

BRITISH STANDARD 4738:1971

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**SPECIFICATION FOR
ENAMELLED
COPPER CONDUCTORS
WITH AN ADDITIONAL
HEAT-BONDING COATING
Part 1. Round wire**

Confirmed

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BRITISH STANDARDS INSTITUTION

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Part 1. Round wire

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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.

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. The BS Yearbook may 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.
- BS 4516. Enamelled copper conductors (polyvinyl acetal base with high mechanical properties).
Part 1. Round wire.
- BS 4520. Enamelled copper conductors (polyurethane base with solderable properties).
Part 1. Round wire.
- BS 4665. Enamelled copper conductors, temperature index 180 (modified polyester base).
Part 1. Round wire.

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 69/32975

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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 Manufacturers of Domestic Electrical Appliances
Association of Mining Electrical and Mechanical Engineers
Association of Supervisory and Executive Engineers
*British Electrical and Allied Manufacturers' Association
British Railways Board
*British Radio Equipment Manufacturers' Association
Crown Agents for Oversea Governments and Administrations
Department of Employment and Productivity
*Electric Cable Makers' Confederation
Electrical Contractors' Association (Incorporated)
Electrical Contractors' Association of Scotland
*Electrical Research Association
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
*Electronic Engineering Association
Engineering Equipment Users' Association
Institution of Electrical Engineers
Lighting Industry Federation Limited
Ministry of Defence
Ministry of Defence, Army Department
Ministry of Defence, Navy Department
Ministry of Public Building and Works
*Ministry of Technology
Municipal Passenger Transport Association (Incorporated)
National Inspection Council for Electrical Installation Contracting
National Physical Laboratory (Ministry of Technology)
Oil Companies Materials Association
Post Office
Public Transport Association
South of Scotland Electricity Board

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 Non-Ferrous Metals Federation High Conductivity Copper Group
Copper Development Association
Covered Conductors Association
Radio and Electronic Component Manufacturers' Federation
Small Electric Motor Manufacturers' Association
Society of Motor Manufacturers and Traders Limited
Telecommunication Engineering and Manufacturing Association
Telephone Manufacturers' Technical Development Committee

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BRITISH STANDARD SPECIFICATION FOR ENAMELLED COPPER CONDUCTORS WITH AN ADDITIONAL HEAT-BONDING COATING

Part 1. Round wire

FOREWORD

In accordance with the practice of publishing British Standards conforming as nearly as possible with internationally agreed recommendations, this standard closely follows the dimensions given in IEC Publication 182*, the methods of test in IEC Publication 251-1† and the requirements in IEC Publications 317-2‡ and 317-5§.

With the decline in the use of imperial units, BS 3759 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.

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 noted in brackets after the clause headings.

SI units are used in preference to 'metric technical units'. The relationship between the units of force in the two systems is:

$$1 \text{ N} = 0.102 \text{ kgf.}$$

* IEC Publication 182, 'Basic dimensions of winding wires', Part 1, 'Diameters of conductors for round winding wires', Part 2, 'Maximum overall diameters of enamelled round winding wires'.

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

‡ IEC Publication 317-2, 'Specifications for particular types of winding wires', Part 2, 'Heat or solvent bonding self-fluxing enamelled round copper wires'.

§ IEC Publication 317-5, 'Specifications for particular types of winding wires', Part 5, 'Heat or solvent bonding enamelled round copper wire with high mechanical properties'.

SPECIFICATION

1. SCOPE

1.1 General. This Part of this British Standard gives requirements and dimensions for round copper wire covered with a synthetic enamel and with an additional top coat to enable contiguous turns in a wound coil to be bonded by heat application.

1.2 Sizes. The requirements of this standard are applicable to wires having a bare diameter from 0.020 mm up to and including 2.000 mm, when covered with the enamel specified in BS 4520, Part 1* or BS 4665, Part 1†, and to wire having a bare diameter from 0.050 mm up to and including 2.000 mm, when covered with the enamel specified in BS 4516, Part 1‡.

1.3 Thickness of covering. The bonding coat is applied to any of the thicknesses of enamel specified in the relevant British Standard for the basic enamelled wire. The appropriate thickness of bonding coat is applied to meet the requirements of this standard.

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) *Tolerance.* The permissible divergence of an actual magnitude from that prescribed.
- (4) *Crack.* Any discontinuity in the enamel which penetrates significantly below the surface and which is visible at the stated magnification.

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 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.

* BS 4520, 'Enamelled copper conductors (polyurethane base with solderable properties)', Part 1, 'Round wire'.

† BS 4665, 'Enamelled copper conductors, temperature index 180 (modified polyester base)', Part 1, 'Round wire'.

‡ BS 4516, 'Enamelled copper conductors (polyvinyl acetal base with high mechanical properties)', Part 1, 'Round wire'.

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3.2 The wire to be tested shall be removed from the packaging in such a way that the wire shall 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 specimen.

3.3 When no specific range of size 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 16. These have been obtained by applying the tolerances given in Table 1.

4.2.2 Out of roundness of conductor (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 conductor 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 16.

4.3 Resistance (wires of conductor diameter up to and including 1.000 mm) (IEC Publication 251-1, Clause 5). The resistance of the conductor at 20°C shall be within the limits given in Table 16 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 above 1.000 mm diameter are included in Table 16 for information only.

5. ENAMEL COVERING

5.1 Basic enamelled wire. The basic enamelled wire, before application of the bonding coat, shall comply with all the requirements of the relevant British Standard for the particular type of enamel and thickness of covering.

* 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	0.530	0.006
0.080	0.003	0.560	0.006
0.090	0.003	0.600	0.006
0.100	0.003	0.630	0.006
0.112	0.003	0.670	0.007
0.125	0.003	0.710	0.007
0.132	0.003	0.750	0.008
0.140	0.003	0.800	0.008
0.150	0.003	0.850	0.009
0.160	0.003	0.900	0.009
0.170	0.003	0.950	0.010
0.180	0.003	1.000	0.010
0.190	0.003	1.060	0.011
0.200	0.003	1.120	0.011
0.212	0.003	1.180	0.012
0.224	0.003	1.250	0.013
0.236	0.004	1.320	0.013
0.250	0.004	1.400	0.014
0.265	0.004	1.500	0.015
0.280	0.004	1.600	0.016
0.300	0.004	1.700	0.017
0.315	0.004	1.800	0.018
0.335	0.004	1.900	0.019
0.355	0.004	2.000	0.020
0.375	0.005		
0.400	0.005		
0.425	0.005		
0.450	0.005		
0.475	0.005		
0.500	0.005		

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5.2 Bonding coat. The enamelled wire shall be completely and uniformly covered with a flexible coating having heat-bonding properties, which will satisfy the requirements of this standard. The coated wire shall have a smooth surface, free of embedded particles of dust or other deleterious material.

5.2.1 Test requirements. The coated wire shall, in general, comply with the test requirements specified in the British Standard for the basic enamelled wire, with certain modifications as indicated in the following subclauses.

5.2.2 Lubrication. Unless otherwise agreed, the wire shall be lubricated with a neutral hydrocarbon oil or wax to assist in the handling of the coated wire. This lubricant shall be kept to a minimum and shall have no deleterious effect on the final bond strength.

5.3 Diameter of conductor and overall diameters. When determined by the method described in Appendix A the conductor shall conform to the appropriate limits laid down in Table 16 and the overall diameters of the coated enamelled wire shall conform to the maximum and minimum limits laid down in Table 16.

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

5.4.1 Mandrel winding test. After winding 10 contiguous turns on a polished mandrel, the diameter of which is specified in Table 2, the covering of the sample shall show no cracks when examined under a magnification of between 6 and 10 times.

The mandrel shall be rotated at between 1 and 3 turns per second, the tension on the wire being just sufficient to keep it in contact with the mandrel. It is essential that care should 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	
—	0.040	0.150 mm*
0.040	0.250	$3d$ *
0.250	2.000	d

* The wire shall be stretched 20 % or to the breaking point, whichever is less, before winding on the mandrel.

5.4.2 Jerk test (for wires of conductor diameter up to and including 1·000 mm). The covering shall show no cracks or loss of adhesion when tested in accordance with Appendix C.

5.4.3 Peel test (for wires of conductor diameter over 1·000 mm). When tested in accordance with Appendix D the covering shall show no loss of flexibility or adhesion.

5.5 Heat shock (IEC Publication 251-1, Clause 9). Three test specimens shall be prepared as described in 5.4.1 but using the mandrel diameters given in Table 3, and heated for 30 min in an electrically heated oven with forced air circulation at the temperature given in the corresponding clause in the specification for the basic enamelled wire*.

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 to 10 times. Each specimen shall be free of cracks.

TABLE 3. MANDREL DIAMETERS FOR HEAT SHOCK TEST

Nominal conductor diameter		Mandrel diameter (d = nominal diameter of conductor in mm)		
Over	Up to and including	Grades 1, 2 and 3 BS 4516 Part 1†	Grades 1 and 2 BS 4665, Part 1‡ and BS 4520, Part 1§	Grade 3 BS 4665 Part 1‡
mm	mm			
—	0·040		0·150 mm	—
0·040	0·160	$3d $	$3d $	$4d $
0·160	0·250	$3d $	$4d $	$5d $
0·250	1·000	d	$2d$	$3d$
1·000	2·000	d	$3d$	$4d$

* 155°C to 160°C for enamelled conductors complying with BS 4516 Part 1 and BS 4520 Part 1, 200°C to 205°C for enamelled conductors complying with BS 4665, Part 1.

† BS 4516, 'Enamelled copper conductors (polyvinyl acetal base with high mechanical properties)', Part 1, 'Round wire'.

‡ BS 4665, 'Enamelled copper conductors, temperature index 180 (modified polyester base) Part 1, 'Round wire'.

§ BS 4520, 'Enamelled copper conductors (polyurethane base with solderable properties)', Part 1, 'Round wire'.

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

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5.6 Cut-through (IEC Publication 251-1, Clause 10). When tested in accordance with Appendix E, specimens shall show no failure after 2 min at the temperature given in the corresponding clause in the specification for the basic enamelled wire*.

5.7 Breakdown voltage (IEC Publication 251-1, Clause 13).

5.7.1 The wire shall meet the requirements specified in 5.7.2 and 5.7.3 when tested at room temperature in accordance with Appendix F.

5.7.2 Wires of conductor diameter up to and including 0.040 mm. At least four of the five samples tested shall not break down at a voltage less than the appropriate values given in Table 4.

5.7.3 Wires of conductor diameter over 0.040 mm. The breakdown voltage shall not be less than the values given in Table 4. If, however, one of the five samples tested breaks down at a lower voltage than that given in Table 4, the test shall be repeated with a second series of five samples and then no breakdown shall occur.

5.8 Solder test (IEC Publication 251-1, Clause 17). Applicable only to coated base wires to BS 4520, Part 1†. When tested in accordance with Appendix G the surface of the solder coating shall be smooth and free from holes and enamel or coating residues.

5.9 Bond strength test (IEC Publication 251-1, Clause 18). When tested in accordance with Appendix H, no turn other than the first or last turns shall separate when the load given in Table 5 is applied.

* 170°C for enamelled conductors complying with BS 4516 Part 1 and BS 4520 Part 1, 265°C for enamelled conductors complying with BS 4665, Part 1.

† BS 4520, 'Enamelled copper conductors (polyurethane base with solderable properties)', Part 1, 'Round wire'.

TABLE 4. BREAKDOWN VOLTAGES

Nominal conductor diameter		Minimum breakdown voltage, r.m.s.		
		Grade 1	Grade 2	Grade 3
mm		V	V	V
0.020		40	115	
0.0224		40	115	
0.025		60	140	
0.028		60	140	
0.030		60	140	
0.032		70	175	
0.036		70	175	
0.040		100	230	
0.045		350	700	
0.050		350	700	
0.056		375	750	
0.060		375	750	
0.063		400	800	
Over	Up to and including			
mm	mm			
0.063	0.080	500	950	1400
0.080	0.100	600	1200	1600
0.100	0.125	700	1300	1800
0.125	0.160	800	1500	2200
0.160	0.200	900	1700	2500
0.200	0.250	1000	2000	3000
0.250	0.315	1200	2200	3300
0.315	0.400	1400	2400	3700
0.400	0.500	1600	2800	4000
0.500	0.710	1800	3100	4400
0.710	0.850	1900	3500	4700
0.850	0.950	2000	3700	5100
0.950	1.120	2100	3800	5300
1.120	1.320	2200	3900	5600
1.320	1.600	2300	4000	5900
1.600	1.900	2400	4300	6100
1.900	2.000	2500	4400	6300