BRITISH STANDARD

BS 215-2:1970

Specification for

Aluminium conductors and aluminium conductors, steel-reinforced — For overhead power transmission —

Part 2: Aluminium conductors, steel-reinforced

UDC 621.315.55:669.71

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:

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Association of Bronze and Brass Founders
Institution of Structural Engineers
Association of Consulting Engineers
Lead Development Association
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The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

British Railways Board
Institute of iron & Steel Wire Manufacturers
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
Institute of Sheet Metal Engineering

This British Standard, having been approved by the Non-ferrous Metals Industry Standards Committee, was published under the authority of the Executive Board on 31 March 1970

First published, October, 1925
First revision, January, 1930
Second revision, March, 1934
Third revision, December, 1956
Fourth revision, March 1970

The following BSI references relate to the work on this standard:
Committee reference NFE/24
Draft for comment 68/29132

ISBN 580 05769 0

Amendments issued since publication

Amd. No.	Date	Comments

Contents

Foreword

This British Standard was first published as BS 215-2 in 1956; previously the requirements for steel-cored aluminium conductors were included together with those for aluminium stranded conductors now covered by BS 215-1 in the one publication.

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 209, "Aluminium conductors, steel-reinforced".

As a result there are a number of changes in the specification. Throughout the term "aluminium conductor, steel-reinforced", has been adopted in preference to the earlier "steel-cored aluminium conductor" as the former is now in more general use. 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 also been amended, the strength of the steel component now being based on the stress at 1 % elongation of the steel wires, which has been made a requirement for the steel wires.

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 conductors are designated by nominal aluminium areas (mm^2) in place of the formerly used nominal copper areas (in^2). For convenience the nominal aluminium areas have been taken as being numerically 1 000 times the previous nominal copper areas.

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.

Detailed requirements for aluminium and steel wires are not included in this standard but are specified in BS 2627[1)] and BS 4565[2)] respectively.

All stresses are quoted in terms of the hectobar (hbar)[3)].

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 3242, *Aluminium alloy stranded conductors for overhead power transmission.*

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. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 205, *Glossary of terms used in electrical engineering.*

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1) BS 2627, "Wrought aluminium for electrical purposes. Wire".

2) BS 4565, "Galvanized steel wire for aluminium conductors, steel-reinforced".

3) 1 hbar = 10 MN/m^2 = 10 N/mm^2.

BS 2627, *Wrought aluminium for electrical purposes. Wire.*

BS 4565, *Galvanized steel wire for aluminium conductors, steel-reinforced.*

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 8, 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.

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1 General

1.1 Scope

Part 2 of this British Standard applies to aluminium conductors, steel-reinforced for overhead power transmission.

1.2 Definitions

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

aluminium conductor, steel-reinforced

a conductor consisting of seven or more aluminium and galvanized steel wires built up in concentric layers. The centre wire or wires are of galvanized steel and the outer layer or layers of aluminium

diameter

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

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-hand lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically

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

for other definitions reference should be made to BS 205[4)]

1.3 Standards for hard-drawn aluminium wires

1.3.1 Resistivity. The resistivity of aluminium wire depends upon its purity and its physical condition. For the purposes of this British Standard, the maximum value permitted is 2.8264 μΩ cm at 20 °C, and this value shall also be used as the standard resistivity for the purpose of calculation.

1.3.2 Density. At a temperature of 20 °C the density of hard-drawn aluminium wire is to be taken as 2.703 g/cm^3.

1.3.3 Coefficient of linear expansion. The coefficient of linear expansion of hard-drawn aluminium 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 hard-drawn aluminium wire, measured between two potential points rigidly fixed to the wire, is taken as 0.004 03/ °C.

1.4 Standards for galvanized steel wire

1.4.1 Density. At a temperature of 20 °C, the density of galvanized steel wire is to be taken as 7.80 g/cm^3.

1.4.2 Coefficient of linear expansion. In order to obtain uniformity in calculations, a value of 11.5×10^{-6}/ °C may be taken as the value for the coefficient of linear expansion of galvanized steel wires used for the cores of aluminium conductors, steel-reinforced.

2 Material

The aluminium wires used in the construction of the conductor shall be material G1E in the H9 condition as specified in BS 2627[5)].

The galvanized steel wires shall be of the standard tensile strength grade given in BS 4565[6)] unless one of the higher tensile strength grades is specified by the purchaser.

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

The aluminium and steel wires for the standard constructions covered by this specification shall have the diameters specified in Table 2 and Table 3 respectively. The diameters of the steel wires shall be measured over the zinc coating.

3.2 Standard sizes of aluminium conductors, steel-reinforced

3.2.1 The sizes of standard aluminium conductors, steel-reinforced are given in Table 4.

3.2.2 The masses (excluding the mass of grease for corrosion protection) and resistances may be taken as being in accordance with Table 4.

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

[5)] BS 2627, "Wrought aluminium for electrical purposes. Wire".

[6)] BS 4565, "Galvanized steel wire for aluminium conductors, steel-reinforced"

3.3 Joints in wires

3.3.1 Aluminium wires. In aluminium conductors, steel-reinforced, containing any number of aluminium wires, joints in individual aluminium wires are permitted, in addition to those made in the base rod or wire before final drawing, but no two such joints shall be less than 15 m apart in the complete stranded conductor. Such joints shall be made by resistance or cold-pressure butt-welding. They are not required to fulfil the mechanical 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.

3.3.2 Galvanized steel wires. There shall be no joints, except those made in the base rod or wire before final drawing, in steel wires forming the core of an aluminium conductor, steel-reinforced, unless the core consists of seven or more galvanized steel wires. In the latter case joints in individual wires are permitted, in addition to those made in the base rod or wire before final drawing, but no two such joints shall be less than 15 m apart in the complete steel core. Joints in galvanized steel wires shall be made by resistance butt-welding and shall be protected against corrosion.

3.4 Stranding

3.4.1 The wires used in the construction of an aluminium conductor, steel-reinforced shall, before stranding, satisfy all the relevant requirements of this standard.

3.4.2 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.

3.4.3 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.

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

3.4.5 Steel wires shall be formed during stranding so that they remain inert when the conductor is cut.

3.5 Completed conductor

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

Table 1 — Lay ratios for aluminium conductors, steel-reinforced

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of wires		Ratio aluminium wire diameter to steel wire diameter	Lay ratios for steel core		Lay ratios for aluminium layers							
					6-wire layer		12-wire layer		18-wire layer		24-wire layer	
Aluminium	Steel		min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
6	1	1.000	—	—	10	14	—	—	—	—	—	—
6	7	3.000	13	28	10	14	—	—	—	—	—	—
12	7	1.000	13	28	—	—	10	14	—	—	—	—
18	1	1.000	—	—	10	16	10	14	—	—	—	—
30	7	1.000	13	28	—	—	10	16	10	14	—	—
54	7	1.000	13	28	—	—	10	17	10	16	10	14

4 Tests

4.1 Selection of test samples

4.1.1 Samples for the tests specified in **4.3** shall be taken by the manufacturer before stranding, from not less than 10 % of the individual lengths of aluminium and galvanized steel wire which will be included in any one consignment of stranded conductor.

One sample, sufficient to provide one test specimen for each of the appropriate tests, 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 Tests

4.3.1 Aluminium wires. The test samples of aluminium wires taken under **4.1.1** shall be subjected to the following tests in accordance with BS 2627[7)] and shall meet the requirements of that standard:

Tensile test.

Wrapping test.

Resistivity test.

Test samples of aluminium wires taken under **4.1.2** shall be subjected to the same tests but in the case of the tensile test the tensile strength of the specimen shall be not less than 95 % of the appropriate minimum value specified in BS 2627[7)].

4.3.2 Steel wires. The test samples of galvanized steel wires taken under **4.1.1** shall be subjected to the following tests in accordance with BS 4565[8)] and shall meet the requirements of that standard.

Determination of stress at 1 % elongation.

Tensile test.

Torsion test or elongation test as appropriate.

Wrapping test.

Galvanizing test.

The test samples of galvanized steel wires taken under **4.1.2** shall be subjected to the following tests in accordance with BS 4565[8)].

Determination of stress at 1 % elongation.

Tensile test.

Torsion test or elongation test as appropriate.

Wrapping test.

Galvanizing test.

In the case of the tensile test the tensile strength of the specimen shall be not less than 95 % of the appropriate minimum value specified in BS 4565[9)].

In the case of the elongation test the elongation of the specimen shall.be not less than the appropriate minimum value specified in BS 4565[9)] reduced in numerical value by 0.5.

In the case of the stress at 1 % elongation, torsion, wrapping and galvanizing tests the appropriate requirements of BS 4565[9)] shall be met.

NOTE Because of the difficulty in straightening samples taken from stranded cores, it is recommended that determination of stress at 1 % elongation on samples taken under **4.1.2** be carried out on the centre wire only.

4.4 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**.

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7) BS 2627, "Wrought aluminium for electrical purposes. Wire".

8) BS 4565, "Galvanized steel wire for aluminium conductors, steel-reinforced".

9) BS 4565, "Galvanized steel wire for aluminium conductors, steel-reinforced".

Table 2 — Aluminium wires used in the construction of standard aluminium conductors, steel-reinforced

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
2.36	4.374	11.82	6.461	770	2.36
2.59	5.269	14.24	5.365	906	2.59
2.79	6.114	16.53	4.623	1 030	2.79
3.00	7.069	19.11	3.999	1 190	3.00
3.18	7.942	21.47	3.559	1 310	3.18
3.35	8.814	23.82	3.207	1 450	3.35
3.61	10.24	27.67	2.761	1 660	3.61
3.86	11.70	31.63	2.415	1 870	3.86
4.72	17.50	47.30	1.615	2 780	4.72

NOTE The values in Columns 2 to 5 are given for information only.

Table 3 — Steel wires used in the construction of standard aluminium conductors, steel-reinforced

1	2	3	4	1
Standard diameter	**Cross-sectional area of standard diameter wire**	**Mass per km**	**Minimum load at 1 % elongation for standard diameter wire**	**Standard diameter**
mm	mm^2	kg	N	mm
1.57	1.936	15.10	2 280	1.57
2.36	4.374	34.12	4 990	2.36
2.59	5.269	41.09	6 010	2.59
2.79	6.114	47.69	6 970	2.79
3.00	7.069	55.13	8 060	3.00
3.18	7.942	61.95	8 740	3.18
3.35	8.814	68.75	9 700	3.35
3.61	10.24	79.84	11 260	3.61
3.86	11.70	91.28	12 870	3.86

NOTE The values in Columns 2 to 4 are given for information only.

Table 4 — Standard aluminium conductors, steel-reinforced

1	2	3	4	5	6	7	8	9	1
Nominal aluminium area	Stranding and wire diameter		Sectional area of aluminium	Total sectional area	Approximate overall diameter	Approximate mass per km	Calculated d.c. resistance at 20 °C per km	Calculated breaking load	Nominal aluminium area
	Aluminium	Steel							
mm^2	mm	mm	mm^2	mm^2	mm	kg	Ω	kN	mm^2
25	6/2.36	1/2.36	26.24	30.62	7.08	106	1.093	9.61	25
30	6/2.59	1/2.59	31.61	36.88	7.77	128	0.907 7	11.45	30
40	6/3.00	1/3.00	42.41	49.48	9.00	172	0.676 6	15.20	40
50	6/3.35	1/3.35	52.88	61.70	10.05	214	0.542 6	18.35	50
70	12/2.79	7/2.79	73.37	116.2	13.95	538	0.393 6	61.20	70
100	6/4.72	7/1.57	105.0	118.5	14.15	394	0.273 3	32.70	100
150	30/2.59	7/2.59	158.1	194.9	18.13	726	0.182 8	69.20	150
150	18/3.35	1/3.35	158.7	167.5	16.75	506	0.181 5	35.70	150
175	30/2.79	7/2.79	183.4	226.2	19.53	842	0.157 6	79.80	175
175	18/3.61	1/3.61	184.3	194.5	18.05	587	0.156 3	41.10	175
200	30/3.00	7/3.00	212.1	261.5	21.00	974	0.136 3	92.25	200
200	18/3.86	1/3.86	210.6	222.3	19.30	671	0.136 7	46.55	200
400	54/3.18	7/3.18	428.9	484.5	28.62	1 621	0.067 40	131.9	400

NOTE 1 For the basis of calculation of this table, see Appendix A .

NOTE 2 The sectional area is the sum of the cross-sectional areas of the relevant individual wires.

NOTE 3 Attention is drawn to the fact that the aluminium sectional areas of standard conductors covered by this specification are larger than the nominal aluminium areas by which they are identified; they should not be compared directly with conductors manufactured exactly to those nominal areas.

Appendix A Notes on the calculation of Table 4

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. In aluminium conductors, steel-reinforced the conductivity of the steel core is neglected and the resistance of the conductor is calculated with reference to the resistance of the aluminium wires only. The resistance of any length of stranded conductor is the resistance of the same length of any one aluminium wire multiplied by a constant, as set out in Table 5.

The mass of each wire in a length 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 the layer (see **A.1** above). The total mass of any length of conductor is, therefore, obtained by multiplying the mass of an equal length of straight wire by the appropriate constant set out in Table 5. The masses of the steel core and aluminium wires are calculated separately and added together.

In calculating the stranding constants in Table 5, 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 a conductor, in terms of the strengths of the individual component wires, may be taken to be the sum of the strengths of the aluminium wires calculated from the specified minimum tensile strengths plus the sum of the strengths of the steel wires calculated from the specified minimum stress at 1 % elongation.

Table 5 — Stranding constants

1	2	3	4	5
Number of wires in conductor		Stranding constants		
		Mass		Electrical resistance
Aluminium	Steel	Aluminium	Steel	
6	1	6.091	1.000	0.169 2
6	7	6.091	7.032	0.169 2
12	7	12.26	7.032	0.085 14
18	1	18.34	1.000	0.056 60
30	7	30.67	7.032	0.034 08
54	7	55.23	7.032	0.018 94

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[10)].

The coefficients of linear expansion given below have been calculated from the practical moduli for the aluminium and steel components of the conductors and coefficients of linear expansion of 23.0×10^{-6} and 11.5×10^{-6}/°C. aluminium and steel respectively.

Number of wires in conductor		Practical (final) modulus of elasticity	Coefficient of linear expansion/ °C
Aluminium	Steel		
		hbar[a]	
6	1	7 900	19.1×10^{-6}
6	7	7 500	19.8×10^{-6}
12	7	10 500	15.3×10^{-6}
18	1	6 600	21.2×10^{-6}
30	7	8 000	17.8×10^{-6}
54	7	6 900	19.3×10^{-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 conductors, steel-reinforced

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

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

Nominal aluminium area	Stranding		Code name
	Aluminium	Steel	
mm^2	mm	mm	
25	6/2.36	1/2.36	GOPHER
30	6/2.59	1/2.59	WEASEL
40	6/3.00	1/3.00	FERRET
50	6/3.35	1/3.35	RABBIT
70	12/2.79	7/2.79	HORSE
100	6/4.72	7/1.57	DOG
150	30/2.59	7/2.59	WOLF
150	18/3.35	1/3.35	DINGO
175	30/2.79	7/2.79	LYNX
175	18/3.61	1/3.61	CARACAL
200	30/3.00	7/3.00	PANTHER
200	18/3.86	1/3.86	JAGUAR
400	54/3.18	7/3.18	ZEBRA

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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of wires in conductor		Ratio aluminium wire diameter to steel wire diameter	Lay ratios for steel core				Lay ratios for aluminium wires						Stranding constants		
			6-wire layer		12-wire layer		Outside layer		Layer immediately beneath outside layer		Innermost layer of conductors with 3 aluminium wire layers		Mass		Electrical resistance
Aluminium	Steel		min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	Aluminium	Steel	
24	7	1.500	13	28	—	—	10	14	10	16	—	—	24.50	7.032	0.042 53
26	7	1.286	13	28	—	—	10	14	10	16	—	—	26.56	7.032	0.039 28
28	7	1.125	13	28	—	—	10	14	10	16	—	—	28.61	7.032	0.036 49
30	19	1.666	13	28	12	24	10	14	10	16	—	—	30.67	19.15	0.034 08
42	7	1.800	13	28	—	—	10	14	10	16	10	17	42.90	7.032	0.024 32
45	7	1.500	13	28	—	—	10	14	10	16	10	17	45.98	7.032	0.022 71
48	7	1.286	13	28	—	—	10	14	10	16	10	17	49.06	7.032	0.021 29
54	19	1.666	13	28	12	24	10	14	10	16	10	17	55.23	19.15	0.018 94

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