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Other IEC publications prepared by the same Technical Committee

The attention of readers is drawn to the inside of the back cover, which lists other IEC publications issued by the Technical Committee which has prepared the present publication.

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 20A, High-voltage Cables, of IEC Technical Committee No. 20, Electric Cables.

A draft was discussed at the meeting held in Oslo in 1976. As a result of this meeting, a draft, Document 20A(Central Office)60, was submitted to the National Committees for approval under the Six Months' Rule in June 1977.

The following countries voted explicitly in favour of publication:

Argentina	Italy
Australia	Japan
Austria	Netherlands
Belgium	Portugal
Denmark	Romania
Egypt	Spain
Finland	Sweden
France	Turkey
Germany	Union of Soviet Socialist Republics
Israel	United Kingdom

Other IEC publications quoted in this standard:

Publications Nos. 28: International Standard of Resistance for Copper.

111: Recommendation for the Resistivity of Commercial Hard-drawn Aluminium Electrical Conductor Wire.

CONDUCTORS OF INSULATED CABLES

INTRODUCTION

This standard is a revision of IEC Publication 228, it supersedes the First Edition dated 1966.

It is intended as a guide to the IEC Technical Committees in drafting standards for electric cables and to the National Committees in drafting specifications for use in their own countries. These Committees should select from the tables of this general standard the conductors appropriate to the particular applications with which they are concerned and either include the applicable details in their cable specifications or make appropriate references to this standard.

In preparing this edition the main objects have been to take account of experience and developments since the First Edition was published and to simplify the standard so far as is compatible with technical and economic considerations.

The number of classes of conductor has been reduced to four. There are two classes of conductors for cables for fixed installations; Class 1 is for solid conductors only and Class 2 for stranded conductors. For flexible conductors there are also two classes; as these correspond closely with Classes 5 and 6 of the 1966 edition, those class numbers have been retained to preserve continuity and avoid any confusion. Classes 3 and 4 have been omitted, since they have had relatively little use and Classes 2 and 5 respectively are considered suitable for most of the applications for which Classes 3 and 4 have been employed.

The number of different specified maximum resistance values for different types of conductor of the same nominal cross-sectional area has been reduced as follows:

For Classes 1 and 2, conductors of the same material and same nominal cross-sectional area have the same specified maximum resistances for both classes and for both single- and multicore cables and whether the conductors are circular, compacted circular or shaped. However, to avoid too large divergences from previous values, the differences in specified resistances between plain and metal-coated copper conductors have been retained.

Also in these two classes, the specified maximum resistance of each nominal cross-sectional area of aluminium conductor in the range up to and including 10 mm^2 is the same as for the next smaller standard size of copper conductor. The object of this is to provide equivalence of resistance between the small sizes of wiring cables with copper and aluminium conductors. For 16 mm^2 and above, separate resistances are retained between copper and aluminium conductors.

As metal-coated and metal-clad aluminium conductors are included for the first time, in order to avoid a proliferation of different resistance values for various materials in these categories, as well as aluminium alloys, the same resistances are specified for all these types of " aluminium " conductors. To achieve this standardization of resistance, there may be a variation in wire sizes used for the same nominal cross-sectional areas according to the particular material used.

The resistance values chosen for Classes 1 and 2 are those which were specified for Class 2 in the 1966 edition for multicore cables for the nominal cross-sectional areas from 2.5 mm^2 up to 400 mm^2 and for single core cables for the nominal cross-sectional areas above 400 mm^2. For the sizes up to 1.5 mm^2, for which the differences between the resistances of Class 1 and Class 2 conductors in the 1966 edition were larger than for the other sizes, the lower values specified for Class 1 in the 1966 edition for multicore cables have been adopted, in order to avoid any large increase in resistance values.

For flexible conductors of Classes 5 and 6, copper conductors only are included. The resistance values for these two classes are the same and correspond to the resistance values for multicore cables specified in the 1966 edition for Class 5, the difference between plain and metal-coated conductors again being retained.

As a result of the simplification achieved by combining resistances of single- and multicore cables and different forms of conductor into common resistance values, the method of calculation of resistances included in the 1966 edition is no longer strictly applicable and is now omitted. However, the following summary of the derivation of the present values from the previous values provides a means, if required, of determining their origin.

CLASS 1 AND CLASS 2

COPPER CONDUCTORS

Up to 1.5 mm²	As Class 1 multicore of 1966 edition.
2.5 mm² up to 400 mm²	As Class 2 multicore of 1966 edition.
500 mm² and above	As Class 2 single-core of 1966 edition.

ALUMINIUM CONDUCTORS

Up to 10 mm²	As next smaller standard nominal cross-sectional area of copper conductor.
16 mm² up to 400 mm²	As Class 2 multicore of 1966 edition.
500 mm² and above	As Class 2 single-core of 1966 edition.

CLASS 5 AND CLASS 6

As Class 5 multicore of 1966 edition.

Table V, specifying temperature correction factors, has been simplified by adopting the same factors for both copper and aluminium conductors. It is considered that this table gives practical values well within the accuracy which can normally be achieved in the measurement of conductor temperature and length of cable. However, more exact formulae for calculating correction factors for copper and aluminium conductors separately are also given.

1. Scope

This standard specifies the standardized nominal cross-sectional areas from 0.5 mm² to 2 000 mm², as well as numbers and diameters of wires and resistance values for conductors in electric cables and flexible cords.

It does not apply to conductors for telecommunication purposes, and it applies to conductors of special design only when stated in the specification for the type of cable. Conductors of special design are, for example, conductors for pressure cables, conductors in extra-flexible welding cables or in special types of flexible cables having the cores twisted together with unusually short lays.

2. Classification

The conductors have been divided into four classes: 1, 2, 5 and 6.

Those in Classes 1 and 2 are intended for use in cables for fixed installations, Class 1 being solid conductors and Class 2 stranded conductors.

Classes 5 and 6 are intended for use in flexible cables and cords, Class 6 being more flexible than Class 5.

3. Materials

The conductors may consist of:

— plain or metal-coated annealed copper

— or plain or metal-coated aluminium or aluminium alloy

— or metal-clad aluminium

— or metal-coated metal-clad aluminium

as specified for the different types of conductors in Clause 4.

The term " metal-coated " means coated with a thin layer of suitable metal, such as tin, tin alloy or lead alloy for the coating of copper, or copper, nickel or tin for the coating of aluminium or aluminium alloy.

The term "metal-clad aluminium" means wire consisting of a core of aluminium to which is metallurgically bonded an outer shell of another metal.

4. Cables for fixed installations

4.1 *Solid conductors (Class 1)*

Solid conductors shall comply with the following requirements:

4.1.1 The conductors shall consist of:

— plain or metal-coated annealed copper;

— or plain or metal-coated aluminium or aluminium alloy;

— or metal-clad aluminium;

— or metal-coated metal-clad aluminium.

4.1.2 Solid copper conductors shall be of circular cross-section.

The solid copper conductors having nominal cross-sectional areas of 25 mm² and above included in Table I are intended for particular types of cable only and not for general purposes.

4.1.3 Solid aluminium conductors of sizes up to and including 16 mm² shall be of circular cross-section. Sizes 25 mm² and above shall be of circular cross-section for single-core cables and may be of either circular or shaped cross-section for multicore cables.

Conductors with cross-sectional areas of 95 mm² and above may be subdivided into up to five sections.

4.1.4 The resistance of each conductor at 20 °C shall not exceed the appropriate maximum value given in Table I.

4.2 *Stranded circular non-compacted conductors (Class 2)*

Stranded circular non-compacted conductors shall comply with the following requirements:

4.2.1 Conductors shall consist of:

— plain or metal-coated annealed copper;
— or plain or metal-coated aluminium or aluminium alloy;
— or metal-clad aluminium;
— or metal-coated metal-clad aluminium.

Stranded aluminium conductors shall normally have a cross-sectional area not less than 10 mm², but 4 mm² and 6 mm² may be used subject to the special considerations of the suitability of the conductor for the type of cable and its applications.

4.2.2 The wires in each conductor shall all have the same nominal diameter.

4.2.3 The number of wires in each conductor shall be not less than the appropriate minimum number given in Table II. The minimum number of wires is not specified for cross-sectional areas from 1 200 mm² to 2 000 mm².

4.2.4 The resistance of each conductor at 20 °C shall not exceed the appropriate maximum value given in Table II.

4.3 *Stranded compacted circular conductors and stranded shaped conductors (Class 2)*

Stranded compacted circular conductors and stranded-shaped conductors shall comply with the following requirements:

4.3.1 Conductors shall consist of:

— plain or metal-coated annealed copper;
— or plain aluminium or aluminium alloy.

Stranded compacted circular aluminium conductors shall have a cross-sectional area not less than 16 mm². Stranded shaped copper or aluminium conductors shall have a cross-sectional area not less than 25 mm².

4.3.2 The ratio of the diameters of two different wires in the same conductor shall not exceed 2.

4.3.3 The number of wires in each conductor shall be not less than the appropriate minimum number given in Table II. The minimum number of wires is not specified for cross-sectional areas from 1 200 mm² to 2 000 mm².

4.3.4 The resistance of each conductor at 20 °C shall not exceed the appropriate maximum value given in Table II.

5. **Flexible conductors (Classes 5 and 6)**

Flexible conductors shall comply with the following requirements:

5.1 Conductors shall consist of plain or metal-coated annealed copper.

5.2 The wires in each conductor shall all have the same nominal diameter.

5.3 The diameter of the wires in each conductor shall not exceed the appropriate maximum value given in Table III or Table IV.

5.4 The resistance of each conductor at 20 °C shall not exceed the appropriate maximum value given in Table III or Table IV.

6. Check of compliance with Clauses 4 and 5

Compliance with the requirements of Sub-Clauses 4.1.1, 4.1.2, 4.1.3, 4.2.1, 4.2.2, 4.2.3, 4.3.1, 4.3.2, 4.3.3, 5.1, 5.2 and 5.3 shall be checked on the completed cable by inspection and by measurement where practicable.

Compliance with the requirements of Sub-Clauses 4.1.4, 4.2.4, 4.3.4 and 5.4 shall be checked either by measuring the resistance of the conductor over the complete length of cable or flexible cord and dividing by the length of the cable or flexible cord, or by similar measurements made on a sample of cable or flexible cord at least 1 m long.

If necessary, correction to 20 °C and 1 km length shall be made by applying the following formula:

$$R_{20} = R_t \times k_t \times \frac{1\,000}{L}$$

where:

R_{20} is the resistance at 20 °C, in ohms per kilometre

R_t is the measured resistance of L m of cable or flexible cord at t °C, in ohms

k_t is the temperature correction factor for resistance at the temperature of t °C

L is the length of the cable or flexible cord in metres

t is the temperature of the conductor at the time of measurement in degrees Celsius

Values of the temperature correction factor k_t are given in Table V for a normal range of temperatures. The values are based on the following formula:

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

This formula is approximate, but gives practical values well within the accuracies which can normally be achieved in the measurements of conductor temperature and length of cable or flexible cord.

The more exact formulae for the temperature correction factors for copper and aluminium are:

Copper conductors Plain or metal-coated

$$k_{tCu} = \frac{254.5}{234.5 + t} = \frac{1}{1 + 0.003\,93\ (t - 20)}$$

Aluminium or aluminium alloy Plain or metal-coated or metal-clad or metal-coated metal-clad.

$$k_{1Al} = \frac{248}{228 + t} = \frac{1}{1 + 0.004\,03\ (t - 20)}$$

The values for the temperature resistance coefficients are given in I E C Publication 28: International Standard of Resistance for Copper, and I E C Publication 111: Recommendation for the Resistivity of Commercial Hard-drawn Aluminium Electrical Conductor Wire.

TABLE I

Class 1

Solid conductors for single-core and multicore cables

1	2	3	4
Nominal cross-sectional area	Maximum resistance of conductor at 20 °C		
	Circular copper conductors		Aluminium conductors circular or shaped, plain, metal-coated or metal-clad
	Plain	Metal-coated	
mm²	Ω/km	Ω/km	Ω/km
0.5	36.0	36.7	—
0.75	24.5	24.8	—
1	18.1	18.2	—
1.5	12.1	12.2	18.1 [2]
2.5	7.41	7.56	12.1 [2]
4	4.61	4.70	7.41 [2]
6	3.08	3.11	4.61 [2]
10	1.83	1.84	3.08 [2]
16	1.15	1.16	1.91 [2]
25	0.727 [1]	—	1.20
35	0.524 [1]	—	0.868
50	0.387 [1]	—	0.641
70	0.268 [1]	—	0.443
95	0.193 [1]	—	0.320
120	0.153 [1]	—	0.253
150	0.124 [1]	—	0.206
185	—	—	0.164
240	—	—	0.125
300	—	—	0.100

[1] See Sub-clause 4.1.2.

[2] Aluminium conductors 1.5 mm² to 16 mm² circular only. See Sub-clause 4.1.3.

TABLE II

Class 2

Stranded conductors for single-core and multicore cables

1	2	3	4	5	6	7	8	9	10
Nominal cross-sectional area	Minimum number of wires in the conductor						Maximum resistance of conductor at 20 °C		
	Circular conductor (non-compacted)		Circular compacted conductor		Shaped conductor		Copper conductor		Aluminium conductor, plain metal-coated or metal-clad wires
							Plain wires	Metal-coated wires	
mm²	Cu	Al	Cu	Al	Cu	Al	Ω/km	Ω/km	Ω/km
0.5	7	—	—	—	—	—	36.0	36.7	—
0.75	7	—	—	—	—	—	24.5	24.8	—
1	7	—	—	—	—	—	18.1	18.2	—
1.5	7	—	6	—	—	—	12.1	12.2	—
2.5	7	—	6	—	—	—	7.41	7.56	—
4	7	7 [2]	6	—	—	—	4.61	4.70	7.41
6	7	7 [2]	6	—	—	—	3.08	3.11	4.61
10	7	7	6	—	—	—	1.83	1.84	3.08
16	7	7	6	6	—	—	1.15	1.16	1.91
25	7	7	6	6	6	6	0.727	0.734	1.20
35	7	7	6	6	6	6	0.524	0.529	0.868
50	19	19	6	6	6	6	0.387	0.391	0.641
70	19	19	12	12	12	12	0.268	0.270	0.443
95	19	19	15	15	15	15	0.193	0.195	0.320
120	37	37	18	15	18	15	0.153	0.154	0.253
150	37	37	18	15	18	15	0.124	0.126	0.206
185	37	37	30	30	30	30	0.0991	0.100	0.164
240	61	61	34	30	34	30	0.0754	0.0762	0.125
300	61	61	34	30	34	30	0.0601	0.0607	0.100
400	61	61	53	53	53	53	0.0470	0.0475	0.0778
500	61	61	53	53	53	53	0.0366	0.0369	0.0605
630	91	91	53	53	53	53	0.0283	0.0286	0.0469
800	91	91	53	53	—	—	0.0221	0.0224	0.0367
1 000	91	91	53	53	—	—	0.0176	0.0177	0.0291
1 200	[1]		[1]		—		0.0151		0.0247
(1 400) [3]	[1]		[1]		—		0.0129		0.0212
1 600	[1]		[1]		—		0.0113		0.0186
(1 800) [3]	[1]		[1]		—		0.0101		0.0165
2 000	[1]		[1]		—		0.0090		0.0149

[1] Minimum number of wires not specified.

[2] See Sub-clause 4.2.1.

[3] The sizes in brackets are non-preferred.

TABLE III

Class 5

Flexible copper conductors for single-core and multicore cables

1	2	3	4
Nominal cross-sectional area	Maximum diameter of wires in conductor	Maximum resistance of conductor at 20 °C	
		Plain wires	Metal-coated wires
mm²	mm	Ω/km	Ω/km
0.5	0.21	39.0	40.1
0.75	0.21	26.0	26.7
1	0.21	19.5	20.0
1.5	0.26	13.3	13.7
2.5	0.26	7.98	8.21
4	0.31	4.95	5.09
6	0.31	3.30	3.39
10	0.41	1.91	1.95
16	0.41	1.21	1.24
25	0.41	0.780	0.795
35	0.41	0.554	0.565
50	0.41	0.386	0.393
70	0.51	0.272	0.277
95	0.51	0.206	0.210
120	0.51	0.161	0.164
150	0.51	0.129	0.132
185	0.51	0.106	0.108
240	0.51	0.0801	0.0817
300	0.51	0.0641	0.0654
400	0.51	0.0486	0.0495
500	0.61	0.0384	0.0391
630	0.61	0.0287	0.0292

TABLE IV

Class 6

Flexible copper conductors for single-core and multicore cables

1	2	3	4
Nominal cross-sectional area	Maximum diameter of wires in conductor	Maximum resistance of conductor at 20 °C	
		Plain wires	Metal-coated wires
mm²	mm	Ω/km	Ω/km
0.5	0.16	39.0	40.1
0.75	0.16	26.0	26.7
1	0.16	19.5	20.0
1.5	0.16	13.3	13.7
2.5	0.16	7.98	8.21
4	0.16	4.95	5.09
6	0.21	3.30	3.39
10	0.21	1.91	1.95
16	0.21	1.21	1.24
25	0.21	0.780	0.795
35	0.21	0.554	0.565
50	0.31	0.386	0.393
70	0.31	0.272	0.277
95	0.31	0.206	0.210
120	0.31	0.161	0.164
150	0.31	0.129	0.132
185	0.41	0.106	0.108
240	0.41	0.0801	0.0817
300	0.41	0.0641	0.0654

TABLE V

Temperature correction factors k_t for conductor resistance to correct the measured resistance at t °C to 20 °C

Temperature of conductor at time of measurement t °C	Correction factor k_t
5	1.064
6	1.059
7	1.055
8	1.050
9	1.046
10	1.042
11	1.037
12	1.033
13	1.029
14	1.025
15	1.020
16	1.016
17	1.012
18	1.008
19	1.004
20	1.000
21	0.996
22	0.992
23	0.988
24	0.984
25	0.980
26	0.977
27	0.973
28	0.969
29	0.965
30	0.962

The values of correction factors k_t in the table are based on a resistance–temperature coefficient of 0.004 per °C at 20 °C. See Clause 6.