	7.41
v)	6	7	3	—	—	3.08	3.11	4.61
vi)	10	7	7	6	—	1.83	1.84	3.08
vii)	16	7	7	6	6	1.15	1.16	1.91
viii)	25	7	7	6	6	0.727	0.734	1.20
ix)	35	7	7	6	6	0.524	0.529	0.868
x)	50	19	19	6	6	0.387	0.391	0.641
xi)	70	19	19	12	12	0.268	0.270	0.443
xii)	95	19	19	15	15	0.193	0.195	0.320
xiii)	120	37	37	18	15	0.153	0.154	0.253
xiv)	150	37	37	18	15	0.124	0.126	0.206
xv)	185	37	37	30	30	0.099 1	0.100	0.164
xvi)	240	61	37	34	30	0.075 4	0.076 2	0.125
xvii)	300	61	61	34	30	0.060 1	0.060 7	0.100
xviii)	400	61	61	53	53	0.047 0	0.047 5	0.077 8
xix)	500	61	61	53	53	0.036 6	0.036 9	0.060 5
xx)	630	91	91	53	53	0.028 3	0.028 6	0.046 9
xxi)	800[1)]	91	91	53	53	0.022 1	0.022 4	0.036 7
xxii)	1 000[1)]	91	91	53	53	0.017 6	0.017 7	0.029 1
xxiii)	1 200[2)]	—	[3)]	—	—	0.015 1	0.015 1	0.024 7
xxiv)	1 400[2)]	—	[3)]	—	—	0.012 9	0.012 9	0.021 2
xxv)	1 600[2)]	—	[3)]	—	—	0.011 3	0.011 3	0.018 6
xxvi)	1 800[2)]	—	[3)]	—	—	0.010 1	0.010 1	0.016 5
xxvii)	2 000[2)]	—	[3)]	—	—	0.009 0	0.009 0	0.014 9
xxviii)	2 500[2)]	—	[3)]	—	—	0.007 2	0.007 2	0.012 7

[1)] These are segmental conductors.

[2)] Can be either stranded or segmental.

[3)] The minimum number of wires for these sizes is not specified. These sizes may be constructed from 4, 5 or 6 equal segments (Milliken).

NOTE — In case 800 and 1 000 square mm if constructed as per segment construction then the minimum number of wires is not specified. However the number of segments can be 4, 5 or 6.

Table 3 Flexible Copper Conductors for Single Core and Multicore Cables (Class 5)

(*Clauses* 6.4.3 *and* 7.3.1)

Sl No.	Nominal Cross-Sectional Area	Maximum Diameter of Wires in Conductor	Maximum Resistance of Conductor at 20° C	
			Plain Wires	Tinned Wires
	mm^2	mm	Ω/km	Ω/km
(1)	(2)	(3)	(4)	(5)
i)	0.5	0.21	39.0	40.1
ii)	0.75	0.21	26.0	26.7
iii)	1	0.21	19.5	20.0
iv)	1.5	0.26	13.3	13.7
v)	2.5	0.26	7.98	8.21
vi)	4	0.31	4.95	5.09
vii)	6	0.31	3.30	3.39
viii)	10	0.41	1.91	1.95
ix)	16	0.41	1.21	1.24
x)	25	0.41	0.780	0.795
xi)	35	0.41	0.554	0.565
xii)	50	0.41	0.386	0.393
xiii)	70	0.51	0.272	0.277
xiv)	95	0.51	0.206	0.210
xv)	120	0.51	0.161	0.164
xvi)	150	0.51	0.129	0.132
xvii)	185	0.51	0.106	0.108
xviii)	240	0.51	0.080 1	0.081 7
xix)	300	0.51	0.064 1	0.065 4
xx)	400	0.51	0.048 6	0.049 5
xxi)	500	0.61	0.038 4	0.039 1
xxii)	630	0.61	0.028 7	0.029 2

Table 4 Flexible Copper Conductors for Single Core and Multicore Cables (Class 6)

(*Clauses* 6.4.3 *and* 7.3.1)

Sl No.	Nominal Cross-Sectional Area	Maximum Diameter of Wires in Conductor	Maximum Resistance of Conductor at 20°C	
			Plain Wires	Tinned Wires
	mm^2	mm	Ω/km	Ω/km
(1)	(2)	(3)	(4)	(5)
i)	0.5	0.16	39.0	40.1
ii)	0.75	0.16	26.0	26.7
iii)	1	0.16	19.5	20.0
iv)	1.5	0.16	13.3	13.7
v)	2.5	0.16	7.98	8.21
vi)	4	0.16	4.95	5.09
vii)	6	0.21	3.30	3.39
viii)	10	0.21	1.91	1.95
ix)	16	0.21	1.21	1.24
x)	25	0.21	0.780	0.795
xi)	35	0.21	0.554	0.565
xii)	50	0.31	0.386	0.393
xiii)	70	0.31	0.272	0.277
xiv)	95	0.31	0.206	0.210
xv)	120	0.31	0.161	0.164
xvi)	150	0.31	0.129	0.132
xvii)	185	0.41	0.106	0.108
xviii)	240	0.41	0.080 1	0.081 7
xix)	300	0.41	0.064 1	0.065 4

Table 5 Flexible Aluminium Conductors for Welding Cables

(*Clauses* 6.5.3 and 7.3.1)

Sl No.	Nominal Cross-Sectional Area	Maximum Diameter of Wires in Conductor	Maximum Resistance of Conductor at 20°C
	mm^2	mm	Ω/km
(1)	(2)	(3)	(4)
i)	25	0.31	1.23
ii)	35	0.31	0.901
iii)	50	0.31	0.634
iv)	70	0.31	0.445
v)	95	0.31	0.334
vi)	120	0.31	0.256

Table 6 Temperature Correction Factors k_t for Conductor Resistance to Correct the Measured Resistance at t °C to 20°C

(*Clause* 7.3)

Temperature of Conductor at time of Measurement	Correction Factor	Temperature of Conductor at Time of Measurement	Correction Factor
t °C	k_t	t °C	k_t
(1)	(2)	(1)	(2)
5	1.064	28	0.969
6	1.059	29	0.965
7	1.055	30	0.962
8	1.050	31	0.958
9	1.046	32	0.954
10	1.042	33	0.951
11	1.037	34	0.947
12	1.033	35	0.943
13	1.029	36	0.940
14	1.025	37	0.936
15	1.020	38	0.933
16	1.016	39	0.929
17	1.012	40	0.926
18	1.008	41	0.923
19	1.004	42	0.919
20	1.000	43	0.916
21	0.996	44	0.912
22	0.992	45	0.909
23	0.988	46	0.906
24	0.984	47	0.903
25	0.980	48	0.899
26	0.977	49	0.896
27	0.973	50	0.893

k_t is based on resistance temperature co-efficient of 0.004 per °C at 20°C using following formula :

$$k_t = \frac{1}{1+0.004\,(t-20)} = \frac{250}{230+t}$$