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Full document details: BS 480-1:1954

Superseded by 480 : 1966
+ 7 amendments

BRITISH STANDARD 480 : Part 1 : 1954

IMPREGNATED PAPER-INSULATED CABLES

FOR ELECTRICITY SUPPLY

Part 1: Lead or lead-alloy sheathed cables for working voltages up to and including 33kV

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IMPREGNATED PAPER-INSULATED CABLES FOR ELECTRICITY SUPPLY

Part 1 : Lead or lead-alloy sheathed cables for working voltages up to and including 33kV

B.S. 480 : Part 1 : 1954

Price ~~6/-~~ 7/- net

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THIS BRITISH STANDARD, having been approved by the Electrical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 23rd July, 1954.

First published, March, 1933
First revision, May, 1942
Second revision, July, 1954

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 2000, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook, price 12s. 6d.

This standard makes reference to the following British Standards :—

B.S. 77. Voltages for a.c. transmission and distribution systems of authorized undertakers.
B.S. 84. Screw threads of Whitworth form.
B.S. 205. Glossary of terms used in electrical engineering.
B.S. 350. Conversion factors and tables.
B.S. 443. Testing of the zinc coating on galvanized wires.
B.S. 801. ~~Lead and lead-alloys for cable sheathing.~~ See Amdt. 2
B.S. 1442. Galvanized mild steel wire for armouring cables.

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 B.S.I. references relate to the work on this Standard :—
Committee reference ELE/3/10 Draft for comment CR(ELE) 500

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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 :—

*Admiralty
*Air Ministry
*Association of Consulting Engineers (Incorporated)
*Association of Supervising Electrical Engineers
*British Electrical and Allied Industries Research Association
British Electrical and Allied Manufacturers' Association
British Electrical Development Association
*British Electricity Authority and Area Boards
*British Railways. The British Transport Commission
*Cable Makers' Association
*Crown Agents for Oversea Governments and Administrations
Electric Lamp Manufacturers' Association
Electric Light Fittings Association
*Electrical Contractors' Association (Incorporated)
Electrical Contractors' Association of Scotland
Engineering Equipment Users' Association
*General Post Office
*Institution of Electrical Engineers
*Ministry of Fuel and Power
Ministry of Labour and National Service (Factory Dept.)
*Ministry of Supply
*Ministry of Works
*National Physical Laboratory
*North of Scotland Hydro-Electric Board
Oil Companies Materials Committee
Public Transport Association (Incorporated)
Radio Industry Council
War Office

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 the standard :—

British Plastics Federation
British Steel Wire Industries Association
Engineering Standards Co-ordinating Committee, Cables and Wires Panel
Independent Cable Makers' Association
London Transport Executive
Municipal Passenger Transport Association
National Coal Board

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BRITISH STANDARD SPECIFICATION FOR

IMPREGNATED PAPER-INSULATED CABLES FOR ELECTRICITY SUPPLY

Part 1. Lead or lead-alloy sheathed cables for working voltages up to and including 33kV

FOREWORD

This revision of B.S. 480 includes requirements for lead or lead-alloy sheathed cables, and aluminium sheathed cables, which are dealt with in separate, self-contained parts as follows :—

Part 1. Lead or lead-alloy sheathed cables for working voltages up to and including 33kV.

Part 2. Aluminium sheathed cables for working voltages up to and including 22kV.

This British Standard now contains ' quality ' clauses dealing with the composition of the various components of the cable.

Part 1 of the standard now includes requirements for 33kV solid type power cables. These cables have an impulse strength greater than 194kV which is the impulse withstand voltage currently used in the United Kingdom.

The basic reference temperature for certain properties of ' standard annealed copper ' has been amended from 60°F. to 20°C.

The practice in B.S. 480 : 1942 of specifying minimum and maximum diameters over lead sheath and overall has been abandoned in favour of nominal diameters.

Cables which comply with the requirements for minimum insulation and sheath thickness will have the stated nominal diameters, which allow reasonable manufacturing tolerances.

When cable is to be installed in vertical (or steeply inclined) situations, and/or where compliance with the requirements of Clause 26*b* is required, this should be stated when asking for a quotation or placing an order.

For details of current ratings and maximum permissible operating conductor temperatures, reference should be made to the Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers, where applicable, and otherwise to Electrical Research Association Report F/T 183.*

The voltages applied after the bending test have been increased, for cables up to and including 11kV, and a physical examination of the test sample is now specified for all cables, with the intention of accumulating data for a revision of this standard in the future.

* This report supersedes E.R.A. Report F/T 128.

See amdt No 6.

SPECIFICATION

SECTION ONE : GENERAL

SCOPE

1. Part 1 of this British Standard relates to impregnated paper-insulated lead or lead-alloy sheathed cables for operating voltages up to and including 33kV.

The operating voltage mentioned at the head of Tables 8–15 and Table 17 is the system voltage, as defined in B.S. 77*, for which the cables are designed and it refers to :

a. the voltage between phases, in three-phase systems ;

b. the voltage between outer conductors, in three-wire a.c. or d.c. systems ;

c. the voltage between conductors, in two-wire a.c. or d.c. systems.

For the purposes of this standard a system may be considered to be an earthed system if :

(i) the neutral point is earthed in such a manner that the maximum voltage which can occur between any conductor and earth does not exceed 80 per cent of the system voltage, *or*

(ii) a device is installed which automatically and instantly cuts out any part of the system which becomes accidentally earthed, *or*

(iii) the neutral point is earthed through an arc suppression coil, with arrangements for isolation within an hour of the occurrence of a fault. For cables for 11kV and over, excluding belted cables, this period may be increased to eight hours per operation provided that the total period in any year does not exceed 125 hours.

DEFINITIONS

2. For the purposes of this British Standard the definitions relating to electric cables in B.S. 205, ' Glossary of terms used in electrical engineering,' shall apply.

INTERNATIONAL STANDARDS OF RESISTANCE FOR COPPER

3. The following values adopted by the International Electrotechnical Commission† for ' standard annealed copper,' have been taken as standard for annealed high-conductivity copper :—

a. At a temperature of 20°C. the volume resistivity of standard annealed copper is 1/58 = 0·017 241 . . . ohm square millimetre per metre, $\left(\frac{\text{ohm mm}^2}{\text{m}}\right)$. Copper which has this resistivity is said to have a conductivity of 100 per cent.

Amdt No 6

* B.S. 77, ' Voltages for a.c. transmission and distribution systems of authorized undertakers '.

† I.E.C. Publication No. 28.

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(Amdt No. 6)

b. At a temperature of 20°C. the density of standard annealed copper is 8·89 grammes per cubic centimetre, $\left(\frac{g}{cm^3}\right)$.

c. At a temperature of 20°C. the coefficient of linear expansion of standard annealed copper is 0·000 017 per degree Centigrade.

NOTE. The above value of the coefficient of linear expansion may be applied to annealed copper over a temperature range from 0°C. to 150°C.

d. At a temperature of 20°C. the coefficient of variation of the resistance with temperature of standard annealed copper, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, is :

$$0{\cdot}003\,93 = \frac{1}{254{\cdot}45\ldots} \text{ per degree Centigrade.}$$

e. As a consequence, it follows from *a* and *b* that at a temperature of 20°C. the mass resistivity of standard annealed copper is 1/58 × 8·89 = 0·153 28 . . . ohm gramme per metre per metre.

NOTE. For the purpose of calculating the tables, the decimal equivalent of 1/58 has been extended to 0·017 241 379.....

RESISTANCE OF A SOLID CONDUCTOR AT 20°C.

4. For the purpose of calculating the tables, the resistance of a solid conductor of standard annealed copper at 20°C., 1000 yards in length, and of a uniform cross-sectional area of one square inch, has been taken as 0·024 436 6 ohm.

TABLES FOR CONVERTING VALUES FROM BRITISH TO METRIC MEASURE

5. The metric equivalent of the dimensions given in this specification may be obtained from B.S. 350, ' Conversion factors and tables.'

DIMENSIONS, WEIGHTS AND RESISTANCES OF STANDARD COPPER WIRES AND STRANDED CONDUCTORS

Page 10 Amdt No. 6

6. The dimensions, nominal weights, and resistances of standard circular copper wires used for circular conductors shall be in accordance with the values specified in Table 5.

The dimensions, nominal weights and resistances of standard circular stranded conductors shall be in accordance with the values specified in Table 6.

The standard resistances of shaped conductors shall be in accordance with the values specified in Table 6. In the formation of shaped conductors containing less than 19 wires the same number of wires shall be used as for a circular conductor of equivalent area. For conductors having 19 wires or more the number or wires shall be the same as in a circular

(Amdt No. 6)

conductor of equivalent area, subject to a maximum permissible variation of plus or minus one wire. All the wires in any given shaped conductor shall be of the same nominal size.

In Table 6 the areas and resistances of the stranded conductors have been calculated by multiplying the corresponding values for one of the single wires of which the stranded conductor is composed, by the constants specified in Table 1, which allows for an increase of 2 per cent in the length of each wire, except the centre wire.

TABLE 1. CONSTANTS FOR THE CALCULATION OF CROSS-SECTIONAL AREAS AND RESISTANCES OF STRANDED CONDUCTORS

Number of wires stranded	Constant	
	Area	Resistance
7	6·882 35	0·145 299
19	18·647 1	0·053 627 8
37	36·294 1	0·027 552 7
61	59·823 5	0·016 715 8
91	89·235 3	0·011 206 3
127	124·629	0·008 030 23

TOLERANCES ON THE STANDARD RESISTANCE OF WIRES AND STRANDED CONDUCTORS

7. The tolerances on the standard resistance of wires and stranded conductors shall be as specified in Table 2.

TABLE 2. TOLERANCES ON RESISTANCE OF WIRES AND STRANDED CONDUCTORS

Conductors	Tolerance on resistance
	per cent
Circular wires	+3
Stranded conductors	+2

The values corresponding to the tolerances shown above are specified in Tables 5 and 6. In Table 6 an additional 2 per cent increase in resistance is allowed for twin and multicore cables, to take into account the increase in length due to the laying up of the cores.

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FORM OF CONDUCTORS

8. Unless otherwise specified in the tables the conductors of all twin and multicore cables are shaped.

VARIATION OF RESISTANCE WITH TEMPERATURE

9. The constants for converting the resistance of annealed copper at a temperature T°C. to the standard temperature 20°C. shall be as specified in Columns 2 and 5 of Table 7, and the reciprocals for converting the resistance at 20°C. to the resistance of T°C. shall be as specified in Columns 3 and 6 of Table 7.

SECTION TWO : CONSTRUCTION

See Amdt No. 6

CONDUCTORS

10. *a. Materials.* The conductor shall be composed of plain annealed copper wire which, before stranding, shall be approximately circular in section, smooth, uniform in quality, free from scale, inequalities, spills, splits and other defects.

The term 'annealed' signifies that the wire before stranding is capable of at least 15 per cent elongation without fracture, the test piece being not less than 6 in. and not more than 12 in. long.

The stranded conductor shall be clean and reasonably uniform in size and shape and its surface shall be free from sharp edges.

b. Jointing. Not more than two joints shall be allowed in any one of the single wires forming every complete length of conductor, and no joint shall be within 12 in. of any other joint in the same layer. Joints shall be brazed, silver soldered or electrically welded. No joint shall be made in the conductor after it has been stranded.

INSULATION

Amdt. V

11. *a. Paper.* All paper used for cable insulation shall be uniform in texture, long fibred and free from dark spots, imperfectly pulped materials, woody matter, lime spots, metallic particles ~~or~~ and other deleterious substances. It shall contain no mechanical wood pulp or esparto.

The paper shall be free from chemical impurities, acids, alkalis and salts to the extent that not more than 1 per cent by weight is soluble in water. Chemicals used in pulping, bleaching or other process of manufacture shall be removed. The paper shall be free from loading materials and from gelatine, albumen and resin size. The ash from a moisture-free sample shall not exceed 1·5 per cent by weight.

The paper shall be applied in the form of tapes laid helically, successive layers when applied in the same direction breaking joint so as to form a reasonably smooth and compact covering of uniform thickness.

Samples of crease-free impregnated paper tapes shall be taken from completed cables when requested and, when tested by the following method, the breaking strength of the test strips specified shall be not less than 4 lb. per mil of thickness and the elongation at break shall be not less than 1·5 per cent.

Method. Cut the impregnated paper tapes into strips ⅝ in. wide and not less than 9 in. long and condition them for 24 hours at a relative humidity of 65 per cent and a temperature of 17–~~20~~ 21°C. After removing surplus compound, measure the thickness of the conditioned impregnated paper tapes to the nearest 0·1 mil (0·0001 in.), and then test the tapes in a tensile testing machine having a distance of approximately 7 in. between grips.

Amdt No 1 Page 23

b. Core identification. All 1100 volt twin and multicore cables shall have the cores identified by numbers printed on the outer layer (or layers) of paper at frequent intervals as shown below. The numbers 1, 2 and 3 indicate live conductors and 0 the neutral.

Twin { 0, 1 } 3-core { 0–1, 2, 3 } 4-core { 0, 1, 2, 3 }

5-core { 0, 1, 2, 3, 4 (special-purpose conductor) }

The sequence of laying up of the cores shall be as shown above. All 3-core cables for voltages of 3300 volts and above shall have the cores identified by numbers as follows :—

1 2 3

The printing shall preferably be in white on a dark background.

The core identification tapes shall comply with the requirements of Sub-clause *a*. The dyes used shall not fade unduly, shall be chemically neutral, and shall have no injurious effect on the fibres of the paper.

c. Screening. For cables described in the tables as screened cables, the screening applied over each individual core shall consist of either metallized paper or non-ferrous metal tape. The nominal thickness of the aluminium foil on metallized paper shall be 0·0005 in. and that of metal tape 0·003 in.

LAYING UP TWIN AND MULTICORE CABLES

12. *a. Belted cables.* In twin and multicore belted cables the insulated conductors shall be laid up together, wormed with paper or jute, and covered with further layers of paper to form a compact and circular cable.

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b. Screened cables. In 3-core screened cables the three insulated and screened conductors shall be laid up together, wormed with paper or jute, and shall have a binder of copper woven fabric tape applied overall. (See diagram of 3-core screened cable in Appendix A.)

c. S.L. cables. In 3-core S.L. cables the three insulated and sheathed cores, protected in the manner described in Clause 18, shall be laid up together, wormed with suitable compounded jute and shall have a binder of suitable compounded fibrous material, applied over the laid-up cores. This shall comprise the bedding for the armour as described in Clause 18.

d. Direction of lay. The direction of lay of the cores shall be right-hand for all twin and multicore cables. The term 'right-hand' has the same meaning as specified for screw threads in B.S. 84.*

IMPREGNATION

13. The insulation shall be suitably dried and impregnated with a compound so that no deterioration of the insulation occurs under working conditions.

THICKNESS OF INSULATION

14. The thickness of insulation determined in accordance with Clause 15 shall be not less than the values specified in the appropriate table.

MEASUREMENT OF INSULATION THICKNESS

15. *a. Method.* Measurement of the insulation thickness shall be made on a representative sample of the cable, not more than 6 in. in length and taken not less than 12 in. from the end of a factory length.

The thickness of insulation shall be determined by bunching together the individual strips of paper removed from the finished cable (without removing surplus compound from the papers) and measuring the total thickness with a micrometer having the characteristics defined below. All the papers comprising the insulation shall be included in the measurement. When the thickness of insulation is so great that it is inconvenient to bunch all the papers comprising the insulation thickness to be measured, it shall be permissible to separate the papers into as few groups as are necessary to measure each individual group and add the results to obtain the total thickness.

The faces of the micrometer shall be cleaned between successive measurements.

b. Micrometer. The apparatus may be any form of precision dead weight micrometer capable of gauging the thickness of a number of impregnated tapes, up to a possible total thickness of 0·25 in., with an instrument error not exceeding ± 0·2 mil (0·0002 in.).

The micrometer shall be provided with two parallel plane faces between which the paper can be placed for measurement. One of the

* B.S. 84, 'Screw threads of Whitworth form'.

faces shall be able to move in a direction perpendicular to the other, which is fixed. The movable face of the pressure foot shall be circular, and have a diameter of 0·25 (± 0·01) in. The area of contact between the fixed face and the pressure foot shall be equal to the area of the pressure foot. The faces shall be concentric and parallel to within 0·0001 in. over the range of travel.

The pressure foot shall exert a steady pressure of 50 (± 2·5) lb/sq. in.

MANUFACTURER'S IDENTIFICATION

16. The manufacturer's identification shall be provided throughout the length of the cable by means of a tape under the lead or lead-alloy sheath printed with the manufacturer's name at intervals not greater than one foot.

LEAD OR LEAD-ALLOY SHEATH

17. *a. Composition and quality.* The composition of the lead or lead-alloy sheath shall be in accordance with B.S. 801*.

The sheath shall be impervious to moisture, reasonably close fitting and free from defects.

b. Thickness. The minimum thickness of the sheath determined in accordance with Sub-clause *c* shall be not less than the value specified in the appropriate table.

c. Measurement of thickness of sheath. The measurement shall be taken either on a ring or, for cables less than 0·5 in. diameter over sheath, on a flattened circumferential strip carefully cut from a sample. In either case, the sample to be measured shall be taken not less than 12 in. from the end of a factory length.

The thickness of the sheath shall be determined at a sufficient number of points around the circumference of the ring sample or along the surface of the strip sample to ensure that the minimum thickness is measured.

The measurements shall be made with a micrometer having either one flat nose and a ball nose or one flat nose and a flat rectangular nose 1/32 in. wide and 3/32 in. long. When the tests are made on the ring sample, the ball nose or the ~~flat~~ flat rectangular nose shall be applied to the inside of the ring. Amdt No 1 Page 2/3

BEDDING

18. The bedding for armoured cables, except S.L. cables, shall consist of a complete layer or layers of suitable compounded fibrous materials; additional compound shall be applied under and over each separate layer. When cables are intended for laying direct in the ground or are to be drawn into ducts, additional protection shall be provided consisting of two compounded paper tapes applied immediately over the previously compounded lead or lead-alloy sheath. Alternatively, for this additional

*B.S. 801, 'Lead and lead-alloys ~~for cable sheathing~~ sheaths of electric cable'. See Amdt. 2.

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