Specification for

Aluminium alloy stranded conductors for overhead power transmission

Co-operating organizations

The Non-ferrous Metals Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Aluminium Federation*
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Association of Consulting Engineers
Board of Trade
British Bronze and Brass Ingot Manufacturers' Association
British Electrical and Allied Manufacturers' Association*
British Lead Manufacturers' Association
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British Railways Board
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
Institute of Iron and Steel Wire Manufacturers
Institute of Sheet Metal Engineering

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Contents

Foreword

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 5 000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price £ 1. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 18, *Methods for tensile testing of metals.*

BS 3239, *Determination of resistivity of metallic electrical conductor materials.*

This British Standard was first published in 1960. In this revision all dimensions are included in metric units and the requirements of the standard have been amended to conform substantially with those of I.E.C. Publication 208, *"Aluminium alloy stranded conductors".*

As a result there are a number of changes in the specification. Lay ratio is now defined as the ratio of the axial length of a complete turn of the helix to the external diameter of the helix instead of to the mean diameter of the helix as hitherto. The basis for calculating conductor breaking loads has been altered. Values of the moduli of elasticity quoted in an appendix are practical values obtained by test, which are considered to be of more practical significance than the calculated values formerly quoted.

In the course of metrication the sizes of standard conductors, of which the number has been restricted, have been maintained unchanged except for negligible differences due to the expression of wire diameters in millimetres.

The sizes of aluminium alloy conductors are designated by nominal aluminium areas (mm^2) in place of the formerly used nominal copper areas (in^2). It follows from this that the nominal aluminium areas refer to hard drawn electrical purity aluminium.

At the present time there is an increasing use of conductors of constructions other than those covered in this standard. To facilitate standardization of these constructions lay ratio limits and the appropriate stranding factors are included in an appendix.

All stresses are quoted in terms of the hectobar (hbar)[1)].

Other British Standards dealing with aluminium conductors for overhead lines are listed below:

BS 215, *Aluminium conductors and aluminium conductors, steel-reinforced for overhead power transmission.*

BS 215-1, *Aluminium stranded conductors.*

BS 215-2, *Aluminium conductors, steel-reinforced.*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1)] 1 hbar = 10 MN/m^2 = 10 N/mm^2.

1 General

1.1 Scope

This British Standard applies to aluminium alloy stranded conductors for overhead power transmission.

1.2 Definitions

For the purposes of this British Standard the following definitions apply.

1.2.1
stranded conductor

a conductor consisting of seven or more aluminium alloy wires of the same nominal diameter twisted together in concentric layers. When the conductor consists of more than one layer, successive layers are twisted in opposite directions

1.2.2
diameter

the mean of two measurements at right angles taken at the same cross section

1.2.3
direction of lay

the direction of lay is defined as right-hand or left-hand. With right-hand lay, the wires conform to the direction of the central part of the letter Z when the conductor is held vertically. With left-and lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically

1.2.4
lay ratio

the ratio of the axial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix

1.2.5
heat-treatment batch

one furnace load of material heat-treated at the same time, at the same temperature and for the same length of time

for other definitions, reference should be made to BS 205[2)]

1.3 Standards for aluminium alloy wire

1.3.1 Resistivity. For the purposes of this British Standard, the standard value of resistivity of aluminium alloy which shall be used for calculation is taken as 3.25 μ Ω cm at 20 °C. The maximum value permitted is 3 . 28 μ Ω cm at 20 °C.

1.3.2 Density. At a temperature of 20 °C, the density of aluminium alloy wire is to be taken as 2.70 g/cm^3.

1.3.3 Coefficient of linear expansion. The coefficient of linear expansion of aluminium alloy wire is to be taken as 23×10^{-6}/°C.

1.3.4 Constant mass temperature coefficient. At a temperature of 20 °C the "constant mass" temperature coefficient of resistance of aluminium alloy wire, measured between two potential points rigidly fixed to the wire, is taken as 0.003 60/°C.

2 Material

The conductor shall be constructed of heat-treated aluminium-magnesium-silicon alloy wires having the mechanical and electrical properties specified in this British Standard.

NOTE A suitable material is one containing amounts of magnesium and silicon appropriate to the mechanical and electrical properties specified and containing not more than 0.05 % copper.

By agreement between the purchaser and the manufacturer a suitable grease may be applied to the centre wire, or additionally to wires in specific layers, evenly throughout the length of the conductor.

3 Dimensions and construction

3.1 Standard sizes of wires

After drawing and heat treatment, the aluminium alloy wires for the standard constructions covered by this specification shall have the diameters specified in Table 2.

3.2 Tolerances on the standard diameters of wires

A tolerance of ± 1 % is permitted on the standard diameters of all wires. The cross section of any wire shall not depart from circularity by more than an amount corresponding to a tolerance of 1 % on the standard diameter.

3.3 Standard sizes of aluminium alloy stranded conductors

The sizes of standard aluminium alloy stranded conductors are given in Table 3.

The masses (excluding the mass of grease for corrosion protection) and resistances may be taken as being in accordance with Table 3.

[2)] BS 205, "Glossary of terms used in electrical engineering".

3.4 Joints in wires

3.4.1 Conductors containing seven wires. There shall be no joint in any wire of a stranded conductor containing seven wires, except those made in the base rod or wire before final drawing.

3.4.2 Conductors containing more than seven wires. In stranded conductors containing more than seven wires, in addition to joints made in the base rod before final drawing, joints in individual wires made by cold-pressure butt-welding are permitted in any layer and those made by resistance butt-welding are permitted in any layer except the outermost layer. No two such joints shall be less than 15 m apart in the complete stranded conductor. They are not required to fulfil the mechanical or electrical requirements for unjointed wires. Joints made by resistance butt-welding shall, subsequent to welding, be annealed over a distance of at least 200 mm on each side of the joint.

3.5 Stranding

3.5.1 The wire used in the construction of a stranded conductor shall, before stranding, satisfy all the relevant requirements of this standard.

3.5.2 The lay ratio of the different layers shall be within the limits given in Table 1.

NOTE It is important to note that lay ratio is now defined as the ratio of the axial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the *external* diameter of the helix.

3.5.3 In all constructions, the successive layers shall have opposite directions of lay, the outermost layer being right-handed. The wires in each layer shall be evenly and closely stranded.

3.5.4 In aluminium alloy stranded conductors having multiple layers of wires, the lay ratio of any layer shall be not greater than the lay ratio of the layer immediately beneath it.

3.6 Completed conductor

The completed conductor shall be free from dirt, grit, excessive amounts of drawing oil and other foreign deposits.

4 Tests

4.1 Selection of test samples

4.1.1 Samples for the tests specified in **4.3** and **4.4** shall be taken by the manufacturer before stranding, from not less than 10 % of the individual lengths of aluminium alloy wire included in any one final heat-treatment batch. One sample, sufficient to provide one test specimen for each test, shall be taken from each of the selected lengths of wire.

4.1.2 Alternatively, when the purchaser states at the time of ordering that he desires tests to be made in the presence of his representative, samples of wire shall be taken from lengths of stranded conductor selected from approximately 10 % of the lengths included in any one consignment. One sample, sufficient to provide one specimen, for each of the appropriate tests, shall be taken from each of an agreed number of wires of the conductor in each of the selected lengths.

4.2 Place of testing

Unless otherwise agreed between the purchaser and the manufacturer at the time of ordering, all tests shall be made at the manufacturer's works.

4.3 Mechanical tests

4.3.1 Tensile test. The test shall be made in accordance with BS 18[3], on a specimen cut from each of the samples taken as specified in **4.1.1** or **4.1.2**. The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm/min and not greater than 100 mm/min.

Table 1 — Lay ratios for aluminium alloy stranded conductors

1	2	3	4	5	6	7
Number of wires in conductor	Lay ratio					
	6-wire layer		12-wire layer		18-wire layer	
	min.	max.	min.	max.	min.	max.
7	10	14	—	—	—	—
19	10	16	10	14	—	—
37	10	17	10	16	10	14

[3] BS 18, "Methods for tensile testing of metals".

When tested before or after stranding, the tensile strength of the specimen shall be not less than 29. 5 hbar[4)].

4.3.2 Elongation test. The test shall be made in accordance with BS 18[5)].The load shall be applied gradually and uniformly on a specimen cut from each of the samples taken as specified in **4.1.1** or **4.1.2** having an original gauge length of 250 mm.

The elongation shall be measured on the gauge length after the fractured ends have been fitted together. The determination shall be valid, whatever the position of the fracture, if the specified value is reached. If the specified value is not reached, the determination shall be valid only if the fracture occurs between the gauge marks and not closer than 25 mm to either mark.

When tested before or after stranding, the elongation shall be not less than 3.5 %.

4.4 Electrical resistivity test

The resistivity of one specimen cut from each of the samples taken as specified in **4.1.1** or **4.1.2** shall be determined in accordance with the routine method given in BS 3239[6)].

The resistivity at 20 °C shall not exceed 3.28 μ Ω cm.

4.5 Certificate of compliance

When the purchaser does not call for tests on wires taken from the stranded conductor the manufacturer shall, if requested, furnish him with a certificate giving the results of the tests made on the samples taken in accordance with **4.1.1**.

Table 2 — Aluminium alloy wires used in the construction of standard aluminium alloy stranded conductors

1	2	3	4	5	1
Standard diameter	**Cross-sectional area of standard diameter wire**	**Mass per km**	**Standard resistance at 20 °C per km**	**Minimum breaking load for standard diameter wire**	**Standard diameter**
mm	mm^2	kg	Ω	N	mm
2.34	4.301	11.61	7.557	1 270	2.34
2.54	5.067	13.68	6.414	1 490	2.54
2.95	6.835	18.45	4.755	2 020	2.95
3.30	8.553	23.09	3.800	2 520	3.30
3.48	9.511	25.68	3.417	2 810	3.48
3.53	9.787	26.42	3.321	2 890	3.53
3.76	11.10	29.98	2.927	3 280	3.76
4.65	16.98	45.85	1.914	5 010	4.65
NOTE The values given in Columns 2 to 5 are given for information only.					

Table 3 — Standard aluminium alloy stranded conductors

1	2	3	4	5	6	7	1
Nominal aluminium area	**Stranding and wire diameter**	**Sectional area**	**Approximate overall diameter**	**Approximate mass per km**	**Calculated d.c. resistance at 20 °C per km**	**Calculated breaking load**	**Nominal aluminium area**
mm^2	mm	mm^2	mm	kg	Ω	kN	mm^2
25	7/2.34	30.10	7.02	82	1.094	8.44	25
30	7/2.54	35.47	7.62	97	0.928 1	9.94	30
40	7/2.95	47.84	8.85	131	0.688 0	13.40	40
50	7/3.30	59.87	9.90	164	0.549 8	16.80	50
100	7/4.65	118.9	13.95	325	0.276 9	33.30	100
150	19/3.48	180.7	17.40	497	0.183 0	50.65	150
175	19/3.76	211.0	18.80	580	0.156 8	59.10	175
300	37/3.53	362.1	24.71	997	0.091 55	101.5	300
NOTE 1 For the basis of calculation of this table, see Appendix A. NOTE 2 The sectional area of an aluminium alloy stranded conductor is the sum of the cross-sectional areas of the individual wires. NOTE 3 Attention is drawn to the fact that the sectional areas of standard conductors covered by the specification refer to aluminium alloy areas. Consequently they are larger than the nominal aluminium areas by which they are identified.							

4) 1 hbar = 10 MN/m^2 = 10 N/mm^2.

5) BS 18, "Methods for tensile testing of metals"

6) BS 3229, "Determination of resistivity of metallic electrical conductor materials".

Appendix A Notes on the calculation of Table 3

A.1 Increase in length due to stranding. When straightened out, each wire in any particular layer of a stranded conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

A.2 Resistance and mass of conductor. The resistance of any length of a stranded conductor is the resistance of the same length of any one wire multiplied by a constant, as set out in Table 4.

The mass of each wire in any particular layer of stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the lay ratio of that layer (see **A.1** above). The total mass of any length of an aluminium alloy stranded conductor is, therefore, obtained by multiplying the mass of an equal length of straight wire by an appropriate constant, as set out in Table 4.

In calculating the stranding constants in Table 4, the mean lay ratio, i.e. the arithmetic mean of the relevant minimum and maximum values in Table 1, has been assumed for each layer.

A.3 Calculated breaking load of conductor. The breaking load of an aluminium alloy stranded conductor in terms of the strengths of the individual component wires, may be taken to be 95 % of the sum of the strengths of the individual aluminium alloy wires calculated from the value of the minimum tensile strength given in **4.3.1**.

Table 4 — Stranding constants

1	2	3
Number of wires in conductor	Stranding constants	
	Mass	Electrical resistance
7	7.091	0.144 7
19	19.34	0.053 57
37	37.34	0.027 57

Appendix B Note on modulus of elasticity and coefficient of linear expansion

The practical moduli of elasticity given below are based on an analysis of the final moduli determined from a large number of short-term stress/strain tests and may be taken as applying to conductors stressed between 15 % and 50 % of the breaking load of the conductor. They may be regarded as being accurate to within ± 300 hbar[7)].

Number of wires in conductor	Practical (final) modulus of elasticity	Coefficient of linear expansion/°C
	hbar[a]	
7	5 900	23.0×10^{-6}
19	5 600	23.0×10^{-6}
37	5 600	23.0×10^{-6}

NOTE These values are given for information purposes only.

[a] 1 hbar = 10 MN/m^2 = 10 N/mm^2.

Appendix C Code names for standard aluminium alloy stranded conductors

NOTE These code names are not an essential part of the standard. They are given for convenience in ordering conductors.

Nominal aluminium area	Stranding	Code name
mm^2	mm	
25	7/2.34	ALMOND
30	7/2.54	CEDAR
40	7/2.95	FIR
50	7/3.30	HAZEL
100	7/4.65	OAK
150	19/3.48	ASH
175	19/3.76	ELM
300	37/3.53	UPAS

7) 1 hbar = 10 MN/m^2 = 10 N/mm^2.

Appendix D Lay ratios and stranding constants for non-standard constructions

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of wires in conductor	Lay ratio										Stranding constants	
	6-wire layer		12-wire layer		18-wire layer		24-wire layer		30-wire layer		Mass	Electrical resistance
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.		
61	10	17	10	16	10	15	10	14	—	—	62.35	0.016 76
91	10	17	10	16	10	15	10	14	10	13	93.26	0.011 26

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