

BRITISH STANDARD 4516 : Part 1 : 1969

CONFIRMED APRIL 1987

SPECIFICATION FOR
ENAMELLED
COPPER CONDUCTORS
(Polyvinyl Acetal Base with High
Mechanical Properties)

Part 1. Round Wire

BRITISH STANDARDS INSTITUTION

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BRITISH STANDARDS INSTITUTION

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The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

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 5000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, which may be purchased from BSI Sales Department. It may also be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 1036. Electrolytic tough pitch high conductivity copper.

BS 1489. The packaging of covered winding wires for electrical purposes.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard:
Committee reference ELE/36 Draft for comment 68/30298

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CO-OPERATING ORGANIZATIONS

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

- Associated Offices' Technical Committee
- Association of Consulting Engineers
- Association of Mining Electrical and Mechanical Engineers
- Association of Supervising Electrical Engineers
- *British Electrical and Allied Manufacturers' Association
- British Electrical Development Association
- British Railways Board
- Crown Agents for Overseas Governments and Administrations
- Department of Employment and Productivity
(H.M. Factory Inspectorate)
- *Electric Cable Makers' Confederation
- Electric Lamp Industry Council
- Electric Light Fittings Association
- Electrical Contractors' Association (Incorporated)
- Electrical Contractors' Association of Scotland
- *Electrical Research Association
- Electricity Council, the Generating Board and the Area Boards
in England and Wales
- *Electronic Engineering Association
- Engineering Equipment Users' Association
- Institution of Electrical Engineers
- Ministry of Defence, Army Department
- *Ministry of Defence, Navy Department
- Ministry of Power
- Ministry of Public Building and Works
- Ministry of Technology
- *Ministry of Technology (Aviation)
- *Ministry of Technology (National Physical Laboratory)
- Municipal Passenger Transport Association (Incorporated)
- National Inspection Council for Electrical Installation
Contracting
- Oil Companies Materials Association
- *Post Office
- Public Transport Association (Incorporated)
- South of England Electricity Board

The Government departments 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 Non-ferrous Metals Federation High Conductivity
Copper Group
- British Radio Equipment Manufacturers' Association
- Copper Development Association
- Covered Conductors Association
- Radio and Electronic Component Manufacturers' Federation
- Society of Motor Manufacturers and Traders Ltd.
- Telecommunication Engineering and Manufacturing Association
- Telephone Manufacturers' Technical Development Committee

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BRITISH STANDARD SPECIFICATION FOR

ENAMELLED COPPER CONDUCTORS

(Polyvinyl Acetal Base with High
Mechanical Properties)

PART 1. ROUND WIRE

FOREWORD

*As altered
Sept., 1973*

In accordance with the practice of publishing British Standards which are as nearly as possible in line with internationally agreed recommendations, this replacement for BS 1844 : Part 3* closely follows the dimensions given in IEC Publication 182†, the requirements given in IEC Publication 317-1‡ and methods of test given in IEC Publication 251-1§.

With the decline in the use of imperial units, BS 1844 : Part 1* will eventually be withdrawn.

Some wire sizes additional to those recommended in IEC Publication 182 have been included at the request of certain sections of the electrical industry. These are indicated as non-preferred sizes.

Unlike the IEC Recommendation§ for enamelled wire with high mechanical properties, the scope of this British Standard has been limited to enamel with a polyvinyl acetal base, and the cure test specified in BS 1844* has been retained.

Only three grades of thickness of enamel are included, Grade 1 replacing the old 'F' thickness, Grade 2 replacing the old 'M' thickness, and Grade 3 replacing the old 'T' thickness. It has been found necessary to specify a minimum increase in diameter due to the enamel, which is not included in the IEC Recommendation. The tolerances on resistance of some of the smaller wires are less than those recommended by the IEC. This has been found necessary, to meet the need for close control in these diameters.

The type of enamelled wire with low extractable matter, as used in the refrigeration industry, is not included. It is intended to publish a separate specification for this.

Enamelled wire which meets the requirements of this specification meets all the requirements of the IEC Publications, and to facilitate cross reference the clause numbers of the IEC Publications have been indicated.

* BS 1844, 'Enamelled copper conductors (enamel with vinyl acetal base)

Part 1. Round wire.

Part 3. Round wire: metric units'.

† IEC Publication 182, 'Basic dimensions of winding wires'.

‡ IEC Publication 317-1, 'Specifications for particular types of winding wires', Part 1, 'Enamelled round copper wires with high mechanical properties'.

§ IEC Publication 251-1, 'Methods of test for winding wires', Part 1, 'Enamelled round wires'.

SI units are used in preference to 'metric technical units'. The relationship between the units of force in the two systems is: $1 \text{ N} = 0.102 \text{ kgf}$.

Requirements for rectangular conductors covered with enamel having a polyvinyl acetal base will be given in Part 2 of this British Standard.

SPECIFICATION

1. SCOPE

1.1 General. This Part of this British Standard specifies requirements and dimensions for round copper wire covered with a synthetic enamel with high mechanical properties based on a vinyl acetal resin.

The type of enamelled wire with low extractable matter as used in the refrigeration industry is not included.

1.2 Sizes. The requirements of the standard are applicable to wires having a bare diameter from 0.050 mm to 5.000 mm inclusive. The standard sizes are given in Table 14. The preferred sizes are given in bold type.

1.3 Thickness of covering. Three thicknesses of covering are specified as follows:

Grade 1. Applicable to wires having a bare diameter from 0.050 mm up to and including 5.000 mm. Range of preferred sizes from 0.125 mm up to and including 2.000 mm.

Grade 2. Applicable to wires having a bare diameter from 0.050 mm up to and including 5.000 mm. Range of preferred sizes from 0.100 mm up to and including 4.500 mm.

Grade 3. Applicable to wires having a bare diameter from 0.08 mm up to and including 5.000 mm. Range of preferred sizes from 0.125 mm up to and including 4.500 mm.

2. DEFINITIONS

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

- (1) *Wire.* The insulated material as received.
- (2) *Conductor.* The bare metal after removal of the enamel.
- (3) *Increase in diameter due to the covering.* The difference between the diameter over the enamel and the diameter of the conductor.
- (4) *Tolerance.* The permissible divergence of an actual magnitude from that prescribed.
- (5) *Crack.* Any discontinuity in the enamel which penetrates significantly below the surface and which is visible at the stated magnification.

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3. GENERAL REQUIREMENTS AND TEST CONDITIONS

3.1 Unless otherwise specified, all tests shall be carried out within a temperature range of 15 °C to 35 °C and a relative humidity range of 45 % to 75 %. Before measurements are made, the specimens shall be preconditioned under these atmospheric conditions for a time sufficient to allow specimens to reach stability.

3.2 The wire to be tested shall be removed from the packaging in such a way that the wire will not be subjected to tension or unnecessary bends; before each test sufficient wire shall be discarded to ensure that any damaged wire is not included in the test specimens.

3.3 When no specific range of sizes is given for a test, the test is applicable to all sizes.

4. CONDUCTOR

4.1 Material. The conductor shall be manufactured from high conductivity copper complying with the requirements of BS 1036*.

4.2 Tolerance on conductor diameter (IEC Publication 251-1, Clause 4).

4.2.1 Wires of conductor diameter 0.071 mm and larger. When measured by the method described in Appendix A, the conductor diameters shall be within the appropriate limits given in Table 14. These have been obtained by applying the tolerances given in Table 1.

* BS 1036, 'Electrolytic tough pitch high conductivity copper'.

TABLE 1. TOLERANCES ON CONDUCTOR DIAMETER

1	2	1	2
Nominal conductor diameter	Tolerance ±	Nominal conductor diameter	Tolerance ±
mm	mm	mm	mm
0.071	0.003	0.710	0.007
0.080	0.003	0.750	0.008
0.090	0.003	0.800	0.008
0.100	0.003	0.850	0.009
0.112	0.003	0.900	0.009
0.125	0.003	0.950	0.010
0.132	0.003	1.000	0.010
0.140	0.003	1.060	0.011
0.150	0.003	1.120	0.011
0.160	0.003	1.180	0.012
0.170	0.003	1.250	0.013
0.180	0.003	1.320	0.013
0.190	0.003	1.400	0.014
0.200	0.003	1.500	0.015
0.212	0.003	1.600	0.016
0.224	0.003	1.700	0.017
0.236	0.004	1.800	0.018
0.250	0.004	1.900	0.019
0.265	0.004	2.000	0.020
0.280	0.004	2.120	0.021
0.300	0.004	2.240	0.022
0.315	0.004	2.360	0.024
0.335	0.004	2.500	0.025
0.355	0.004	2.650	0.027
0.375	0.005	2.800	0.028
0.400	0.005	3.000	0.030
0.425	0.005	3.150	0.032
0.450	0.005	3.350	0.034
0.475	0.005	3.550	0.036
0.500	0.005	3.750	0.038
0.530	0.006	4.000	0.040
0.560	0.006	4.250	0.043
0.600	0.006	4.500	0.045
0.630	0.006	4.750	0.048
0.670	0.007	5.000	0.050

4.2.2 Out of roundness of conductor (for wires of conductor diameter 0.071 mm and larger). The out of roundness, as defined in Appendix A, shall not exceed the figure given in Column 2 of Table 1.

4.2.3 Wires of diameter smaller than 0.071 mm. The conductor diameters shall be deemed to be correct if the resistances are within the appropriate limits given in Table 14.

4.3 Resistance (for wires of conductor diameter up to and including 1.0 mm) (IEC Publication 251-1, Clause 5). The resistance of the conductor at 20 °C shall be within the limits given in Table 14 when measured in accordance with Appendix B. The maximum and minimum resistance values given in the table include tolerances on both the resistivity of the material and the diameter of the wire, and no further tolerance is applicable.

NOTE. The nominal resistances of conductors of diameters above 1.00 mm are included in Table 14 for information only.

5. ENAMEL COVERING

5.1 General. The conductor shall be completely and uniformly covered with a durable, flexible, synthetic enamel based on a vinyl acetal resin. The enamel shall have a smooth surface free from embedded particles of dust and other deleterious material.

Unless otherwise agreed, the wire shall be lubricated with a neutral hydrocarbon oil or wax. Unless otherwise specified the quantity of oil shall be a minimum and shall not fling during the winding operation. The lubricant shall have no deleterious effect on impregnants in normal use.

5.2 Overall diameter and increase in diameter. When determined by the method described in Appendix A, the overall diameter of the enamelled wire shall not exceed the appropriate value for the thickness of covering and diameter of wire given in Table 14 and the increase in diameter due to the enamel shall not be less than the appropriate value given in Table 14.

5.3 Flexibility and adherence (IEC Publication 251-1, Clause 8).

5.3.1 Mandrel winding test. After winding ten contiguous turns on a polished mandrel of the diameter specified in Table 2, the covering of the sample shall show no cracks when examined under a magnification of six times to ten times.

The mandrel shall be rotated at between one and three turns per second, the tension on the wire being just sufficient to keep it in contact with the mandrel. Care shall be taken to avoid elongation or twisting of the wire. Three tests shall be made.

TABLE 2. MANDREL DIAMETERS FOR WINDING TEST

Nominal conductor diameter		Mandrel diameter (d = nominal diameter of conductor in mm)
Over	Up to and including	
mm	mm	
0.250	0.250	$3d^*$
2.000	2.000	d
	5.000	$2d$

* The wire is stretched 20 % or to the breaking point of the copper whichever is less before winding on the mandrel.

5.3.2 Jerk test (for wires of conductor diameter up to and including 1.0 mm). The covering shall show no cracks or loss of adhesion when tested in accordance with Appendix C.

5.3.3 Peel test (for wires of conductor diameter over 1.0 mm). When tested in accordance with Appendix D, the covering shall show no sign of loss of flexibility or adhesion.

5.4 Heat shock (IEC Publication 251-1, Clause 9). Three test specimens shall be prepared as prescribed in Subclause 5.3.1 and put for 30 min into an electrically heated forced-air circulating oven at a temperature between 155 °C and 160 °C.

After removal from the oven, the specimens shall be allowed to cool to room temperature and shall then be examined for cracks under a magnification of 6 times to 10 times. Each specimen shall be free from cracks.

5.5 Cut-through (IEC Publication 251-1, Clause 10). When tested in accordance with Appendix E, specimens shall show no failure after 2 min at 170 °C.

5.6 Resistance to abrasion (for wires of diameter 0.250 mm up to and including 2.500 mm) (IEC Publication 251-1, Clause 11). When tested in accordance with Appendix F the average of the number of strokes shall be not less than 50 and no individual value shall be less than 20. The load applied shall be as given in Table 3.

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TABLE 3. LOADS FOR ABRASION TEST

Nominal conductor diameter *	Load			Nominal conductor diameter	Load		
	Grade 1	Grade 2	Grade 3		Grade 1	Grade 2	Grade 3
mm	N	N	N	mm	N	N	N
0.250	1.6	2.0	2.6	1.060	4.7	5.9	7.2
0.280	1.7	2.2	2.8	1.120	4.9	6.1	7.5
0.315	1.9	2.4	3.0	1.180	5.1	6.3	7.7
0.355	2.1	2.7	3.3	1.250	5.3	6.6	8.0
0.400	2.3	2.9	3.6	1.320	5.5	6.8	8.3
0.450	2.6	3.2	3.9	1.400	5.7	7.1	8.6
0.500	2.7	3.4	4.2	1.500	6.0	7.4	9.0
0.560	3.0	3.7	4.6	1.600	6.2	7.7	9.4
0.630	3.2	4.0	4.9	1.700	6.5	8.0	9.8
0.710	3.5	4.4	5.4	1.800	6.8	8.3	10.1
0.750	3.7	4.7	5.7	1.900	6.8	8.3	10.1
0.800	3.8	4.9	6.0	2.000	6.8	8.3	10.1
0.850	4.0	5.1	6.2	2.120	6.8	8.3	10.1
0.900	4.2	5.3	6.5	2.240	6.8	8.3	10.1
0.950	4.4	5.5	6.7	2.360	6.8	8.3	10.1
1.000	4.5	5.7	7.0	2.500	6.8	8.3	10.1

* For intermediate sizes, the appropriate load is that given for the next finer size.

5.7 Solvent tests

5.7.1 Standard solvent (IEC Publication 251-1, Clause 12). With a pencil hardness 'H', the enamel shall not be removed down to the conductor when tested in accordance with Appendix G.

5.7.2 Cure test. A sample of the enamelled wire shall be conditioned by baking at $130 \pm 2^\circ\text{C}$ for 10 min and allowed to cool to room temperature. Not less than 100 mm of the sample shall then be immersed, without bending, for 5 min in a boiling mixture initially containing 30 % commercial grade toluene and 70 % denaturated ethyl alcohol by volume. On removal from the liquid, the enamel film shall show no visible swelling or blistering. Any effect on the film within a distance of 12.5 mm from the immersed end of the sample shall be disregarded.

5.8 Breakdown voltages (IEC Publication 251-1, Clause 13).

5.8.1 The wire shall meet the requirements of 5.8.2. and 5.8.3 as appropriate when tested at room temperature in accordance with Appendix H.

5.8.2 Wires of conductor diameter up to and including 2.500 mm. No sample tested shall break down at a voltage less than the appropriate value given in