BRITISH STANDARD

BS 3988:1970

Incorporating Amendment Nos. 1, 2 and 3

Specification for

Wrought aluminium for electrical purposes — Solid conductors for insulated cables

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*
Association of Bronze and Brass Founders
Association of Consulting Engineers
Board of Trade
British Bronze and Brass Ingot Manufacturers' Association
British Electrical and Allied Manufacturers' Association*
British Lead Manufacturers' Association
British Non-ferrous Metals Federation
British Non-ferrous Metals Federation — High Conductivity Copper Group
British Non-ferrous Metals Research Association
Copper Development Association
Crown Agents for Overseas Governments and Administrations
Electric Cable Makers Confederation*
Institute of British Foundrymen
Institute of Metals
Institution of Mechanical Engineers (Automobile Division)
Institution of Mining and Metallurgy
Institution of Production Engineers
Institution of Structural Engineers
Lead Development Association
Light Metal Founders' Association
London Metal Exchange
Magnesium Industry Council
Ministry of Defence, Army Department
Ministry of Defence, Navy Department
National Brassfoundry Association
Non-ferrous Metal Stockists*
Post Office*
Royal Institute of British Architects
Society of Motor Manufacturers and Traders Ltd.
Tin Research Institute
Zinc Development Association
Individual manufacturer

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
Electricity Supply Industry in England and Wales
Institute of Iron and Steel Wire Manufacturers
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 28 January 1970

First published February 1966
First revision January 1970

The following BSI references relate to the work on this standard:
Committee reference NFM/35
Draft for comment 68/22311

ISBN 580 05575 2

Amendments issued since publication

Amd. No.	Date of issue	Comments
773	August 1971	
3380	June 1980	
5843	February 1989	Indicated by a sideline in the margin

Contents

Foreword

This standard makes reference to the following publications:

BS 18, *Method for tensile testing of metals (including aerospace materials).*

BS 2627, *Specification for wrought aluminium for electrical purposes. Wire.*

BS 2897, *Specification for wrought aluminium for electrical purposes. Strip with drawn or rolled edges.*

BS 2898, *Specification for wrought aluminium and aluminium alloys for electrical purposes. Bars, extruded round tube and sections.*

BS 5714, *Method of measurement of resistivity of metallic materials.*

BS 6360, *Specification for conductors in insulated cables and cords.*

IEC Publication 121 Recommendation for commercial annealed aluminium electrical conductor wire

"Registration record of international alloy designations and chemical composition limits for wrought aluminium and wrought aluminium alloys" (available from the Aluminium Association Inc., 900 19th Street, N.W., Suite 300, Washington DC 20006, USA)".

This British Standard was first published in 1966 under the authority of the Non-ferrous Metals Industry Standards Committee and at the request of the Aluminium Industry in view of the increasing use of aluminium for electrical conductors of many types.

Materials complying with this standard are suitable for insulated cables made to the appropriate British Standards and for which the conductors must comply with the requirements of BS 6360, "*Specification for conductors in insulated cables and cords*".

It is important to note that this standard lays down requirements only for the material supplied for cable manufacture, whereas BS 6360 lays down requirements for the conductors in the finished cable. This is in accordance with the method now uniformly adopted by the Institution for specifying the materials used in cable manufacture.

The resistance values and other associated physical properties take into account the relevant IEC Recommendations, namely IEC Publication No. 121:1960, "Recommendations for commercial annealed aluminium electrical conductor wire".

In this edition all dimensions are shown in metric units which are not exact equivalents of the original inch values.

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

This standard is one of a series of standards for wrought aluminium and aluminium alloys for electrical purposes.

Other standards in this series are:

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

BS 2897, *Wrought aluminium for electrical purposes. Strip with drawn or rolled edges.*

BS 2898, *Wrought aluminium and aluminium alloys for electrical purposes. Bars, extruded round tube and sections.*

As a major step towards alignment of aluminium and aluminium alloy compositions on an international basis, a substantial number of countries have agreed to adopt a 4-digit classification for alloy composition designation. This system is administered by the Aluminium Association Inc., who issue the "Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminium Alloys."

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

By amendment, it has been decided to introduce this system into the British Standards concerned with these types of material in place of the material designations formerly used. The details of the system are given in Appendix B.

The temper designations and associated mechanical property requirements remain unaltered for the present and therefore may not necessarily align precisely with those in the standards of other countries.

Material 1350 therefore replaces material C1E. Minor compositional changes have been made."

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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

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

1.1 Scope

This British Standard specifies requirements for circular solid and 2-, 3- and 4-core shaped solid conductors in a range of standard sizes from 16 mm^2 up to and including 300 mm^2.

1.2 Definitions

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

diameter (for circular solid conductors)

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

shaped solid conductor

a conductor of one of the shapes shown in Table 2, Table 3A, Table 3B and Table 4, the dimensions of which are as defined

1.3 Freedom from defects

The material shall be free from defects prejudicial to its use as an electrical conductor.

1.4 Joints

There shall be no joints in the finished conductor. In the case of conductors drawn to size, joints made in the base rod before final drawing shall be permitted.

1.5 Selection of test samples

Test samples for the tensile, elongation and electrical resistance tests specified in **1.6**, **1.7** and **1.8** shall be selected as follows:

Lengths of conductor of the same dimensions, produced in the same way and of the same condition, shall be grouped into batches not exceeding 1 000 kg in weight and test samples shall be cut from one length selected from each batch. Before the test samples are cut off they shall be marked to identify them. The test samples shall be taken from the conductor as supplied and shall not be annealed or mechanically worked other than straightening before testing.

1.6 Tensile test

The test shall be carried out in accordance with BS 18[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 per minute and not greater than 100 mm per minute.

1.7 Elongation test

The test shall be carried out in accordance with BS 18[2)]. The load shall be applied gradually and uniformly on straightened lengths of conductor, 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.

1.8 Electrical resistance test

The resistance shall be determined by measurement in accordance with the routine method given in BS 5714[3)].

1.9 Retests

Should any one of the test pieces first selected fail to pass the mechanical or resistance tests, two further samples from the same batch shall be selected for testing, one of which shall be taken from the length from which the original test sample was taken, unless that length has been withdrawn by the supplier.

Should the test pieces from both these additional samples satisfy the requirements of the mechanical and resistance tests, the batch represented by these samples shall be deemed to comply with the standard. Should the test pieces from either of the two additional samples fail, the batch represented shall be deemed not to comply with the standard.

1.10 Certificate of compliance

The supplier shall, if required, certify that the material complies with the requirements of this standard.

1.11 *Text deleted*

1.12 *Text deleted*

1.13 *Text deleted*

[2)] BS 18, "*Method for tensile testing of metals (including aerospace materials)*".

[3)] BS 5714, "*Method of measurement of resistivity of metallic materials*".

Material 1350 (former BS designation C1E)

2 Specific requirements

2.1 General

The material shall comply with the general requirements of Section 1 and shall have the following chemical composition, condition, dimensions and mechanical and electrical properties.

2.2 Chemical composition limits[4)5)]

The chemical composition of material 1350 shall be as follows:

Silicon		0.10
Iron		0.40
Copper		0.05
Manganese		0.01
Chromium		0.01
Zinc		0.05
Gallium		0.03
Boron		0.05
Vanadium + Titanium		0.02
Others[a]	Each	0.03
	Total	0.10
Aluminium		min. 99.50[b]

[a] Analysis is regularly made only for the elements for which specific limits are shown. If, however, the presence of other elements is suspected to be, or in the course of routine analysis is indicated to be, in excess of the specified limits, further analysis is made to determine that these other elements are not in excess of the amount specified.

[b] The aluminium content for unalloyed aluminium not made by a refining process is the difference between 100.00 % and the sum of all other metallic elements present in amounts of 0.010 % or more each, expressed to the second decimal before determining the sum.

2.3 Condition

The material shall be supplied in the condition which provides the properties given in **2.5** and **2.6**.

2.4 Dimensions

2.4.1 Circular solid conductors. The diameters of circular solid conductors shall be within the limits specified in Columns 7 and 8 of Table 1, and the difference between the maximum and minimum measurements taken at the same cross section shall not exceed 1 %.

2.4.2 Shaped solid conductors. The dimensions of shaped solid conductors shall be such that the profile of the conductor shall at no point lie outside the envelope defined by the dimensions specified in Columns 12, 13, 14 and 15 of Table 2, Table 3A, Table 3B and Table 4 and the widths and depths shall be not less than the values specified in Columns 10 and 11 of Table 2, Table 3A, Table 3B and Table 4.

The angle subtended by the two flat faces of 3- and 4-core shaped solid conductors shall not vary from that specified by more than ± 1°.

The flat faces of shaped solid conductors shall not show any degree of concavity.

2.5 Mechanical properties

The mechanical properties, obtained from test pieces selected as specified in **1.5** and prepared and tested as specified in **1.6** and **1.7** shall be as follows:

Tensile strength max.	Elongation on 250 mm min.
hbar[a]	%
8.0	25

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

2.6 Electrical resistance

The resistance per kilometre at 20 °C determined in accordance with **1.8** shall not exceed the appropriate value given in Column 4 of Table 1, Table 2, Table 3A, Table 3B and Table 4.

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4) Composition in per cent maximum unless shown as a range or a minimum.

5) For the purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis is rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the following.

When the figure next beyond the last figure or place to be retained is less than 5, the figure in the last place retained should be kept unchanged.

When the figure next beyond the last figure or place to be retained is greater than 5, the figure in the last place retained should be increased by 1.

When the figure next beyond the last figure or place to be retained is 5 and

a) there are no figures, or only zeros, beyond this 5, if the figure in the last place to be retained is odd, it should be increased by 1; if even, it should be kept unchanged;

b) if the 5 next beyond the figure in the last place to be retained is followed by any figures other than zero, the figure in the last place retained should be increased by 1, whether odd or even.

Table 1 — Circular solid conductors

1	2	3	4	5	6	7	8	1
Nominal area	Calculated area	Resistance per km at 20 °C		Nominal weight per km	Diameter			Nominal area
		Standard	Maximum[a]		Nominal	Minimum	Maximum	
mm^2	mm^2	ohm	ohm	kg	mm	mm	mm	mm^2
16	15.62	1.79	1.83	43.0	4.50	4.46	4.54	16
25	24.48	1.14	1.16	66.2	5.58	5.52	5.64	25
35	33.96	0.825	0.842	91.8	6.58	6.51	6.65	35
50	45.97	0.610	0.622	124	7.65	7.57	7.73	50
70	66.44	0.422	0.430	180	9.20	9.11	9.29	70
95	92.14	0.304	0.310	249	10.83	10.72	10.94	95
120	116.5	0.241	0.246	315	12.18	12.06	12.30	120
150	143.1	0.196	0.200	387	13.50	13.36	13.64	150
185	179.5	0.156	0.159	485	15.12	14.97	15.27	185
240	235.9	0.119	0.121	638	17.33	17.16	17.50	240
300	295.8	0.0948	0.0967	800	19.41	19.22	19.60	300

[a] Including an allowance of 2 % over the standard value.

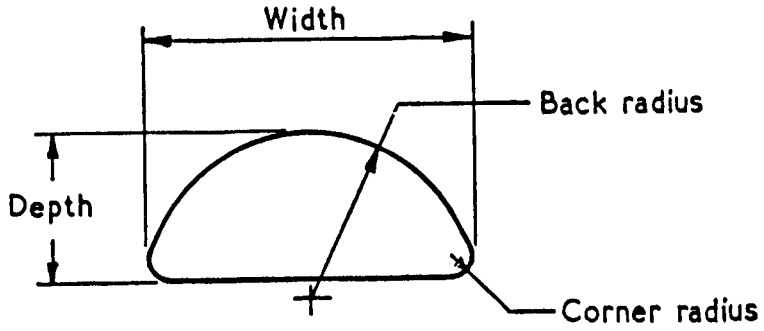

Table 2 — 2-core shaped solid conductors

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
Nominal area	Calculated area	Resistance per km at 20 °C		Nominal weight per km	Nominal dimensions				Minimum dimensions		Dimensions of maximum envelope				Nominal area
		Standard	Maximum[a]		Width	Depth	Back radius	Corner radius	Width	Depth	Width	Depth	Back radius	Corner radius	
mm^2	mm^2	ohm	ohm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm^2
16	15.62	1.79	1.84	42.2	6.82	2.95	3.65	0.50	6.68	2.87	6.89	2.98	3.68	0.50	16
25	24.48	1.14	1.17	66.2	8.57	3.70	4.50	0.50	8.36	3.56	8.66	3.74	4.54	0.50	25
35	33.96	0.825	0.850	91.8	10.02	4.40	5.20	0.52	9.74	4.20	10.12	4.44	5.25	0.52	35
50	45.97	0.610	0.628	124	11.54	5.16	5.96	0.59	11.24	4.95	11.66	5.21	6.02	0.60	50
70	66.44	0.422	0.435	180	13.74	6.25	7.05	0.70	13.40	6.03	13.80	6.28	7.08	0.71	70
95	92.14	0.304	0.313	249	16.05	7.40	8.20	0.82	15.68	7.16	16.13	7.43	8.23	0.82	95
120	116.5	0.241	0.248	315	17.95	8.36	9.16	0.91	17.55	8.10	18.03	8.39	9.20	0.92	120
150	143.1	0.196	0.202	387	20.00	9.22	10.22	1.02	19.57	8.95	20.10	9.27	10.27	1.03	150
185	179.5	0.156	0.161	485	22.29	10.37	11.37	1.13	21.83	10.08	22.40	10.42	11.42	1.14	185
240	235.9	0.119	0.123	638	25.51	11.90	13.00	1.30	25.00	11.59	25.63	11.96	13.07	1.31	240
300	295.8	0.0948	0.0976	800	28.44	13.37	14.47	1.44	27.88	13.04	28.58	13.44	14.54	1.45	300

[a] Including an allowance of 3 % over the standard value.

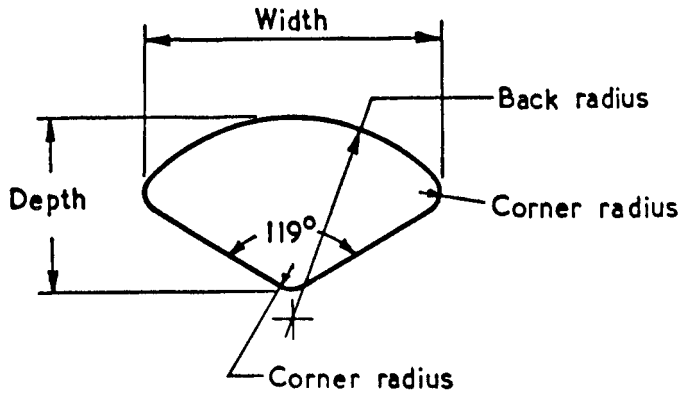

Table 3A — 3-core shaped solid conductors for voltages up to and including 1 900/3 300 V

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
Nominal area	Calculated area	Resistance per km at 20 °C		Nominal weight per km	Nominal dimensions				Minimum dimensions		Dimensions of maximum envelope				Nominal area
		Standard	Maximum[a]		Width	Depth	Back radius	Corner radius	Width	Depth	Width	Depth	Back radius	Corner radius	
mm^2	mm^2	ohm	ohm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm^2
16	15.62	1.79	1.84	42.2	6.53	3.70	4.60	0.50	6.39	3.60	6.60	3.74	4.64	0.50	16
25	24.48	1.14	1.17	66.2	8.22	4.66	5.67	0.56	8.02	4.51	8.30	4.71	5.72	0.57	25
35	33.96	0.825	0.850	91.8	9.66	5.50	6.53	0.65	9.39	5.29	9.76	5.56	6.58	0.66	35
50	45.97	0.610	0.628	124	11.20	6.42	7.47	0.74	10.90	6.19	11.31	6.48	7.55	0.76	50
70	66.44	0.422	0.435	180	13.42	7.74	8.81	0.88	13.09	7.49	13.49	7.78	8.85	0.88	70
95	92.14	0.304	0.313	249	15.76	9.14	10.24	1.02	15.39	8.87	15.84	9.19	10.29	1.03	95
120	116.5	0.241	0.248	315	17.69	10.30	11.41	1.14	17.29	10.02	17.78	10.35	11.47	1.15	120
150	143.1	0.196	0.202	387	19.64	11.40	12.76	1.27	19.22	11.10	19.74	11.46	12.82	1.28	150
185	179.5	0.156	0.161	485	21.97	12.78	14.17	1.41	21.51	12.46	22.07	12.84	14.24	1.42	185
240	235.9	0.119	0.123	638	25.17	14.66	16.20	1.62	24.66	14.31	25.29	14.73	16.28	1.63	240
300	295.8	0.0948	0.0976	800	28.14	16.44	18.01	1.80	27.59	16.06	28.28	16.52	18.09	1.81	300

[a] Including an allowance of 3 % over the standard value.

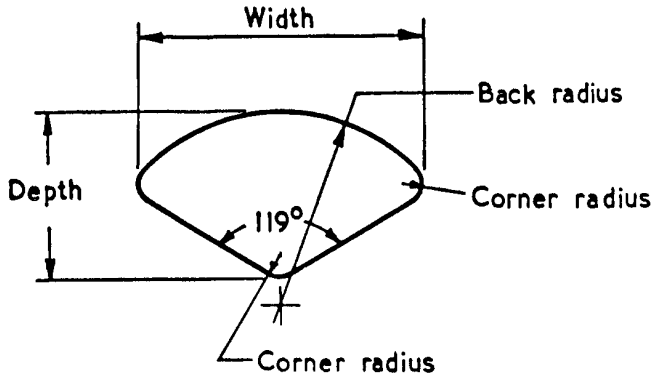

Table 3B — 3-core shaped solid conductors for voltages of 3 800/6 600 V and above

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
Nominal area	Calculated area	Resistance per km at 20 °C		Nominal weight per km	Nominal dimensions				Minimum dimensions		Dimensions of maximum envelope				Nominal area
		Standard	Maximum[a]		Width	Depth	Back radius	Corner radius	Width	Depth	Width	Depth	Back radius	Corner radius	
mm^2	mm^2	ohm	ohm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm^2
70	66.44	0.422	0.435	180	11.28	7.86	9.94	2.80	10.98	7.61	11.35	7.90	9.97	2.80	70
95	92.14	0.304	0.313	249	13.92	9.12	11.42	2.80	13.58	8.85	14.00	9.16	11.47	2.80	95
120	116.5	0.241	0.248	315	15.31	10.24	12.58	3.00	15.44	9.96	15.91	10.29	12.63	3.00	120
150	143.1	0.196	0.202	387	17.93	11.30	13.87	3.00	17.53	11.00	18.03	11.35	13.92	3.00	150
185	179.5	0.156	0.161	485	20.52	12.62	15.42	3.00	20.08	12.30	20.64	12.63	15.48	3.00	185
240	235.9	0.119	0.123	638	24.02	14.45	17.49	3.00	23.53	14.10	24.16	14.53	17.56	3.00	240
300	295.8	0.0948	0.0976	800	27.30	16.19	19.45	3.00	26.76	15.82	27.45	16.27	19.54	3.00	300

[a] Including an allowance of 3 % over the standard value.

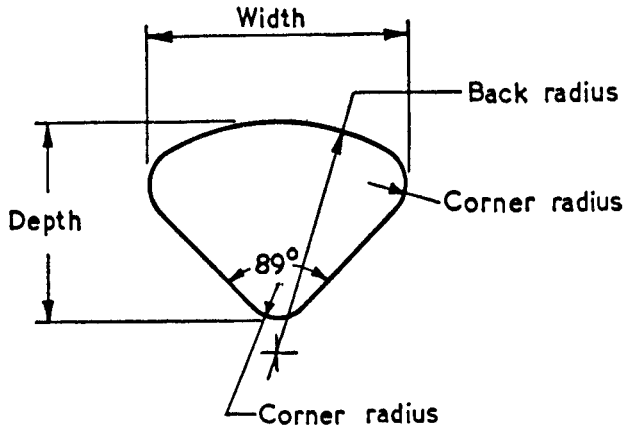

Table 4 — 4-core shaped solid conductors

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
Nominal area	Calculated area	Resistance per km at 20 °C		Nominal weight per km	Nominal dimensions				Minimum dimensions		Dimensions of maximum envelope				Nominal area
		Standard	Maximum[a]		Width	Depth	Back radius	Corner radius	Width	Depth	Width	Depth	Back radius	Corner radius	
mm^2	mm^2	ohm	ohm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm^2
16	15.62	1.79	1.84	42.2	5.96	4.21	5.44	0.54	5.83	4.11	6.02	4.25	5.48	0.55	16
25	24.48	1.14	1.17	66.2	7.45	5.28	6.71	0.67	7.26	5.12	7.52	5.33	6.77	0.68	25
35	33.96	0.825	0.850	91.8	8.78	6.24	7.71	0.77	8.52	6.02	8.87	6.30	7.78	0.78	35
50	45.97	0.610	0.628	124	10.21	7.28	8.79	0.87	9.93	7.04	10.31	7.35	8.87	0.89	50
70	66.44	0.422	0.435	180	12.26	8.77	10.35	1.03	11.95	8.51	12.32	8.81	10.40	1.04	70
95	92.14	0.304	0.313	249	14.43	10.35	12.00	1.20	14.08	10.06	14.49	10.40	12.06	1.21	95
120	116.5	0.241	0.248	315	16.22	11.65	13.36	1.33	15.85	11.35	16.29	11.71	13.42	1.34	120
150	143.1	0.196	0.202	387	17.99	12.90	14.96	1.49	17.59	12.58	18.08	12.96	15.03	1.50	150
185	179.5	0.156	0.161	485	20.14	14.46	16.59	1.65	19.71	14.11	20.25	14.53	16.67	1.67	185
240	235.9	0.119	0.123	638	23.08	16.59	18.59	1.89	22.60	16.21	23.20	16.67	19.04	1.90	240
300	295.8	0.0948	0.0976	800	25.83	18.59	21.06	2.10	25.31	18.18	25.96	18.68	21.18	2.12	300

[a] Including an allowance of 3 % over the standard value.

Appendix A Standard values (for information only)

For the purposes of this British Standard the following standard values have been adopted:

a) Density at 20 °C	2.703 g/cm^3
b) Constant mass temperature coefficient of resistance at 20 °C, measured between two potential points rigidly fixed to the conductors	0.004 03/°C
c) Coefficient of linear expansion between 0 and 30 °C	23×10^{-6}/°C
d) Volume resistivity at 20 °C	2.803 microhm cm

Appendix B Details of the international alloy designations and chemical composition limits for wrought aluminium alloys system

B.1 Alloys groups: general

The first of the four digits in the designation indicates the alloy group as follows:

Aluminium, 99.00 % minimum and greater	1 xxx
Aluminium alloys groups	
by major alloying elements	
Copper	2 xxx
Manganese	3 xxx
Silicon	4 xxx
Magnesium	5 xxx
Magnesium and silicon	6 xxx
Zinc	7 xxx
Other element	8 xxx
Unused series	9 xxx

B.2 1 xxx group

In the 1 xxx group for minimum purities of 99.00 % and greater, the last two of the four digits in the designation indicate the minimum aluminium percentage. These digits are the same as the two digits to the right of the decimal point in the minimum aluminium percentage when it is expressed to the nearest 0.01 %.

The second digit in the designation indicates modifications in impurity limits or alloying elements. If the second digit in the designation is zero, it indicates unalloyed aluminium having natural impurity limits: integers 1 to 9, which are assigned consecutively as needed, indicate special control of one or more individual impurities or alloying elements.

B.3 2 xxx to 8 xxx groups

In the 2 xxx to 8 xxx groups the last two of the four digits in the designation have no special significance but serve only to identify the different aluminium alloys in the group. The second digit in the alloy designation indicates alloy modifications. If the second digit in the designation is zero, it indicates the original alloy; integers 1 to 9, which are assigned consecutively, indicate alloy modifications.

B.4 National variations

National variations of wrought aluminium and wrought aluminium alloys registered by another country are identified by a serial letter after the numerical designation. The serial letters are assigned in alphabetical sequence starting with A for the first national variation registered, but omitting I, O and Q.

BSI — British Standards Institution

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