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Third edition
2004-11

Âmes des câbles isolés

Conductors of insulated cables

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CONDUCTORS OF INSULATED CABLES

FOREWORD

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International Standard IEC 60228 has been prepared by IEC technical committee 20: Electric cables.

This third edition cancels and replaces the IEC 60228 (1978), its Amendment 1 (1993) and its first supplement, IEC 60228A (1982).

The principal changes with respect to the previous edition are as follows:

a) the consolidation of material from IEC 60228A;
b) addition of a definition for nominal cross-sectional area;
c) an increase in the range of conductor sizes in Tables 1 and 2;
d) addition of a note that solid aluminum alloy conductors, having the same dimensions as aluminum conductors, will have a higher resistance;
e) strengthening of the recommendations for dimensional limits of compacted stranded copper conductors.

The text of this standard is based on the following documents:

FDIS	Report on voting
20/718/FDIS	20/737/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

Conductors described in IEC 60228 are specified in metric sizes. Canada at present uses conductor sizes and characteristics according to the American Wire Gauge (AWG) system and kcmil for larger sizes as shown below. The use of these sizes is currently prescribed uniformly across Canada for installations by sub-national regulations. IEC TC 20 cable product standards do not prescribe cables with AWG/kcmil conductors.

AWG				kcmil			
Conductor size	**Nominal cross-sectional area mm^2**	**Conductor size**	**Nominal cross-sectional area mm^2**	**Conductor size**	**Nominal cross-sectional area mm^2**	**Conductor size**	**Nominal cross-sectional area mm^2**
-	-	-	-	250	127	750	380
-	-	-	-	300	152	800	405
20	0,519	4	21,2	350	177	900	456
18	0,823	3	26,7	400	203	1000	507
16	1,31	2	33,6	450	228	1200	608
14	2,08	1	42,4	500	253	1250	633
12	3,31	1/0	53,5	550	279	1500	760
10	5,26	2/0	67,4	600	304	1750	887
8	8,37	3/0	85,0	650	329	2000	1010
6	13,3	4/0	107	700	355	-	-

INTRODUCTION

IEC 60228 is intended as a fundamental reference standard for IEC Technical Committees and National 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 incorporate IEC 60228A into it and maintain a simplified yet informative standard so far as is compatible with technical and economic considerations.

CONDUCTORS OF INSULATED CABLES

1 Scope

This International Standard specifies the nominal cross-sectional areas, in the range 0,5 mm^2 to 2 500 mm^2, for conductors in electric power cables and cords of a wide range of types. Requirements for numbers and sizes of wires and resistance values are also included. These conductors include solid and stranded copper, aluminium and aluminium alloy conductors in cables for fixed installations and flexible copper conductors.

The standard does not apply to conductors for telecommunication purposes.

The applicability of this standard to a particular type of cable is as specified in the standard for the type of cable.

Unless indicated to the contrary in a particular clause, this standard relates to the conductors in the finished cable and not to the conductor as made or supplied for inclusion into a cable.

Informative annexes are included giving supplementary information covering temperature correction factors for resistance measurement (Annex B) and dimensional limits of circular conductors (Annex C).

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
metal-coated
coated with a thin layer of suitable metal, such as tin or tin alloy

2.2
nominal cross-sectional area
value that identifies a particular size of conductor but is not subject to direct measurement

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

3 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. Classes 5 and 6 are intended for use in flexible cables and cords but may also be used for fixed installations.

- Class 1: solid conductors.
- Class 2: stranded conductors.
- Class 5: flexible conductors.
- Class 6: flexible conductors which are more flexible than class 5.

4 Materials

4.1 Introduction

The conductors shall consist of one of the following:

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

4.2 Solid aluminium conductors

Circular and shaped solid aluminium conductors shall be made from aluminium such that the tensile strength of the completed conductor is within the following limits:

Nominal cross-sectional area mm²	Tensile strength N/mm²
10 and 16	110 to 165
25 and 35	60 to 130
50	60 to 110
70 and above	60 to 90

NOTE The values given above are not applicable to aluminium alloy conductors.

4.3 Circular and shaped stranded aluminium conductors

Stranded aluminium conductors shall be made from aluminium such that the tensile strength of the individual wires is within the following limits:

Nominal cross-sectional area mm²	Tensile strength N/mm²
10	up to 200
16 and above	125 to 205

NOTE 1 The values given above are not applicable to aluminium alloy conductors.

NOTE 2 This data can only be checked on wires taken before stranding and not on wires taken from a stranded conductor.

5 Solid conductors and stranded conductors

5.1 Solid conductors (class 1)

5.1.1 Construction

a) Solid conductors (class 1) shall consist of one of the materials specified in Clause 4.

b) Solid copper conductors shall be of circular cross-section.

NOTE Solid copper conductors having nominal cross-sectional areas of 25 mm² and above are for particular types of cable, e.g. mineral insulated, and not for general purposes.

c) Solid aluminium and solid aluminium alloy conductors of sizes 10 mm² to 35 mm² shall be of circular cross-section. Larger sizes shall be of circular cross-section for single-core cables and may be of either circular or shaped cross-section for multi-core cables.

5.1.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 7, shall not exceed the appropriate maximum value given in Table 1.

NOTE For solid aluminium alloy conductors, having the same nominal cross-sectional area as an aluminium conductor the resistance value given in Table 1 should be multiplied by a factor of 1,162 unless otherwise agreed between the manufacturer and the purchaser.

5.2 Stranded circular non-compacted conductors (class 2)

5.2.1 Construction

a) Stranded circular non-compacted conductors (class 2) shall consist of one of the materials specified in Clause 4.

b) Stranded aluminium or aluminium alloy conductors shall have a cross-sectional area not less than 10 mm^2.

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

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

5.2.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 7, shall not exceed the appropriate maximum value given in Table 2.

5.3 Stranded compacted circular conductors and stranded shaped conductors (class 2)

5.3.1 Construction

a) Stranded compacted circular conductors and stranded shaped conductors (class 2) shall consist of one of the materials specified in Clause 4. Stranded compacted circular aluminium or aluminium alloy conductors shall have a nominal cross-sectional area not less than 10 mm^2. Stranded shaped copper, aluminium or aluminium alloy conductors shall have a nominal cross-sectional area of not less than 25 mm^2.

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

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

NOTE This requirement applies to conductors made with wires of circular cross-section before compaction and not to conductors made with pre-shaped wires.

5.3.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 7, shall not exceed the appropriate value given in Table 2.

6 Flexible conductors (classes 5 and 6)

6.1 Construction

a) Flexible conductors (classes 5 and 6) shall consist of plain or metal-coated annealed copper.

b) The wires in each conductor shall have the same nominal diameter.

c) The diameter of the wires in each conductor shall not exceed the appropriate maximum value given in Tables 3 or 4.

6.2 Resistance

The resistance of each conductor at 20 °C, when determined in accordance with Clause 7, shall not exceed the appropriate maximum value given in Tables 3 or 4.

7 Check of compliance with Clauses 5 and 6

Compliance with the requirements of 5.1.1, 5.2.1, 5.3.1 and 6.1 shall be checked on the completed cable by inspection and measurement where practicable.

Compliance with the requirements for resistance given in 5.1.2, 5.2.2, 5.3.2 and 6.2 shall be checked by measurement in accordance with Annex A and corrected for temperature by the factors in Table A.1.

Table 1 – 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, annealed copper conductors		Aluminium and aluminium alloy conductors, circular or shaped [c]
	Plain	Metal-Coated	
mm^2	Ω/km	Ω/km	Ω/km
0,5	36,0	36,7	-
0,75	24,5	24,8	-
1,0	18,1	18,2	-
1,5	12,1	12,2	-
2,5	7,41	7,56	-
4	4,61	4,70	-
6	3,08	3,11	-
10	1,83	1,84	3,08 [a]
16	1,15	1,16	1,91 [a]
25	0,727 [b]	-	1,20 [a]
35	0,524 [b]	-	0,868 [a]
50	0,387 [b]	-	0,641
70	0,268 [b]	-	0,443
95	0,193 [b]	-	0,320 [d]
120	0,153 [b]	-	0,253 [d]
150	0,124 [b]	-	0,206 [d]
185	0,101 [b]	-	0,164 [d]
240	0,0775 [b]	-	0,125 [d]
300	0,0620 [b]	-	0,100 [d]
400	0,0465 [b]	-	0,0778
500	-	-	0,0605
630	-	-	0,0469
800	-	-	0,0367
1 000	-	-	0,0291
1 200	-	-	0,0247

[a] Aluminium conductors 10 mm^2 to 35 mm^2 circular only; see 5.1.1 c).

[b] See note to 5.1.1 b).

[c] See note to 5.1.2.

[d] For single core cables, four sectoral shaped conductors may be assembled into a single circular conductor. The maximum resistance of the assembled conductor shall be 25 % of that of the individual component conductors.

Table 2 – Class 2 stranded conductors for single-core and multi-core 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		Circular compacted		Shaped		Annealed copper conductor		Aluminium or aluminium alloy conductor[c]
	Cu	Al	Cu	Al	Cu	Al	Plain wires	Metal-coated wires	
mm²							Ω/km	Ω/km	Ω/km
0,5	7	-	-	-	-	-	36,0	36,7	-
0,75	7	-	-	-	-	-	24,5	24,8	-
1,0	7	-	-	-	-	-	18,1	18,2	-
1,5	7	-	6	-	-	-	12,1	12,2	-
2,5	7	-	6	-	-	-	7,41	7,56	-
4	7	-	6	-	-	-	4,61	4,70	-
6	7	-	6	-	-	-	3,08	3,11	-
10	7	7	6	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	37	37	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	[b]						0,0151	0,0151	0,0247
1 400 [a]	[b]						0,0129	0,0129	0,0212
1 600	[b]						0,0113	0,0113	0,0186
1 800 [a]	[b]						0,0101	0,0101	0,0165
2 000	[b]						0,0090	0,0090	0,0149
2 500	[b]						0,0072	0,0072	0,0127

[a] These sizes are non-preferred. Other non-preferred sizes are recognized for some specialized applications but are not within the scope of this standard.

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

[c] For stranded aluminium alloy conductors having the same nominal cross-sectional area as an aluminium conductor the resistance value should be agreed between the manufacturer and the purchaser.

Table 3 – Class 5 flexible copper conductors for single core and multi-core 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
mm^2	mm	Ω/km	Ω/km
0,5	0,21	39,0	40,1
0,75	0,21	26,0	26,7
1,0	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 4 – Class 6 flexible copper conductors for single-core and multi-core 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
mm^2	mm	Ω/km	Ω/km
0,5	0,16	39,0	40,1
0,75	0,16	26,0	26,7
1,0	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

Annex A
(normative)

Measurement of resistance

The cable shall be kept in the test area for sufficient time to ensure that the conductor temperature has reached a level which permits an accurate determination of resistance using the correction factors provided.

Measure the d.c. resistance of the conductor(s), either on a complete length of cable or flexible cord or on a sample of cable or flexible cord of at least 1 m in length, at room temperature and record the temperature at which the measurement is made. Adjust the measured resistance by means of the correction factors given in Table A.1.

Calculate the resistance per kilometre length of cable from the length of the complete cable and not from the length of the individual core or wires.

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

k_t is the temperature correction factor from Table A.1;

R_{20} is the conductor resistance at 20 °C, in Ω/km;

R_t is the measured conductor resistance, in Ω;

L is the length of the cable, in m.

Table A.1 – Temperature correction factors k_t for conductor resistance to correct the measured resistance at t °C to 20 °C

1	2	1	2
Temperature of conductor at time of measurement t °C	**Correction factor, k_t All conductors**	**Temperature of conductor at time of measurement** t °C	**Correction factor, k_t All conductors**
0	1,087	21	0,996
1	1,082	22	0,992
2	1,078	23	0,988
3	1,073	24	0,984
4	1,068	25	0,980
5	1,064	26	0,977
6	1,059	27	0,973
7	1,055	28	0,969
8	1,050	29	0,965
9	1,046	30	0,962
10	1,042	31	0,958
11	1,037	32	0,954
12	1,033	33	0,951
13	1,029	34	0,947
14	1,025	35	0,943
15	1,020	36	0,940
16	1,016	37	0,936
17	1,012	38	0,933
18	1,008	39	0,929
19	1,004	40	0,926
20	1,000		

NOTE The values of correction factors k_t are based on a resistance-temperature coefficient of 0,004 per K at 20 °C.

The values of temperature correction factors specified in column 2 are approximate but give practical values well within the accuracy that can normally be achieved in the measurements of conductor temperature and length of cables or flexible cords.

For more accurate values for the temperature correction factors for copper and aluminium, reference should be made to Annex B. However, these should not be treated as a requirement for testing in compliance with this standard in the assessment of resistances.

Annex B
(informative)

Exact formulae for the temperature correction factors

a) Annealed copper conductors: plain or metal coated

$$k_{t,Cu} = \frac{254,5}{234,5 + t} = \frac{1}{1 + 0,00393\,(t - 20)}$$

b) Aluminium conductors

$$k_{t,Al} = \frac{248}{228 + t} = \frac{1}{1 + 0,00403\,(t - 20)}$$

NOTE For aluminium alloys, reference should be made to the manufacturer.

In all the above cases, t refers to the temperature of the conductor at the time of measurement in degrees Celsius.

Annex C
(informative)

Guidance on the dimensional limits of circular conductors

C.1 Object

This annex is intended as a guide to manufacturers of cables and cable connectors to assist in ensuring that the conductors and connectors are dimensionally compatible. It gives guidance on dimensional limits for the following types of conductor included in this standard:

a) circular solid conductors, (class 1) of copper, aluminium and aluminium alloy;

b) circular and compacted circular stranded conductors, (class 2), of copper, aluminium and aluminium alloy.

c) flexible conductors, (classes 5 and 6), of copper.

C.2 Dimensional limits for circular copper conductors

The diameters of circular copper conductors should not exceed the values given in Table C.1.

If minimum diameters for class 1 circular copper conductors are needed, reference can be made to the minimum diameters for solid circular aluminium or aluminium alloy conductors indicated in Table C.3.

C.3 Dimensional limits for stranded compacted circular copper, aluminium and aluminium alloy conductors

The diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.2.

In the exceptional case of uncompacted circular stranded aluminium or aluminium alloy conductors the maximum diameters should not exceed the corresponding values for copper conductors given in column 3 of Table C.1.

C.4 Dimensional limits for circular solid aluminium conductors

The diameters of circular solid aluminium and aluminium alloy conductors should not exceed the maximum values and should be not less than the minimum values given in Table C.3.

Table C.1 – Maximum diameters of circular copper conductors – solid, non-compacted stranded and flexible

1	2	3	4
Cross sectional area mm²	Conductors in cables for fixed installations		Flexible conductors (Classes 5 and 6) mm
	Solid (Class 1) mm	Stranded (Class 2) mm	
0,5	0,9	1,1	1,1
0,75	1,0	1,2	1,3
1,0	1,2	1,4	1,5
1,5	1,5	1,7	1,8
2,5	1,9	2,2	2,4
4	2,4	2,7	3,0
6	2,9	3,3	3,9
10	3,7	4,2	5,1
16	4,6	5,3	6,3
25 [a]	5,7	6,6	7,8
35 [a]	6,7	7,9	9,2
50 [a]	7,8	9,1	11,0
70 [a]	9,4	11,0	13,1
95 [a]	11,0	12,9	15,1
120 [a]	12,4	14,5	17,0
150 [a]	13,8	16,2	19,0
185	15,4	18,0	21,0
240	17,6	20,6	24,0
300	19,8	23,1	27,0
400	22,2	26,1	31,0
500	-	29,2	35,0
630	-	33,2	39,0
800	-	37,6	-
1 000	-	42,2	-

NOTE The values given for flexible conductors are intended to allow for both class 5 and class 6 conductors.

[a] See 5.1.1 b).

Table C.2 – Minimum and maximum diameters of stranded compacted circular copper, aluminium and aluminium alloy conductors

1	2	3
	Stranded compacted circular conductors (Class 2)	
Cross-sectional area	Minimum diameter	Maximum diameter
mm^2	mm	mm
10	3,6	4,0
16	4,6	5,2
25	5,6	6,5
35	6,6	7,5
50	7,7	8,6
70	9,3	10,2
95	11,0	12,0
120	12,3	13,5
150	13,7	15,0
185	15,3	16,8
240	17,6	19,2
300	19,7	21,6
400	22,3	24,6
500	25,3	27,6
630	28,7	32,5
NOTE 1 The dimensional limits of aluminium conductors with cross-sectional areas above 630 mm^2 are not given as the compaction technology is not generally established.		
NOTE 2 No values are given for compacted copper conductors in the size range 1,5 mm^2 to 6 mm^2.		

Table C.3 – Minimum and maximum diameters of solid circular aluminium conductors

1	2	3
Cross-sectional area	Solid conductors (class 1)	
	Minimum	Maximum
mm^2	mm	mm
10	3,4	3,7
16	4,1	4,6
25	5,2	5,7
35	6,1	6,7
50	7,2	7,8
70	8,7	9,4
95	10,3	11,0
120	11,6	12,4
150	12,9	13,8
185	14,5	15,4
240	16,7	17,6
300	18,8	19,8
400	21,2	22,2
500	24,0	25,1
630	27,3	28,4
800	30,9	32,1
1 000	34,8	36,0
1 200	37,8	39,0

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3, rue de Varembé
1211 Genève 20
Switzerland

or

Fax to: **IEC**/CSC at +41 22 919 03 00

Thank you for your contribution to the standards-making process.

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A Prioritaire

RÉPONSE PAYÉE

SUISSE

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International Electrotechnical Commission
3, rue de Varembé
1211 GENEVA 20
Switzerland

Enquête sur les normes

La CEI ambitionne de vous offrir les meilleures normes possibles. Pour nous assurer que nous continuons à répondre à votre attente, nous avons besoin de quelques renseignements de votre part. Nous vous demandons simplement de consacrer un instant pour répondre au questionnaire ci-après et de nous le retourner par fax au +41 22 919 03 00 ou par courrier à l'adresse ci-dessous. Merci !

Centre du Service Clientèle (CSC)

Commission Electrotechnique Internationale
3, rue de Varembé
1211 Genève 20
Suisse

ou

Télécopie: **CEI**/CSC +41 22 919 03 00

Nous vous remercions de la contribution que vous voudrez bien apporter ainsi à la Normalisation Internationale.

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