Specification for armoured cables with extruded cross-linked polyethylene or ethylene propylene rubber insulation for rated voltages from 3.8/6.6 kV up to 19/33 kV having low emission of smoke and corrosive gases when affected by fire

ICS 29.060.20

Committees responsible for this British Standard

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Association of Consulting Engineers
British Approvals Service for Cables
British Cables Association
British Plastics Federation
Electricity Association
ERA Technology Ltd.
London Underground Ltd.
UK Steel Association

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Contents

Foreword

This new edition of BS 7835 has been prepared by Subcommittee GEL/20/2. It supersedes BS 7835:1996 which is withdrawn.

This edition includes technical changes to bring the standard up to date and is a full review of the standard.

This standard deals with armoured cables in the rated voltage range from 3.8/6.6 kV up to 19/33 kV insulated with cross-linked polyethylene (XLPE) or ethylene propylene rubber compound (EPR), covering cables with improved performance under fire conditions compared to those specified in BS 6622.

Annexes E, F, G, H, J, K, L and M are normative. Annexes A, B, C, D and N are informative. Annex I is spare.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

WARNING. This British Standard calls for the use of procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

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 43 and a back cover.

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1 Scope

This British Standard specifies requirements for the construction and testing of armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 (7.2) kV up to 19/33 (36) kV inclusive which, when assessed by the specified tests, produce lower levels of smoke and corrosive products under exposure to fire compared with cables conforming to BS 6622.

Cables specified in this standard are for use in fixed industrial installations and buildings. The cables are designed for a maximum continuous conductor operating temperature of 90 °C and for a maximum short circuit conductor temperature of 250 °C.

In this standard, the level of corrosive and acid gases is determined by measurement of hydrochloric acid (HCl) in accordance with BS EN 50267-2-1.

NOTE This is an indirect assessment method, and reference should be made to IEC 60695-5-2:1994, 5.1.5 for additional guidance.

The cable types specified in this standard are single-core and three-core cables as follows:

- — stranded copper, stranded aluminium or solid aluminium conductors;
- — cross-linked polyethylene or cross-linked ethylene propylene rubber insulation;
- — copper wire or copper tape metallic screens.

Annex A gives guidance on the selection of cables of appropriate voltage designations for particular systems.

Annex B lists the information that should be provided by the purchaser with an enquiry/order for cables.

Annex C gives recommendations for the installation of cables.

Annex N gives guidance on the use of cables.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 358, *Method for the measurement of voltage with sphere-gaps (one sphere earthed).*

BS 443:1982, *Specification for testing zinc coatings on steel wire and for quality requirements.*

BS 923-1, *Guide on high-voltage testing techniques — Part 1: General.*

BS 4066-3, *Tests on electric cables under fire conditions — Part 3: Tests on bunched wires or cables.*

BS 4727-2:Group 08, *Glossary of electrotechnical, power, telecommunications, electronics, lighting and colour terms — Part 2: Terms particular to power engineering — Group 08: Electric cables.*

BS 4828:1985, *Guide for partial discharge measurements.*

BS 5099, *Specification for spark testing of electric cables.*

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

BS 7655-6.1, *Specification for insulating and sheathing materials for cables — Part 6: Thermoplastic sheathing compounds having low emission of corrosive gases, and suitable for use in cables having low emission of smoke when affected by fire — Section 6.1: General application thermoplastic types.*

BS EN 10002-1, *Tensile testing of metallic materials — Part 1: Method of test at ambient temperature.*

BS EN 50265-2-1:1999, *Common test methods for cables under fire conditions — Test for resistance to vertical flame propagation for a single insulated conductor or cable — Part 2-1: Procedures — 1 kW pre-mixed flame.*

BS EN 50267-2-1, *Common test methods for cables under fire conditions — Test on gases evolved during combustion of materials from cables — Part 2-1: Procedures — Determination of amount of halogen acid gas.*

BS EN 50268, *Common test methods for cables under fire conditions — Measurement of smoke density of cables burning under defined conditions.*

BS EN 60060-2, *High voltage test techniques — Part 2: Measuring systems.*

BS EN 60811-1-1:1995, *Insulating and sheathing materials of electric cables — Common test methods — Part 1: General application — Section 1.1: Measurement of thickness and overall dimensions — Tests for determining the mechanical properties.*

BS EN 60811-1-2:1995, *Insulating and sheathing materials of electric cables — Common test methods — Part 1: General application — Section 1.2: Thermal ageing methods.*

BS EN 60811-1-3:1995, *Insulating and sheathing materials of electric cables — Common test methods — Part 1: General application — Section 1.3: Methods for determining the density — Water absorption tests — Shrinkage test.*

BS EN 60811-2-1:1995, *Insulating and sheathing materials of electric cables — Common test methods — Part 2: Methods specific to elastomeric compounds — Section 2.1: Ozone resistance test — Hot set test — Mineral oil immersion test.*

3 Definitions

For the purposes of this British Standard the definitions given in BS 4727-2:Group 08 and the following apply.

3.1

rated voltage

reference voltage for which the cable is designed

NOTE This is expressed as a combination of the values U_0, U and U_m.

3.2

rated voltage U_0

nominal power-frequency voltage between any conductor and earth or metallic screen for which the cable is suitable

3.3

rated voltage U

nominal power-frequency voltage between phase conductors for which the cable is suitable

3.4

maximum voltage U_m

maximum sustained power-frequency voltage between phase conductors for which the cable is suitable

3.5

cross-linked polyethylene (XLPE)

thermosetting material formed by the cross-linking of thermoplastic polyethylene compound so as to conform to the requirements given in this standard

3.6

cross-linked ethylene propylene rubber (EPR)

compound based on ethylene propylene rubber or similar (ethylene propylene monomer or ethylene propylene diene monomer) which when cross-linked conforms to the requirements given in this standard

3.7

nominal value

value, often used in tables, by which a quantity is designated

NOTE In this standard, nominal values usually give rise to values to be checked by measurements taking into account specified tolerances.

3.8

approximate value

value which is only indicative

NOTE In this standard, values described as "approximate" do not constitute requirements to be checked by measurements.

3.9

routine tests

tests performed by the manufacturer on each manufactured length of cable to check that the whole of each length meets the specified requirements

3.10

sample tests

tests performed by the manufacturer on samples of completed cables, or components taken from a completed cable, at a specified frequency, so as to verify that the finished product meets the specified requirements

3.11

type tests

tests made before supplying, on a general commercial basis, a type of cable covered by this standard in order to demonstrate satisfactory performance characteristics to meet the intended application

NOTE Type tests are of such a nature that, after they have been performed, they need not be repeated unless changes are made in the cable materials or design or manufacturing process which might change the performance characteristics.

3.12

tests after installation

tests intended to demonstrate the integrity of the cable and its accessories as installed

4 Voltage designation

Cables are designated by the voltage U_0, U and U_m expressed in the form U_0/U (U_m).

The voltage designation of cables in this standard are:

3.8/6.6 (7.2) kV   6.35/11 (12) kV
8.7/15 (17.5) kV   12.7/22 (24) kV
19/33 (36) kV.

5 Conductors

5.1 General

Conductors shall be either plain annealed copper or aluminium, circular or shaped, and shall conform to BS 6360. Copper conductors shall be stranded (class 2) and aluminium conductors shall be either solid (class 1) or stranded (class 2).

5.2 Circular conductors

Stranded circular conductors shall be compacted or uncompacted.

5.3 Shaped conductors

Shaped conductors, when used as an alternative to circular conductors for three-core cables of rated voltages 3.8/6.6 (7.2) kV and 6.35/11 (12) kV shall have a conductor cross-sectional area not less than the following:

3.8/6.6 (7.2) kV: 70 mm^2
6.35/11 (12) kV: 95 mm^2

The dimensions of shaped solid aluminium conductors shall be as given in Table 1.

Table 1 — Dimensions of shaped solid aluminium conductors

Nominal cross-sectional area of conductor	Approximate dimensions of conductor				Minimum corner radius of conductor
	Width	Depth	Back radius	Corner radius	
mm^2	mm	mm	mm	mm	mm
70	11.3	7.9	9.9	2.8	2.6
95	13.9	9.1	11.4	2.8	2.6
120	15.8	10.2	12.6	3.0	2.8
150	17.9	11.3	13.9	3.0	2.8
185	20.5	12.6	15.4	3.0	2.8
240	24.0	14.5	17.5	3.0	2.8
300	27.3	16.2	19.5	3.0	2.8

6 Conductor screen

A conductor screen consisting of an extruded layer of cross-linkable semi-conducting compound shall be applied over the conductor and cover the surface of the conductor completely.

NOTE A semi-conducting tape may be applied prior to the extruded layer at the discretion of the manufacturer.

The extruded conductor screen shall be applied in the same operation as the insulation and be fully bonded to the insulation.

7 Insulation

The insulation shall be either XLPE or EPR conforming to the requirements of **20.5**.

The insulation shall be applied by extrusion and cross-linked to form a compact and homogeneous layer.

The colour of the insulation shall be such that it is easily distinguishable from the screening materials.

The minimum and minimum average thickness of insulation shall be as specified in Tables 2 to 11.

8 Insulation screen

8.1 General

An insulation screen shall be applied to all cables and shall consist of a cross-linkable extruded semi-conducting layer in combination with a metallic layer.

8.2 Extruded semi-conducting layer

The extruded semi-conducting layer shall consist of a bonded or strippable semi-conducting compound capable of removal for jointing and terminating (see **C.5**). It shall be applied in the same operation as the insulation, directly over the insulation, and cover the surface of the core completely.

NOTE At the discretion of the manufacturer, semi-conducting tape or a semi-conducting extruded layer may be applied over the semi-conducting insulation screen as a bedding for the metallic layer.

8.3 Metallic layer

8.3.1 *General*

The metallic layer shall be applied either around each core and/or as a collective screen. For rated voltages above 8.7/15 (17.5) kV, a metallic screen shall be applied around each core.

8.3.2 *Metallic screen on each core*

A metallic screen applied directly over the core of single-core cables or each core in three-core cables, shall consist of either helically applied overlapped metallic tape(s) or a concentric layer of copper wires applied helically or in a waveform.

The copper wires shall be spaced with an average gap not greater than 4 mm. No gap shall exceed 8 mm.

NOTE 1 At the discretion of the manufacturer, a copper equalizing tape may be applied.

NOTE 2 At the discretion of the manufacturer, a binder tape may be applied over the metallic screen of single-core cables.

NOTE 3 For single-core cables the armour may serve as the metallic screen.

8.3.3 *Collective metallic screen*

Three-core cables not having a metallic screen over each individual core shall have a collective screen of steel wire armour applied after the cores have been laid up together and over the bedding layer (see clauses **10** and **11**).

9 Laying up

For three-core cables, the cores shall be laid up with a right-hand direction of lay. The metallic screens of individually screened cores shall be in contact with each other. Fillers shall be used to form a substantially compact and circular cable. The fillers shall be compatible with adjacent materials.

NOTE At the discretion of the manufacturer, a binder tape may be applied over laid-up individually screened cores.

10 Bedding layer

For single-core cables with a copper screen the bedding layer shall be extruded.

For three-core cables an extruded or lapped bedding layer shall be applied around the laid-up cores. For cables with a metallic screen on each core the bedding layer shall be extruded. For cables not having a metallic layer on each core the bedding shall be lapped and semi-conducting.

The extruded material, when tested in accordance with BS EN 60811-1-1, shall have a tensile strength of not less than 4 N/mm^2 and elongation at break of not less than 50 %. The nominal and minimum thickness of the extruded bedding layer shall be as specified in Tables 2 to 11.

NOTE If the bedding layer is extruded, the fillers may be applied integrally with the bedding layer.

The lapped bedding layer shall cover the surface of the laid-up cores completely. The thickness of the lapped bedding layer shall be approximately 0.6 mm. The shape of the fillers shall not prevent electrical contact between the insulation screen and the lapped semi-conducting bedding layer.

The materials used for the bedding layer shall be suitable for the operating temperature of the cable and compatible with the other materials used in the cable construction.

11 Armour

11.1 General

All cables specified in this standard shall be armoured.

11.2 Metal layer

For the armouring of three-core cables, round galvanized steel wires shall be used.

NOTE 1 Where the purchaser requires the cable to operate at a higher system fault level a number of galvanized steel wires may be substituted by tinned copper wires subject to agreement with the manufacturer.

NOTE 2 When requested by the purchaser, galvanized steel tape may be used as an alternative to or in conjunction with steel wire armour.

For the armouring of single-core cables either round aluminium wires or aluminium strips shall be used.

The nominal dimensions of the armour shall be as specified in Tables 2 to 11.

Armour shall be applied helically in a single layer with a left-hand lay.

Joints in steel wire armour shall be brazed or welded and any surface irregularity removed.

Joints in aluminium wire or strip shall be made by cold pressure or fusion welding and all surface irregularities removed.

A joint in any wire or strip shall be not less than 1 m from the nearest joint in any other armour wire or strip in the completed cable.

12 Oversheath

12.1 General

The material for the extruded oversheath shall conform to BS 7655-6.1, Type LTS 1.

NOTE Oversheaths are normally black but colours other than black may be provided by agreement between the manufacturer and the purchaser, subject to their suitability for the particular conditions under which the cables are to be used.

12.2 Thickness of oversheath

The nominal and the minimum thickness of oversheath shall be as specified in Tables 2 to 11.

13 Marking

13.1 Marking of oversheath

The external surface of all cables shall be legibly marked with the following elements of marking, in any sequence that is deemed neither to confuse nor conflict.

Element	Example of marking
a) Electric cable	ELECTRIC CABLE
b) Voltage designation	
3.8/6.6 (7.2) kV	6 600 V
6.35/11 (12) kV	11 000 V
8.7/15 (17.5) kV	15 000 V
12.7/22 (24) kV	22 000 V
19/33 (36) kV	33 000 V
c) British Standard number[1)]	BS 7835
d) Manufacturer's identification	XYZ

e) The number of cores, type and nominal area of conductors, e.g.

1) Copper conductor cables: 1 × 50 shall indicate a single-core cable with a 50 mm^2 copper conductor;

2) Aluminium conductor cables: 3 × 50 AL shall indicate a three-core cable with 50 mm^2 aluminium conductors.

The marking of elements a) to d) shall be by embossing or indenting on the oversheath.

1) Marking BS 7835 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Elements a), b) and c) shall appear on two or more primary lines along the axis of the cable, approximately equally spaced around the circumference of the cable.

Elements d) and e) shall appear on at least one line.

NOTE They may be on one of the primary lines or a secondary line or lines and need not be on the same line.

The letters and figures shall consist of upright block characters. The characters shall have a minimum height of 3 mm.

The distance between the end of one element of marking and the beginning of the next identical element shall be not greater than 550 mm, for items a), b) and c), and not greater than 1 100 mm for items d) and e).

13.2 Identification of year of manufacture

A means of identifying the year of manufacture of the cable shall be provided throughout the length of the cable, either internally or by marking on the surface of the cable.

If the identification is internal the distance between the end of one mark and the beginning of the next mark shall be not greater than 550 mm.

NOTE An identification thread may be used as an alternative to internal marking.

If the identification is by marking on the surface, the maximum distance between marks shall be 1 100 mm.

13.3 The mark of an approval organization

If the mark of an approval organization is used, it shall be provided throughout the length of the cable, either as a mark on the surface of the cable, or as an identification thread, as specified by the approval organization.

If the mark is applied to the cable it shall be on the surface in the form of the symbol(s) specified by the approval organization, and shall conform to **13.1** d) and e) in respect of the maximum distance between marks.

13.4 Additional marking

Where additional marking is made, it shall be throughout the length of the cable, either on the external surface of the cable, or by means of a tape or thread within the cable, or by a combination of these methods. If the additional marking is applied to the surface of the cable it shall not render illegible the marking specified in **13.1** to **13.3**.

The additional marking, however made, shall be repeated at intervals not exceeding 1 100 mm.

14 End sealing

Before despatch, the manufacturer shall cap the ends of all cable in order to form a seal to prevent the ingress of water during transportation and storage.

15 Dimensions

The dimensions of the component layers shall be as given in Tables 2 to 11.

NOTE 1 In addition the approximate overall diameters for the following designs of cable are given.

a) Single-core armoured cables with:
- — copper tape screen;
- — extruded bedding layer;
- — aluminium round wire armour.

b) Three-core armoured cables with:
- — copper tape screen on each core;
- — extruded bedding layer;
- — galvanized round steel wire armour.

NOTE 2 The approximate overall diameters are given for information only. If more precise values are required the manufacturer should be consulted.

NOTE 3 For single-core cables the approximate overall diameters relate to cables with round wire armour and may be somewhat less for cables with strip armour.

NOTE 4 The approximate overall diameters given for cables with circular stranded conductors up to and including 630 mm^2 are based on the use of compacted conductors.

NOTE 5 Any smaller conductor cross-sections than those given in Tables 2 to 11 are not recommended. Designs excluded from this specification are indicated by a dash in the tables.

For designs other than those listed, the table specifying the most closely similar design shall be used to determine the dimensions of the various component parts.

Table 2 — Single-core cables 3.8/6.6 (7.2) kV

Nominal cross-sectional area of conductor	Thickness of insulation		Thickness of bedding layer		Nominal armour wire diameter	Armour strip dimensions		Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Min. average	Min. at a point	Nominal		Thickness	Width	Min. at a point	Nominal	Solid aluminium conductors	Stranded conductors
mm^2	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
50	2.15	2.5	0.76	1.2	1.6	1.0	3.6	1.24	1.8	25.9	26.7
70	2.15	2.5	0.76	1.2	1.6	1.0	3.6	1.24	1.8	27.5	28.4
95	2.15	2.5	0.76	1.2	1.6	1.0	3.6	1.32	1.9	29.3	30.3
120	2.15	2.5	0.76	1.2	1.6	1.0	3.6	1.32	1.9	30.6	31.9
150	2.15	2.5	0.76	1.2	1.6	1.0	3.6	1.40	2.0	32.2	33.5
185	2.15	2.5	0.76	1.2	2.0	1.4	4.8	1.40	2.0	34.6	36.1
240	2.24	2.6	0.76	1.2	2.0	1.4	4.8	1.48	2.1	37.2	38.9
300	2.42	2.8	0.76	1.2	2.0	1.4	4.8	1.56	2.2	39.9	41.8
400	2.60	3.0	0.76	1.2	2.0	1.4	4.8	1.64	2.3	—	45.5
500	2.78	3.2	0.84	1.3	2.5	1.8	6.4	1.80	2.5	—	50.5
630	2.78	3.2	0.92	1.4	2.5	1.8	6.4	1.88	2.6	—	54.6
800	2.78	3.2	0.92	1.4	2.5	1.8	6.4	1.96	2.7	—	60.8
1 000	2.78	3.2	1.00	1.5	2.5	1.8	6.4	2.12	2.9	—	65.9

Table 3 — Three-core cables 3.8/6.6 (7.2) kV

Nominal cross-sectional area of conductor	Thickness of insulation		Thickness of bedding layer		Nominal armour wire diameter	Thickness of oversheath		Approximate overall diameter			
								Circular conductors		Shaped conductors	
	Min. at a point	Min. average	Min. at a point	Nominal		Min.	Nominal	Solid aluminium	Stranded	Solid aluminium	Stranded
mm^2	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	2.15	2.5	0.76	1.2	2.0	1.48	2.1	37.9	38.4	—	—
16	2.15	2.5	0.76	1.2	2.0	1.56	2.2	40.1	40.7	—	—
25	2.15	2.5	0.76	1.2	2.0	1.56	2.2	42.4	43.3	—	—
35	2.15	2.5	0.76	1.2	2.0	1.64	2.3	44.8	46.1	—	—
50	2.15	2.5	0.84	1.3	2.5	1.80	2.5	48.7	50.3	—	—
70	2.15	2.5	0.84	1.3	2.5	1.88	2.6	52.2	54.2	50.0	50.8
95	2.15	2.5	0.92	1.4	2.5	1.96	2.7	56.2	58.3	53.1	54.3
120	2.15	2.5	1.00	1.5	2.5	2.04	2.8	59.5	62.1	55.8	57.4
150	2.15	2.5	1.00	1.5	2.5	2.12	2.9	62.5	65.3	58.2	60.3
185	2.15	2.5	1.08	1.6	2.5	2.20	3.0	66.4	69.6	61.3	63.8
240	2.24	2.6	1.16	1.7	2.5	2.36	3.2	72.2	75.8	66.1	69.1
300	2.42	2.8	1.24	1.8	3.15	2.60	3.5	79.7	83.8	72.8	76.3
400	2.60	3.0	1.40	2.0	3.15	2.76	3.7	—	92.1	—	—

Table 4 — Single-core cables 6.35/11 (12) kV

Thickness of insulation:	minimum average: 3.4 mm minimum at a point: 2.96 mm								
Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Armour strip dimensions		Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Nominal		Thickness	Width	Min. at a point	Nominal	Solid aluminium conductors	Stranded conductors
mm²	mm	mm	mm	mm	mm	mm	mm	mm	mm
50	0.76	1.2	1.6	1.0	3.6	1.24	1.8	27.7	28.5
70	0.76	1.2	1.6	1.0	3.6	1.32	1.9	29.5	30.4
95	0.76	1.2	1.6	1.0	3.6	1.32	1.9	31.1	32.1
120	0.76	1.2	1.6	1.0	3.6	1.40	2.0	32.6	33.9
150	0.76	1.2	2.0	1.4	4.8	1.48	2.1	35.0	36.3
185	0.76	1.2	2.0	1.4	4.8	1.48	2.1	36.6	38.1
240	0.76	1.2	2.0	1.4	4.8	1.56	2.2	39.0	40.7
300	0.76	1.2	2.0	1.4	4.8	1.56	2.2	41.1	43.0
400	0.76	1.2	2.0	1.4	4.8	1.72	2.4	—	46.5
500	0.84	1.3	2.5	1.8	6.4	1.80	2.5	—	50.9
630	0.92	1.4	2.5	1.8	6.4	1.88	2.6	—	55.0
800	0.92	1.4	2.5	1.8	6.4	1.96	2.7	—	61.2
1 000	1.00	1.5	2.5	1.8	6.4	2.12	2.9	—	66.3

Table 5 — Three-core cables 6.35/11 (12) kV

Thickness of insulation:	minimum average: 3.4 mm minimum at a point: 2.96 mm								
Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Thickness of oversheath		Approximate overall diameter			
						Circular conductors		Shaped conductors	
	Min. at a point	Nominal		Min. at a point	Nominal	Solid aluminium	Stranded	Solid aluminium	Stranded
mm²	mm	mm	mm	mm	mm	mm	mm	mm	mm
16	0.76	1.2	2.0	1.64	2.3	44.2	44.8	—	—
25	0.84	1.3	2.5	1.72	2.4	47.9	48.8	—	—
35	0.84	1.3	2.5	1.80	2.5	50.3	51.6	—	—
50	0.92	1.4	2.5	1.88	2.6	53.0	54.6	—	—
70	0.92	1.4	2.5	1.96	2.7	56.5	58.5	—	—
95	1.00	1.5	2.5	2.04	2.8	60.5	62.6	57.9	59.1
120	1.08	1.6	2.5	2.20	3.0	64.0	66.6	60.8	62.5
150	1.08	1.6	2.5	2.28	3.1	67.0	69.8	63.3	65.4
185	1.16	1.7	2.5	2.36	3.2	70.9	74.1	66.4	68.9
240	1.24	1.8	3.15	2.52	3.4	77.6	81.2	72.0	75.1
300	1.32	1.9	3.15	2.68	3.6	82.7	86.8	76.4	79.9
400	1.40	2.0	3.15	2.84	3.8	—	94.1	—	—

Table 6 — Single-core cables 8.7/15 (17.5) kV

Thickness of insulation: minimum average: 4.5 mm; minimum at a point: 3.95 mm

Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Armour strip dimensions		Thickness of oversheath		Approximate overall diameter	
	Min. at point	Nominal		Thickness	Width	Min. at a point	Nominal	Solid aluminium conductors	Stranded conductors
mm^2	mm	mm	mm	mm	mm	mm	mm	mm	mm
50	0.76	1.2	1.6	1.0	3.6	1.32	1.9	30.1	30.9
70	0.76	1.2	1.6	1.0	3.6	1.32	1.9	31.7	32.6
95	0.76	1.2	2.0	1.4	4.8	1.40	2.0	34.3	35.3
120	0.76	1.2	2.0	1.4	4.8	1.48	2.1	35.8	37.1
150	0.76	1.2	2.0	1.4	4.8	1.48	2.1	37.2	38.5
185	0.76	1.2	2.0	1.4	4.8	1.56	2.2	39.0	40.5
240	0.76	1.2	2.0	1.4	4.8	1.64	2.3	41.4	43.1
300	0.76	1.2	2.0	1.4	4.8	1.64	2.3	43.5	45.4
400	0.84	1.3	2.5	1.8	6.4	1.80	2.5	—	50.1
500	0.84	1.3	2.5	1.8	6.4	1.88	2.6	—	53.3
630	0.92	1.4	2.5	1.8	6.4	1.96	2.7	—	57.4
800	1.00	1.5	2.5	1.8	6.4	2.04	2.8	—	63.8
1 000	1.08	1.6	2.5	1.8	6.4	2.20	3.0	—	68.9

Table 7 — Three-core cables 8.7/15 (17.5) kV

Thickness of insulation: minimum average: 4.5 mm; minimum at a point: 3.95 mm

Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Thickness of oversheath		Approximate overall diameter	
						Circular conductors	
	Min. at a point	Nominal		Min. at a point	Nominal	Solid aluminium	Stranded
mm^2	mm	mm	mm	mm	mm	mm	mm
25	0.92	1.4	2.5	1.88	2.6	53.3	54.2
35	0.92	1.4	2.5	1.96	2.7	55.6	57.0
50	1.00	1.5	2.5	2.04	2.8	58.3	60.0
70	1.00	1.5	2.5	2.12	2.9	61.9	63.8
95	1.08	1.6	2.5	2.20	3.0	65.8	67.9
120	1.16	1.7	2.5	2.28	3.1	69.1	71.8
150	1.16	1.7	2.5	2.36	3.2	72.2	75.0
185	1.24	1.8	3.15	2.52	3.4	77.6	80.8
240	1.32	1.9	3.15	2.68	3.6	82.9	86.6
300	1.40	2.0	3.15	2.76	3.7	87.8	91.9
400	1.48	2.1	3.15	3.00	4.0	—	99.4

Table 8 — Single-core cables 12.7/22 (24) kV

Thickness of insulation: minimum average: 5.5 mm
minimum at a point: 4.85 mm

Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Armour strip dimensions		Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Nominal		Thickness	Width	Min. at a point	Nominal	Solid aluminium conductors	Stranded conductors
mm^2	mm	mm	mm	mm	mm	mm	mm	mm	mm
50	0.76	1.2	1.6	1.0	3.6	1.40	2.0	32.3	33.1
70	0.76	1.2	2.0	1.4	4.8	1.40	2.0	34.7	35.6
95	0.76	1.2	2.0	1.4	4.8	1.48	2.1	36.5	37.5
120	0.76	1.2	2.0	1.4	4.8	1.48	2.1	37.8	39.1
150	0.76	1.2	2.0	1.4	4.8	1.56	2.2	39.4	40.7
185	0.76	1.2	2.0	1.4	4.8	1.56	2.2	41.0	42.5
240	0.76	1.2	2.0	1.4	4.8	1.64	2.3	43.4	45.1
300	0.84	1.3	2.5	1.8	6.4	1.72	2.4	46.9	48.8
400	0.84	1.3	2.5	1.8	6.4	1.80	2.5	—	52.1
500	0.92	1.4	2.5	1.8	6.4	1.88	2.6	—	55.5
630	0.92	1.4	2.5	1.8	6.4	2.04	2.8	—	59.6
800	1.00	1.5	2.5	1.8	6.4	2.12	2.9	—	66.6
1 000	1.08	1.6	2.5	1.8	6.4	2.20	3.0	—	70.9

Table 9 — Three-core cables 12.7/22 (24) kV

Thickness of insulation: minimum average: 5.5 mm
minimum at a point: 4.85 mm

Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Nominal		Min. at a point	Nominal	Circular conductors	
						Solid aluminium	Stranded
mm^2	mm	mm	mm	mm	mm	mm	mm
35	1.00	1.5	2.5	2.04	2.8	60.3	61.7
50	1.00	1.5	2.5	2.12	2.9	62.9	64.5
70	1.08	1.6	2.5	2.20	3.0	66.6	68.6
95	1.16	1.7	2.5	2.36	3.2	70.7	72.8
120	1.16	1.7	3.15	2.44	3.3	75.1	77.8
150	1.24	1.8	3.15	2.52	3.4	78.4	81.2
185	1.32	1.9	3.15	2.68	3.6	82.5	85.7
240	1.40	2.0	3.15	2.76	3.7	87.7	91.3
300	1.40	2.0	3.15	2.92	3.9	92.6	96.6
400	1.56	2.2	3.15	3.08	4.1	—	104.1

Table 10 — Single-core cables 19/33 (36) kV

Thickness of insulation:	minimum average: 8.0 mm minimum at a point: 7.10 mm								
Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Armour strip dimensions		Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Nominal		Thickness	Width	Min. at a point	Nominal	Solid aluminium conductors	Stranded conductors
mm²	mm	mm	mm	mm	mm	mm	mm	mm	mm
50	0.76	1.2	2.0	1.4	4.8	1.56	2.2	38.5	39.3
70	0.76	1.2	2.0	1.4	4.8	1.56	2.2	40.1	41.0
95	0.76	1.2	2.0	1.4	4.8	1.64	2.3	41.9	42.9
120	0.76	1.2	2.0	1.4	4.8	1.64	2.3	43.2	44.5
150	0.84	1.3	2.5	1.8	6.4	1.72	2.4	46.0	47.3
185	0.84	1.3	2.5	1.8	6.4	1.80	2.5	47.8	49.3
240	0.84	1.3	2.5	1.8	6.4	1.80	2.5	50.0	51.7
300	0.92	1.4	2.5	1.8	6.4	1.88	2.6	52.5	54.5
400	0.92	1.4	2.5	1.8	6.4	1.96	2.7	—	57.7
500	1.00	1.5	2.5	1.8	6.4	2.04	2.8	—	61.1
630	1.00	1.5	2.5	1.8	6.4	2.12	2.9	—	65.0
800	1.08	1.6	2.5	1.8	6.4	2.28	3.1	—	71.6
1 000	1.16	1.7	2.5	1.8	6.4	2.36	3.2	—	76.5

Table 11 — Three-core cables 19/33 (36) kV

Thickness of insulation:	minimum average: 8.0 mm minimum at a point: 7.10 mm						
Nominal cross-sectional area of conductor	Thickness of bedding layer		Nominal armour wire diameter	Thickness of oversheath		Approximate overall diameter	
	Min. at a point	Nominal		Min. at a point	Nominal	Circular conductors	
						Solid aluminium	Stranded
mm²	mm	mm	mm	mm	mm	mm	mm
50	1.24	1.8	3.15	2.52	3.4	76.6	78.2
70	1.24	1.8	3.15	2.60	3.5	80.1	82.1
95	1.32	1.9	3.15	2.68	3.6	84.0	86.1
120	1.40	2.0	3.15	2.76	3.7	87.3	90.0
150	1.40	2.0	3.15	2.84	3.8	90.4	93.2
185	1.48	2.1	3.15	2.92	3.9	94.3	97.5
240	1.56	2.2	3.15	3.08	4.1	99.7	103.3
300	1.64	2.3	3.15	3.24	4.3	104.8	108.8
400	1.72	2.4	3.15	3.40	4.5	—	116.1

16 Schedule of tests

Testing shall be performed in accordance with the schedule of tests given in Table 12.

NOTE 1 Tests classified as "routine" or "sample" may be required as part of any type approval schemes.

NOTE 2 Guidance on type testing is given in annex D.

Table 12 — Schedule of tests

Test		Test method and requirements given in clause
Routine tests		
Spark test		**18.2**
Conductor resistance		**18.3**
Partial discharge test		**18.4**
Voltage test on complete cable		**18.5**
Cable markings		**18.6**
Sample tests		
Conductor material and construction		**19.4**
Conductor screen	— application	**19.5**
Insulation	— hot set	**19.6**
	— colour	**19.7**
	— thickness	**19.8**
Insulation screen	— application	**19.9**
Metallic layer	— application	**19.10**
Laid-up cores		**19.11**
Extruded bedding layer	— thickness	**19.12**
Lapped bedding layer	— application	**19.13**
Armour		
— galvanized steel wires	— diameter	**19.14**
— aluminium wires (round)	— diameter	**19.14**
— aluminium strips	— dimensions	**19.15**
Oversheath	— thickness	**19.16**
Tests under fire conditions	— fire test on single cable	**19.17**
	— smoke emission	**19.18**
Four-hour voltage test		**19.19**
Type tests		
Material tests		
Corner radii of shaped solid conductors		**20.2**
Corrosive and acid gas		**20.3**
Conductor screen	— resistivity	**20.4**
Insulation	— material	**20.5**
Insulation screen	— resistivity	**20.6**
	— strippability	**20.7**
Extruded bedding layer	— material	**20.8**
Armour		
— galvanized steel wires	— mass of zinc coating	**20.9**
	— wrapping test	**20.10**
	— wet compatibility	**20.11**
— aluminium wires (round)	— tensile test	**20.12**
— aluminium strips	— tensile test	**20.12**
Oversheath	— material	**20.13**
Compatibility test		**20.14**

Table 12 — Schedule of tests *(continued)*

Test	Test method and requirements given in clause
Tests under fire conditions	
— test for flame propagation	**20.15**
— smoke emission	**20.16**
Abrasion test	**20.17**
Test for shrinkage of sheath on cable	**20.18**
Electrical tests	
Sequential type tests	
Partial discharge test	**21.2**
Bending test	**21.3**
Power factor (tan δ) in relation to voltage	**21.4**
Power factor (tan δ) in relation to temperature	**21.5**
Heat cycle test	**21.6**
Impulse test	**21.7**
Four-hour voltage test	**21.8**
Adherence of screens at short circuit temperatures	**21.9**
Insulation resistance constant of oversheath	**21.10**

17 Test conditions

17.1 Ambient temperature

Tests shall be made at an ambient temperature within the range 5 °C to 35 °C unless otherwise specified in the details of the particular test.

17.2 Tolerance on temperature values

Unless otherwise specified, the tolerance on temperature values quoted in the test methods shall be as shown in Table 13.

Table 13 — Tolerances on temperature values

Specified temperature, t °C	Tolerance °C
$-40 \le t \le 0$	±2
$0 < t \le 50$	in accordance with relevant clause
$50 < t \le 150$	±2
$t > 150$	±3

17.3 Frequency and waveform of power-frequency test voltages

Unless otherwise specified, alternating test voltages shall have a frequency between 49 Hz and 61 Hz. The waveform shall be substantially sinusoidal.

18 Routine tests

18.1 General

Routine tests shall be as specified in Table 12.

18.2 Spark test on oversheath

The oversheath shall be tested in accordance with BS 5099. No breakdown shall occur.

18.3 Conductor resistance

The d.c. resistance of each conductor shall conform to BS 6360 when measured and corrected to 20 °C in accordance with that standard.

18.4 Partial discharge

The cable shall be tested in accordance with annex E and the magnitude of the discharge on each core shall not exceed 10 pC, at the voltage specified in Table 14.

Table 14 — Voltage for partial discharge test

Rated voltage, U_0 kV	Test voltage r.m.s. kV
3.8	7.5
6.35	12.5
8.7	17.5
12.7	25.5
19.0	38.0

18.5 Voltage test on complete cable

18.5.1 *Method*

Apply the voltage between the conductor(s) and the metallic screen(s) with the metallic screen(s) earthed. Raise the voltage gradually and maintain at the full value for 15 min.

18.5.2 *Requirement*

No breakdown of the insulation shall occur when the completed cable is subjected to a power frequency voltage of the magnitude specified in Table 15.

Table 15 — Voltage for test on complete cable

Rated voltage, U_0 kV	Test voltage r.m.s. kV
3.8	15.0
6.35	25.5
8.7	35.0
12.7	51.0
19.0	76.0

18.6 Cable markings

The cable markings shall be checked by visual examination and measurement and shall conform to the requirements of clause 13.

19 Sample tests

19.1 General

Sample tests shall be as specified in Table 12.

19.2 Frequency of sample tests

Tests shall be carried out on samples taken according to agreed quality control procedures. In the absence of such an agreement for contracts where the total length exceeds 2 km of three-core or 4 km of single-core cables, the insulation hot set test, smoke emission test and four-hour voltage test shall be performed on samples of manufactured cables, in accordance with Table 16.

Table 16 — Number of sample tests

Three-core cables		Single-core cables		Number of samples
Above km	Up to and including km	Above km	Up to and including km	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
etc.	etc.	etc.	etc.	etc.

All other sample tests shall be made on one length from each manufacturing series of the same type and nominal cross-section of cable, but shall be limited to not more than 10 % of the number of lengths in any contract.

19.3 Repetition of tests

If any sample fails in any of the tests specified in **19.1**, two further samples shall be taken from the same batch and submitted to the same test or tests in which the original sample failed. If both additional samples pass the tests, all the cables in the batch from which they were taken shall be regarded as conforming to the requirements of the standard. If either of the additional samples fails, the batch from which they were taken shall be regarded as failing to conform.

19.4 Conductor material and construction

The conductor material and construction shall be checked by visual examination and shall conform to the requirements of clause **5**.

19.5 Conductor screen

The application of the conductor screen shall be checked by visual examination and shall be continuous and cover the surface of the conductor completely.

19.6 Hot set test of insulation

The insulation shall be tested in accordance with BS EN 60811-2-1:1995, clause **9** and shall conform to the requirements of Table 17.

Table 17 — Hot set test conditions and requirements

	XLPE	EPR
Conditions		
Temperature	200 °C	250 °C
Duration	15 min	15 min
Mechanical stress	0.2 N/mm^2	0.2 N/mm^2
Requirements		
Maximum elongation under load	175 %	175 %
Maximum elongation after unloading	15 %	15 %

19.7 Colour of insulation

The colour of the insulation shall be checked by visual examination and shall be easily distinguished from the screening materials.

19.8 Thickness of insulation

The thickness of insulation shall be measured in accordance with annex F. The thickness of extruded conductor and insulation screens shall not be included in the measured insulation thickness. When compared with the relevant value given in Tables 2 to 11 the smallest of the measured values shall be not less than the specified minimum thickness at a point. Similarly, the average of the measurements shall not be less than the specified minimum average thickness.

19.9 Insulation screen

The application of the insulation screen shall be checked by visual examination and shall be continuous and cover the surface of the insulation completely.

19.10 Metallic layer

The gap between adjacent wires of a copper wire screen shall be measured and the average gap shall not exceed 4 mm. No gap shall exceed 8 mm.

19.11 Laid-up cores

The laid-up cores shall be checked by visual examination and shall conform to the requirements of clause **9**.

19.12 Extruded bedding layer

The thickness of the extruded bedding layer shall be measured in accordance with annex F. When compared with the relevant value specified in Tables 2 to 11 the smallest of the measured values shall be not less than the specified minimum thickness at a point.

19.13 Lapped bedding layer

The application of the lapped bedding layer shall be checked by visual examination and shall conform to the requirements of clause **10**.

19.14 Wire armour

19.14.1 ***Method***

Take 10 % of the total number of wires, at random, from one sample of completed cable and determine the diameter of each wire with a micrometer by taking two measurements at right angles to each other.

Take the average of all the measurements as the wire diameter.

19.14.2 ***Requirement***

The diameter of the round armour wires, whether galvanized steel or plain aluminium, shall not fall below the relevant nominal value specified in Tables 2 to 11, as appropriate, by more than 5 %.

19.15 Strip armour

19.15.1 ***Method***

Take 10 % of the total number of strips, at random, from one sample of completed cable and measure the thickness and width of each strip by using a dial micrometer or vernier calliper.

Take the average of the respective measurements as the thickness and width of the strip.

19.15.2 ***Requirement***

The thickness and width of individual strips of aluminium armour shall not differ from the relevant values specified in Tables 2 to 11, as appropriate, by more than 5 %.

19.16 Oversheath thickness

The thickness of the oversheath shall be measured in accordance with annex F. When compared with the relevant value given in Tables 2 to 11, the smallest of the measured values shall be not less than the specified minimum thickness at a point.

19.17 Flame propagation on single cable

The finished cable shall be tested in accordance with BS EN 50265-2-1. After the test the cable shall conform to the performance requirements recommended in BS EN 50265-2-1:1999, annex A.

19.18 Smoke emission test

When a sample of completed cable with a tabulated[2)] overall diameter up to and including 70 mm is tested in accordance with BS EN 50268, the smoke generated shall not result in transmittance levels lower than 60 %. This requirement does not apply to cables with a tabulated overall diameter greater than 70 mm.

NOTE For cables with a tabulated overall diameter greater than 70 mm the test method and requirements are under consideration.

[2)] See relevant construction table (Tables 2 to 11).

19.19 Four-hour voltage test

19.19.1 *Method*

Earth the screen(s) of a piece of cable not less than 5 m in length between terminations. Subject the cable to an alternating power frequency voltage applied between each conductor and the screen(s).

Increase the voltage gradually to the specified value and maintain it at that value for 4 h. Apply the voltage continuously, but if there are any unavoidable interruptions during the 4 h period, increase the period by the time of the interruptions. Ensure that the total of such interruptions does not exceed 1 h, otherwise restart the test.

19.19.2 *Requirement*

No breakdown of the insulation shall occur when the completed cable is subjected to a power frequency voltage of the magnitude specified in Table 18.

Table 18 — Four-hour voltage test

Rated voltage, U_0 kV	Test voltage r.m.s. kV
3.8	15.0
6.35	25.5
8.7	35.0
12.7	51.0
19.0	76.0

20 Type tests — Materials

20.1 General

Type tests shall be as specified in Table 12.

20.2 Corner radii of shaped solid conductors

Remove a sample of the conductor to be tested from the end of the cable. By means of an optical projection method, compare the corner radii with a suitable template of the required radius as specified in Table 1. The minimum corner radii for shaped solid aluminium conductors shall be as specified in Table 1.

20.3 Corrosive and acid gas

Every non-metallic material shall be tested in accordance with BS EN 50267-2-1. The level of HCl shall be not greater than 0.5 %.

20.4 Conductor screen resistivity

The resistivity of the extruded screen shall be measured in accordance with annex G and shall not exceed 500 Ω·m at 90 °C.

20.5 Insulation

The insulation material shall be tested and shall conform to the requirements of Table 19.

Table 19 — Cross-linked polyethylene (XLPE) and ethylene propylene rubber compound (EPR) insulation

Test	Test method in accordance with BS EN 60811:1995		Requirements	
	Section	Clause	XLPE	EPR
Properties in the state as delivered	1-1	9		
Minimum tensile strength			12.5 N/mm^2	4.2 N/mm^2
Minimum elongation at break			200 %	200 %
Properties after ageing in air oven	1-2	8.1		
Temperature			135 °C	135 °C
Duration			168 h	168 h
Maximum variation for tensile strength[a]			25 %	30 %
Maximum variation for elongation at break[a]			25 %	30 %
Properties after ageing in air bomb	1-2	8.2		
Temperature			—	127 °C
Duration			—	40 h
Maximum variation for tensile strength[a]			—	30 %
Maximum variation for elongation at break[a]			—	30 %
Water absorption — gravimetric method	1-3	9.2		
Temperature			85 °C	85 °C
Duration			336 h	336 h
Maximum increase of mass			1 mg/cm^2	5 mg/cm^2
Shrinkage test	1-3	9.2		
Distance between marks "L"			200 mm	—
Temperature			130 °C	—
Duration			1 h	—
Maximum shrinkage			4 %	—
Ozone resistance test	2-1	8.1		
Temperature			—	(25 ± 2) °C
Duration			—	30 h
Ozone concentration			—	250 ppm to 300 ppm
Visual observation			—	no cracks

[a] The variation is the difference between the respective values obtained prior to and after heat treatment expressed as a percentage of the former.

20.6 Insulation screen resistivity

The resistivity of the extruded screen shall be measured in accordance with annex G and shall not exceed 500 Ω·m at 90 °C.

20.7 Insulation screen cold strippability

20.7.1 *General*

Where the manufacturer claims that the screen is strippable, the test specified in **20.7.2** shall be performed at (20 ± 5) °C.

20.7.2 ***Method***

From the cable to be tested, take a core sample of approximate length 400 mm.

Make two parallel cuts, separated by (13 ± 1) mm, in the semi-conducting insulation screen material, down to the insulation and longitudinally from end to end of the core sample.

Remove approximately 50 mm length of the 13 mm wide strip from each end of the core by pulling it away from the core manually.

Mount the sample in a tensile test machine, with one end of the strip clamped in the upper jaws, and with the sample held horizontally at approximately 90° to the clamped strip. Using a pulling speed of approximately 8 mm/s, measure the force required to separate the 13 mm strip, whilst maintaining the strip at approximately 90° to the sample. Continue the movement until approximately the midpoint of the sample is reached.

Repeat the test from the other end of the sample.

20.7.3 ***Requirement***

The force required to remove the insulation screen shall be not less than 18 N and not more than 80 N.

20.8 Extruded bedding layer

The extruded bedding layer material, when tested in accordance with BS EN 60811-1-1, shall have a tensile strength not less than 4 N/mm^2 and elongation at break not less than 50 %.

20.9 Mass of zinc coating of galvanized steel wires

20.9.1 ***Method***

Take, at random, 10 % of the total number of wires from one sample of completed cable and determine the mass by either a gravimetric or gas volumetric method as described in BS 443:1982, clause **8**.

Take the average of all the measurements as the mass of zinc coating.

20.9.2 ***Requirement***

The mass of zinc coating of galvanized steel wires shall conform to Table 20.

Table 20 — Mass of zinc coating

Nominal diameter of armour wire mm	Minimum mass of zinc coating per square metre g
1.6	172
2.0	180
2.5	195
3.15	206

20.10 Wrapping test for galvanized steel wires

20.10.1 ***Method***

Take, at random, 10 % of the total number of wires from one sample of completed cable. Wrap each wire round a cylindrical mandrel for one complete turn. The mandrel shall have a diameter of approximately four times the specified nominal diameter of the wire under test.

20.10.2 ***Requirement***

The mechanical characteristics of the galvanized steel wire armour wires shall be such that none of the wires shall break.

20.11 Wet compatibility test for galvanized steel wires

20.11.1 ***Method***

Galvanized steel wires in contact with semi-conducting carbon loaded tape layers shall be subjected to a wet compatibility test in accordance with annex H.

20.11.2 ***Requirements***

After 7 days the d.c. potential developed across the resistor shall not exceed 0.7 mV. In addition, when viewed without magnification there shall be no visible evidence of rusting on the surface of the immersed portion of the wire or red/brown discoloration of the solution.

20.12 Tensile test for aluminium wires and strips

20.12.1 *Method*

Take, at random, 10 % of the total number of wires or strips from one sample of completed cable. Measure the tensile strength of each wire or strip in accordance with BS EN 10002-1, except that in the case of the aluminium strip, the cross-sectional area shall be determined, to an accuracy of ±1 %, from the mass of a known length and assuming a density of 2.703 g/cm^3.

Take the average of all the measurements to be the tensile strength.

20.12.2 *Requirement*

The tensile strength of aluminium wires shall be not less than 125 N/mm^2.

The tensile strength of the individual strips of aluminium armour shall be not less than 145 N/mm^2.

20.13 Oversheath

The oversheath material shall conform to BS 7655-6.1: Type LTS1.

20.14 Compatibility test

20.14.1 *Method*

Perform the test for compatibility by heating samples of completed cable in an air oven for 7 days at 100 °C, using the procedure specified in BS EN 60811-1-2, and then measuring the properties of the components as follows.

a) *Oversheath:* tensile strength and elongation at break (test procedures as specified in BS EN 60811-1-1:1995, clause **9**).

b) *Extruded bedding layer:* tensile strength and elongation at break (test procedures as specified in BS EN 60811-1-1:1995, clause **9**).

c) *Insulation:* tensile strength and elongation at break (test procedures as specified in BS EN 60811-1-1:1995, clause **9**).

d) *Insulation screen:* resistivity at 90 °C and strippability (if required) (test methods as specified in annex G and **20.7.1**, respectively).

e) *Conductor screen:* resistivity at 90 °C (test method as specified in annex G).

20.14.2 *Requirement*

The cable shall conform to the requirements specified in Table 21.

Table 21 — Compatibility requirements

Component	Test	Requirements	
Oversheath	Minimum tensile strength	10 N/mm^2	
	Minimum elongation at break	100 %	
	Maximum variation of tensile strength[a]	40 %	
	Maximum variation of elongation at break[a]	40 %	
Extruded bedding layer	Minimum tensile strength	6 N/mm^2	
	Minimum elongation at break	100 %	
	Maximum variation of tensile strength[a]	40 %	
	Maximum variation of elongation at break[a]	40 %	
Insulation screen	Maximum resistivity at 90 °C	1 000 Ω·m	
	Force to remove strippable screen	18 N to 80 N	
		XLPE	**EPR**
Insulation	Maximum variation of tensile strength[a]	25 %	30 %
	Maximum variation of elongation at break[a]	25 %	30 %
Conductor screen	Maximum resistivity at 90 °C	1 000 Ω·m	

[a] The variation is the difference between the respective values obtained prior to and after heat treatment, expressed as a percentage of the former.

20.15 Flame propagation on multiple cables

When a complete cable is tested in accordance with BS 4066-3, it shall conform to the requirements specified in BS 4066-3 for category C.

20.16 Smoke emission test

When a sample of completed cable with a tabulated[3] overall diameter up to and including 70 mm is tested in accordance with BS EN 50268, the smoke generated shall not result in transmittance levels lower than 60 %. This requirement does not apply to cables with a tabulated overall diameter greater than 70 mm.

NOTE For cables with a tabulated overall diameter greater than 70 mm the test method and requirements are under consideration.

20.17 Abrasion test

When a sample of complete cable is tested in accordance with annex J, the oversheath, when viewed without magnification, shall show no visible cracks or splits in the external or internal surface.

20.18 Test for shrinkage of oversheath on cable

When a sample of complete cable is tested in accordance with annex K, the shrinkage shall not exceed 4 %.

21 Type tests — Electrical

21.1 ***General***

The electrical tests specified in **21.2** to **21.8** shall be performed on a sample of cable not less than 10 m in length between terminations (excluding accessories, if any) in the sequence specified in Table 12. The tests specified in **21.9** and **21.10** shall be carried out on separate samples of cable.

21.2 Partial discharge test

The cable shall be tested in accordance with annex E and the magnitude of the discharge on each core shall not exceed 5 pC, at the voltage specified in Table 14.

21.3 Bending test

21.3.1 ***Method***

The diameter of the cylinder for the bend test shall be not greater than the following:

— for single-core armoured cables: $15(D + d)$;

— for three-core armoured cables: $12(D + d)$;

where

D is the approximate overall diameter as given in Tables 2 to 11, as appropriate (in mm);

d is the diameter of the conductor (in mm).

NOTE If the conductor is not circular, $d = 1.13 \sqrt{S}$, where S is the nominal cross-sectional area (in mm^2).

Bend the cable sample around the test cylinder for at least one complete turn, at ambient temperature. Unwind and repeat the process but this time bend the sample in the reverse direction. Perform this cycle of operations a total of three times.

After completion of the bending test, visually examine the sample (with normal or corrected vision without magnification). Finally, subject the sample to the partial discharge test described in annex E.

21.3.2 ***Requirement***

The cable shall show no evidence of cracking.

The cable sample shall satisfy the partial discharge test requirements given in **21.2**.

21.4 Tan δ test in relation to voltage

The tan δ of each core of the sample shall be measured at ambient temperature with a.c. voltages equal to $0.5U_0$, $1.0U_0$ and $2.0U_0$ and shall not exceed the limits specified in Table 22.

[3] See relevant construction table (Tables 2 to 11).

Table 22 — Tan δ in relation to voltage

Property	XLPE	EPR
Maximum tan δ at U_0	40×10^{-4}	200×10^{-4}
Maximum increase in tan δ ($0.5U_0$ to $2.0U_0$)	20×10^{-4}	25×10^{-4}

21.5 Tan δ test in relation to temperature

21.5.1 *Method*

Heat the sample of cable by external means or by passing current through the metallic screen or by current loading of the conductor(s).

Measure the tan δ with an a.c. voltage of not less than 2 kV, at power frequency, at a conductor temperature of not less than 95 °C and not greater than 100 °C.

NOTE At the discretion of the manufacturer, this measurement may be carried out during the heating cycle test described in **21.6.1**.

21.5.2 *Requirement*

The measured values shall not exceed the limits specified in Table 23.

Table 23 — Tan δ in relation to temperature

Property	XLPE	EPR
Maximum tan δ at ambient temperature	40×10^{-4}	200×10^{-4}
Maximum tan δ at elevated temperature (i.e. 95 °C to 100 °C)	80×10^{-4}	400×10^{-4}

21.6 Heating cycle test

21.6.1 *Method*

Install the cable sample indoors in a draught-free environment at steady ambient temperature and away from direct sunlight.

Place thermocouples at intervals not exceeding 2 m along the length of the cable in order to measure the temperature of the armour.

Subject the cable sample to a heating cycle of 8 h duration. Maintain the conductor temperature between 95 °C and 100 °C for at least 2 h during the heating period, followed by at least 3 h of natural cooling in air. Perform this cycle 20 times. Confirm that the armour temperature accurately reflects the required conductor temperature by making suitable measurements of phase conductor resistance, or by other means. During the heating cycles, take at least four measurements of partial discharge in accordance with annex E at approximately equal intervals at the end of a cooling cycle, including one measurement at the completion of the test (i.e. after the last heating cycle).

21.6.2 *Requirement*

The discharge magnitude for each of the measurements taken shall not exceed 5 pC at the voltage specified in Table 14.

21.7 Impulse voltage test

When the cable sample is tested in accordance with annex L, at the appropriate voltage specified in Table 24, no breakdown of the insulation shall occur.

Table 24 — Voltage for impulse voltage test

Rated voltage, U_0 kV	Impulse withstand voltage kV
3.8	75
6.35	95
8.7	112
12.7	144
19.0	194

21.8 Four-hour voltage test

The cable shall be tested for conformity to the requirements of **19.19**.

21.9 Adherence of screens at short circuit temperature

21.9.1 *Method*

Subject a separate sample of cable, having a conductor cross-sectional area not greater than 185 mm^2 and at least 5 m in length, to the partial discharge test specified in annex E and then subject it to a current derived from the relevant equation below. Upon completion of the test, allow the sample to cool to ambient temperature and again subject it to the partial discharge test specified in annex E.

Subject one core of cable, 5 m in length, to a current derived from the following equations, as appropriate:

for copper conductors $$I^2t = 11.77 \times 10^4 A^2 \log_{10} \frac{(234 + T_2)}{(234 + T_1)}$$

for aluminium conductors $$I^2t = 5.04 \times 10^4 A^2 \log_{10} \frac{(228 + T_2)}{(228 + T_1)}$$

where

- I is the r.m.s. value of short circuit current (in A);
- t is the duration of short circuit current (in s), maximum 30 s;
- A is the conductor area (in mm^2);
- T_2 is the final conductor temperature = 250 °C;
- T_1 is the initial conductor temperature (in °C).

21.9.2 *Requirement*

The discharge magnitude (q) for both tests shall not exceed 5 pC at the voltage specified in Table 14.

21.10 Insulation resistance constant of oversheath

When a sample of complete cable is subjected to the test specified in annex M, the value of K shall be not less than 0.003 5 MΩ·km.

Annex A (informative)
Recommendations for the selection of cables

A.1 General

The cables specified in this standard are designed to have improved fire performance when installed in air, and are expected to be used primarily in such locations. The cables are also suitable for direct burial in free-draining soil conditions.

Where the cables are to be laid in any other environment, reference should be made to the cable manufacturer.

A.2 Voltage ratings

The rated voltage of the cable for a given application should be suitable for the operating conditions in the system in which the cable is used. To facilitate the selection of the cable, systems are divided into three categories as follows.

a) *Category A*. This category comprises those systems in which any phase conductor that comes in contact with earth or an earth conductor is disconnected from the system within 1 min.

b) *Category B*. This category comprises those systems which, under fault conditions, are operated for a short time with one phase earthed. IEC 60183 recommends that this period should not exceed 1 h. For cables covered by the present standard a longer period, not exceeding 8 h on any occasion, can be tolerated. The total duration of earth faults in any year should not exceed 125 h.

c) *Category C*. This category comprises all systems which do not fall into categories A and B.

NOTE In a system where an earth fault is not automatically and promptly isolated, the extra stresses on the insulation of cables during the earth fault may reduce the life of the cables. If the system is expected to be operated fairly often with a permanent earth fault, it may be advisable to classify the system as category C.

Table A.1 gives the lowest rated voltage of cable that should be used according to the system voltage and category.

Table A.1 — Selection of cables for three-phase a.c. systems

Nominal voltage, U kV	Maximum sustained voltage, U_m kV	System category	Minimum rated voltage of cable, U_0/U kV
6.6 or 6	7.2	A or B	3.8/6.6
6.6 or 6	7.2	C	6.35/11
11 or 10	12	A or B	6.35/11
11 or 10	12	C	8.7/15
15	17.5	A or B	8.7/15
15	17.5	C	12.7/22
22 or 20	24	A or B	12.7/22
22 or 20	24	C	19/33
33 or 30	36	A or B	19/33
NOTE For a 33 kV or 30 kV system of category C, reference should be made to the manufacturer.			

The nominal system voltage, U, given in Table A.1 is the nominal voltage between phases.

The maximum sustained system voltage, U_m, is the highest voltage between phases that can be sustained under normal operating conditions at any time and at any point in the system. It excludes transient voltage variations, due, for example, to lightning impulses, fault conditions and rapid disconnection of loads.

The nominal system voltages shown in Table A.1 are generally in accordance with series 1 of IEC 60038. For system voltages intermediate between the values in Table A.1, the cable should be selected with rated voltage not less than the next highest value (e.g. for a 13.8 kV system of category A or B, the cable should have a rated voltage not less than 8.7/15 kV and for a 13.8 kV system of category C, not less than 12.7/22 kV).

A.3 Selection of metallic coverings

All the cable designs in this standard include metallic coverings surrounding the cores, either individually or collectively, which are intended to be earthed when the cables are in use.

Where it is especially required that the cable should have a positive barrier to water, or a barrier to petroleum and other solvents, it is recommended that the cable includes a metal sheath, details of which should be agreed between the user and the manufacturer at the time of tendering or ordering (see **N.3.2**).

A.4 Metallic coverings — earth fault capacity

The metallic coverings are usually required to carry earth fault current.

Under the condition of an earth fault in the cable itself, due, for example, to spiking, the local heating at the fault position, caused by contact resistances or resistance in the fault, is more intense than in the metallic screen as a whole. This causes fusing of the screen locally and the current which the screen will sustain for a given time under these conditions is less than that for which it is suitable under through-fault conditions.

Advice on the suitability of the type of metallic screen and cross-sectional area should be sought from the manufacturer.

A.5 Current carrying capacity

The cable selected should have a sustained current rating under the conditions of installation not less than the maximum current that it will be required to carry during normal operation. It should also have a short-circuit current rating adequate for the prospective short-circuit current and the time for which it can persist.

Standardized current rating data for the cables in this standard has not been published. Reference should be made to the manufacturer's recommendations.

NOTE 1 Limitation on the temperature of the cables may be imposed in situations where they may be touched.

NOTE 2 Due to the relatively high conductor temperature, there is a risk of drying out the surrounding soil causing an increase in thermal resistivity which in turn would lead to the cable temperature rising to a higher value than anticipated. For cable laid directly in the ground, a suitable de-rating factor should be applied or a lower maximum sustained conductor operating temperature should be assumed, to take into account the possible effect of soil drying out.

NOTE 3 The performance of accessories should be taken into account in deciding the operating temperature of the cable.

Annex B (informative)

Information to be provided with the enquiry or order

The following information should be provided by the purchaser with the enquiry or order:

a) the number of this British Standard;

b) length of cable required and individual drum lengths, if important;

c) voltage designation (see clause **4** and annex A);

d) number of cores;

e) size of phase conductor;

f) conductor material (i.e. copper or aluminium);

g) type of conductor (i.e. stranded or solid, shaped or circular);

h) type of insulation (if a specific type required, i.e. XLPE or EPR) and limiting dimensions (if any) of cores;

i) whether a cold strippable insulation screen is required (see **8.2**);

j) cross-sectional area and type of metallic screen;

k) type of metallic sheath, if required (see **A.3**);

l) type of armour;

m) whether the cable is liable to be exposed to any potentially aggressive environments (e.g. water, oil or acid).

NOTE See annexes A and N for recommendations for selection of cables.

Annex C (informative)

Recommendations for the installation of cables

C.1 General

Cables should be installed in accordance with national regulations and any relevant codes of practice.

C.2 Minimum temperature during installation

It is recommended that the cables specified in this standard be installed only when both the cable and ambient temperatures are above 0 °C and have been so for the previous 24 h, or where special precautions have been taken to maintain the cable above this temperature.

C.3 Minimum installation radius

None of the cables specified in this standard should be bent during installation to a radius smaller than that given in Table C.1

Table C.1 — Bending radius of cable during installation

Type of cable	Minimum bending radius
Single-core armoured	15*D*
Three-core armoured	12*D*
NOTE *D* is the overall diameter of the cable.	

Where possible, larger installation radii should be used, except that the minimum bending radius where the cables are placed in position adjacent to joints and terminations may be reduced to that given in Table C.2 provided that the bending is carefully controlled, e.g. by the use of a former.

Table C.2 — Bending radius of cable adjacent to joints or terminations

Type of cable	Minimum bending radius
Single-core armoured	12*D*
Three-core armoured	10*D*
NOTE *D* is the overall diameter of the cable.	

C.4 Prevention of moisture ingress

Care should be exercised during installation to avoid any damage to cable coverings. This is important in wet or other aggressive environments, especially for cables that do not have an extruded bedding. The protective cap should not be removed from the ends of the cable until immediately prior to termination or jointing. When the caps have been removed the unprotected ends of the cable should not be exposed to moisture.

The possibility of damage to moisture seals during handling and installation or during storage of the cable should be borne in mind. Where such damage may have occurred, the seals should be inspected and remade if necessary.

C.5 Jointing

In the absence of a metal sheath, all earth fault currents return through the armour and/or screens unless there is a parallel bonding connection to relieve them of some of the fault current. In either case it is necessary to ensure that there is no discontinuity in the return circuit via the armour and/or screens and no local spot of high resistance. Careful attention, therefore, should be paid to the design of all bonding clamps in joints and terminations to ensure that each tape, wire or strip contributes equally to the conductance of the bonding connection and that the resistance across a connector is not higher than that of the equivalent length of connected armour and/or screens of the cable.

It is also important to ensure that all tapes, strips or wires and all faces of clamps or connectors making contact with them are thoroughly cleaned during installation and that the clamps are adequately tightened to ensure good electrical contact. Bonding clamps in joints should be electrically connected with a bond having a conductance at least equivalent to that of an equal length of the complete amour and/or screens of the cable, and with adequate thermal capacity to avoid excessive overheating under short circuit conditions.

With all the cables specified in this standard it is important to ensure that the semi-conducting insulation screen (see **8.2**) is removed from the core(s) and any remaining semi-conducting coating or semi-conducting particles are thoroughly removed before application of the stress control components which may be made up of:

a) moulded components;

b) various tapes;

c) heat shrink tubes.

Similar procedures should be followed for joints.

Insulation screens should be removed by the methods recommended by the manufacturer. It is also recommended that the advice of the cable and/or accessory manufacturer be sought on a suitable method of terminating and jointing all cables specified in this standard.

C.6 Compound filling

For compound filled joints, the design of the box and the composition of the filling compound should provide an effective seal to prevent moisture gaining access to the conductor ferrules and armour connections. The filling compound should be compatible with the materials of the cable components with which it comes into contact. Account should be taken of the pouring temperatures or the temperatures resulting from exothermic reaction.

For terminations, provided that adequate clearances are maintained between phases and between each phase and earth, compound filling is not necessary. The minimum clearances should be related to the voltage and category of the system and environmental conditions. Guidance on minimum clearances can be obtained from the appropriate standards for equipment. Where the required clearances cannot be achieved, it is necessary to provide some other effective means of insulation.

C.7 Earthing of amour and screen(s)

Provision should be made for earthing the armour and screens to the main earth system at the supply end by means of a metallic bond of adequate conductance, the bonding connection being as short and straight as possible. It is also desirable to earth the armour and screens at additional accessible positions, unless a single point bonding is being employed.

Special precautions may be necessary to eliminate the risk of corrosion, especially corrosion due to the use of dissimilar metals.

Care should be exercised with single-core cables to ensure that the bonding and earthing arrangements are adequate to cater for circulating currents in the armour and screens.

In special circumstances it may be necessary to employ cross bonding or single-point bonding and in these cases recommendations should be sought from the manufacturer. With single-point bonded systems attention is drawn to the presence of induced voltages on the armour and screens.

C.8 Tests after installation

Tests after installation are not a requirement of this British Standard. However, it is recommended that the appropriate d.c. voltage as given in Table C.3 is applied between each conductor and the armour and screens after all terminating and jointing has been completed but before connection to the system.

Table C.3 — Voltage test after installation

Cable voltage designation kV	D.C. voltage kV
3.8/6.6	15
6.35/11	25
8.7/15	37
12.7/22	50
19/33	76

The voltage should be increased gradually to the full value and maintained continuously for 15 min. No breakdown should occur.

These test voltages are intended for cables immediately after installation and not for cables that have been in service. When testing is required after cables have been in service the manufacturer should be consulted for appropriate test conditions which should take into account the age, environment, history of breakdowns and the purpose of performing the test.

NOTE Alternatives to d.c. testing after installation are currently under consideration.

Annex D (informative)

Guidance on the scope of type tests

D.1 General

Type tests, after they have been successfully completed, need not be repeated unless changes are made which might affect conformity to the requirements. Thus type tests should not normally be required for individual contracts if the tests have already been successfully performed by the manufacturer on similar items.

If the type tests discussed in **D.2** have already been successfully performed by the manufacturer for conformity to BS 6622, repetition of the type tests is not necessary on account of differences in the protective layers applied over the screened cores, unless these would be likely to have a significant effect on the results, taking into account that the prime purpose of the tests in **D.2** is to test the electrical performance of the insulating system.

Guidance for each type test on the extent to which the results of the test on one or more cables can be taken as typical for a range of cables or for similar components used in other cables is given in **D.2** to **D.9**.

D.2 Sequential electrical type tests (see **21.2** to **21.8**)

The sequential type tests, which are primarily electrical tests, are intended to assess the performance of the type of cable. Cables are generally regarded as being of the same type if they are of the same voltage rating and of similar construction.

For the purposes of the sequential type tests, cables of similar construction are generally regarded as those having the same number of cores (single-core or three-core), the same form of conductor (stranded or solid, circular or shaped), the same insulating material (XLPE or EPR), and the same form of semi-conducting screens.

One type of cable embraces a range of different conductor sizes and, if the sequential type tests have been carried out successfully on cable(s) of particular conductor size(s), the results should be regarded as valid for cables of the same type having other conductor sizes. The results of tests on cable of one conductor size in the range 70 mm^2 to 300 mm^2 should be accepted as valid for cables of other conductor sizes in that range. For cables of conductor sizes outside that range, successful tests on cables of two conductor sizes should be accepted as valid for the same type of cable of the two next standard smaller sizes below the smaller size tested, and the two next standard larger sizes above the larger size tested.

The results of tests performed successfully on cables with shaped conductors should be accepted as valid also for cables of otherwise similar type but which have circular conductors.

The results of tests on cables with either stranded copper or stranded aluminium conductors should be accepted as valid for similar cables with stranded conductors of the other metal.

Successful tests on three-core cables should be accepted as valid for single-core cables, otherwise of the same type, for the same range of conductor size. However, as the manufacture of three-core cable may impose greater demands on the insulating system than for single-core cable, tests on single-core cable are generally not regarded as demonstrating the performance of three-core cable.

Tests performed successfully on cables with a strippable extruded semi-conducting screen should be accepted as demonstrating the performance of similar cables with fully bonded extruded screens.

Tests performed successfully on cables of one voltage rating should be accepted as demonstrating the manufacturer's ability to produce satisfactory cables of lower voltage rating utilizing the same materials and processing methods, without additional type testing.

D.3 Compatibility test (see **20.14**)

The object of the compatibility test is to check that different materials forming the components of the cable do not have an unduly adverse effect on each other. It is a test for a type of construction and is largely independent of cable voltage and conductor size or form. A successful test on one cable having a particular construction should be accepted as demonstrating the suitability of the construction, in terms of the manufacturer's selection of materials and processing of the components, for other cables of any rated voltage and size or form of conductor.

D.4 Type tests on components

The type tests on cable components, embracing the physical and chemical tests on insulation and sheathing and the measurement of resistivity on semi-conducting screens, are tests for the type of component, not for the type of cable. The properties of these components covered by these type tests are basically independent of the rated voltage or the size of the cable, unless materials or methods of application and processing are varied according to the cable type.

Successful tests on components from one cable should therefore be accepted as demonstrating the satisfactory performance of an identical component when used in other cables of different rated voltage and/or size.

D.5 Flame propagation (see **20.15**)

To obtain approval for all sizes 50 mm^2 and above, one cable in the range 50 mm^2 to 95 mm^2 should be selected for testing.

To obtain approval for all sizes 35 mm^2 and below, one cable in this range should be selected for testing.

The results of tests on three-core cables may be used to obtain approval for the equivalent range of single-core cables.

Tests on single-core cables cannot be used to obtain approval for three-core cables.

D.6 Smoke emission (see 20.16)

Cables should be selected for testing as follows.

a) To obtain approval for the full range of cables (or for a partial range including cables above 70 mm diameter), the largest size manufactured below 70 mm diameter should be selected for testing.

b) To obtain approval for a partial range of cables, where the largest cable manufactured is below 70 mm diameter, any cable above 40 mm diameter should be selected for testing.

D.7 Abrasion test (see 20.17)

One test should be carried out on each cable selected in accordance with **D.5**.

D.8 Corrosive and acid gas test (see 20.3)

As this is a test on cable components and therefore generally independent of size or number of cores, only one test is necessary.

D.9 Change of material

The tests referred to in **D.5** to **D.8** assume that the materials are consistent throughout the range of conductors for which approval is sought. Where a change occurs, it is necessary to include additional testing as agreed between the manufacturer and the purchaser to ensure that such changes are adequately examined.

D.10 Evidence of type testing

A certificate of type test signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate personnel in his organization should be accepted as evidence of type testing.

Annex E (normative)
Partial discharge test

E.1 Test equipment

E.1.1 *High voltage supply transformer*, of adequate capacity.

E.1.2 *Voltmeter.*

E.1.3 *Calibrator.*

E.1.4 *Discharge-free capacitor and a terminating impedance or reflection suppresser (when required).*

E.1.5 *Partial discharge measuring device*, consisting of a test circuit (see BS 4828), an oscilloscope and, if desired, an indicating instrument in conjunction with a suitable amplifier to detect individual discharge pulses.

For routine tests the minimum detectable discharge shall be not more than 10 pC and for type tests not more than 5 pC. The minimum detectable discharge (often referred to as the "sensitivity" of the equipment) is taken to be twice the level of background noise. Therefore the equipment, during tests with the cable connected, shall have a noise level not greater than 5 pC for routine tests and not greater than 2.5 pC for type tests.

NOTE Individual clearly distinguished interference pulses may be disregarded.

E.2 Calibration

Carry out the charge transfer method of calibration in accordance with BS 4828:1985, **5.2.1**.

NOTE Further guidance on discharge calibration is given in annex III of CIGRE Report 1968-21-01 [1], and IEEE Paper No. 69, CP83-PWR [2].

Connect the calibrator and detection circuit to the cable under test and inject predetermined charges. The calibration discharge q_0 is equal to the product of the calibration pulse amplitude U[4] (in V) and the coupling capacitance C_0 of the calibrator (in F), so long as this capacitance is small compared with the capacitance of the cable under test.

If an instrument incorporating a picocoulomb meter is used, adjust the amplifier gain so that the ratio of the injected signal to the value indicated by the meter is unity. When an oscilloscope is used for the measurement, ensure that the response ratio of the test circuit is better than 0.5 pC/mm. The response ratio is the magnitude in picocoulombs of the calibrating pulse per millimetre deflection on the oscilloscope screen.

[4] U has been used for the calibration pulse amplitude in place of U_0 which is used in BS 4828, in order to avoid confusion with the rated voltage U_0 designated in clause **4**.

The amplifier gain shall not be re-adjusted after the calibration has been completed unless a means is provided for a continuous display of a calibrating signal throughout the test. The means of providing the continuous display of a calibrating signal can be either of the following.

a) The coupling capacitor of the primary calibration circuit is full voltage rated, and is then not disconnected before the high voltage test transformer is energized.

b) A secondary calibrator is connected to the input of the detector. In this case the amplitude of the secondary pulse to produce a given response is pre-calibrated against the primary calibration circuit before the latter circuit is disconnected and the high voltage test transformer is energized.

When tests are to be made on full drum lengths of cable, as in routine tests, an attenuation factor, F, to compensate for the loss of signal amplitude in the cable and coupling capacitor, shall be determined. One method is as follows.

With the cable under test connected to the detection circuit, inject a calibration pulse into the detector terminal, noting its voltage (e_1) and the response at the detector. Then connect the calibrator to each end of the cable in turn and adjust the step wave voltage to produce the same response at the detector as e_1. Record these voltages, e_2 and e_3. Obtain the attenuation factor from these three voltages by the equation:

$$F = \sqrt{\frac{e_3 \times e_2}{{e_1}^2}}$$

Correction for attenuation is generally not necessary for type tests on relatively short lengths of cable. For routine tests, if it is only required to check that the magnitude of any discharge in the cable is not greater than the specified limit, the calibration may be performed with the calibrator at the opposite end of the cable from the detector. Then, provided that the cable is terminated with its characteristic impedance, attenuation of the calibration pulse is at least equal to that of any discharge in the cable length, so that the response to discharge in the cable, compared to the response to the calibration pulse, will indicate a higher level of discharge than the true value.

Provided the apparent discharge under these calibration conditions does not exceed the specified maximum value, there is no need to correct for attenuation.

Correction for attenuation may be required, however, if it is desired to establish the level of discharge in the cables as closely as possible or if it affects the results sufficiently to influence conformity to the specified limits.

E.3 Procedure

For each core to be tested, apply a test voltage, of frequency between 40 Hz and 62 Hz, in sequence between the conductor and the metallic screen. Raise the voltage to $2.25U_0$ and hold for not more than 1 min. Reduce the voltage slowly to $2U_0$ and measure the discharge magnitude at this voltage.

For routine tests on drum lengths, correction for attenuation shall be made. One method is to repeat the test with the detector connected to the other end of the cable under test. If the values of discharge magnitude measured at the two ends of the length are q_1 and q_2, the corrected discharge magnitude, q, can be calculated from the following equation:

$$q = F\sqrt{(q_1 \times q_2)}$$

where F is the attenuation factor obtained from the equation given in **E.2**.

Annex F (normative)

Thickness measurements

F.1 Sampling

Measurement of the thickness of insulation, bedding layer, and oversheath specified in Table 12 shall be made on a sample taken from one end of each drum length of cable selected for the test, having discarded any portion which may have suffered damage.

If any of the thicknesses measured does not conform to clauses **7**, **10**, and **12**, two further samples shall be checked for the non-conforming factors. If both of the further samples meet the specified requirements, the cable shall be deemed to conform to the requirements of this British Standard, but if either does not meet the requirements the cable shall be deemed not to conform.

F.2 Procedure

Make measurements on each component in accordance with the method given in BS EN 60811-1-1:1995, clause **8**, using either the equipment specified in **8.1.2** of that standard or a calibrated hand lens.

In the event of a dispute, the equipment specified in BS EN 60811-1-1:1995, **8.1.2** shall be used.

For three-core cables, measure the insulation thickness on each core.

When determining the average thickness from several measurements, round the resultant value to the nearest 0.1 mm (0.05 mm is rounded upwards).

Annex G (normative)

Method of measuring resistivity of extruded semi-conducting conductor and insulation screens

G.1 Preparation of test pieces

G.1.1 *General*

Prepare test pieces from 150 mm lengths of core taken from completed cable.

G.1.2 *Test pieces for cables with circular conductors*

Prepare the conductor screen test pieces by cutting a sample in half longitudinally and then removing the conductor (see Figure G.1). Prepare the insulation screen test pieces by removing all the coverings from the sample of core (see Figure G.2).

G.1.3 Test pieces for cables with shaped conductors

NOTE For cables having shaped conductors, the same test piece may be used for both conductor and insulation screen measurements.

Prepare the test pieces by cutting 5 mm strips of insulation, including both conductor and insulation screen (see Figure G.3).

G.2 Procedure

Apply four silver painted electrodes A, B, C and D to the semi-conducting surfaces (see Figures G.1 and G.2) or to each of the semi-conducting surfaces (see Figure G.3) as appropriate. Ensure that the two potential electrodes, B and C, are nominally 50 mm apart and the two current electrodes, A and D, are each placed at least 25 mm beyond the potential electrodes.

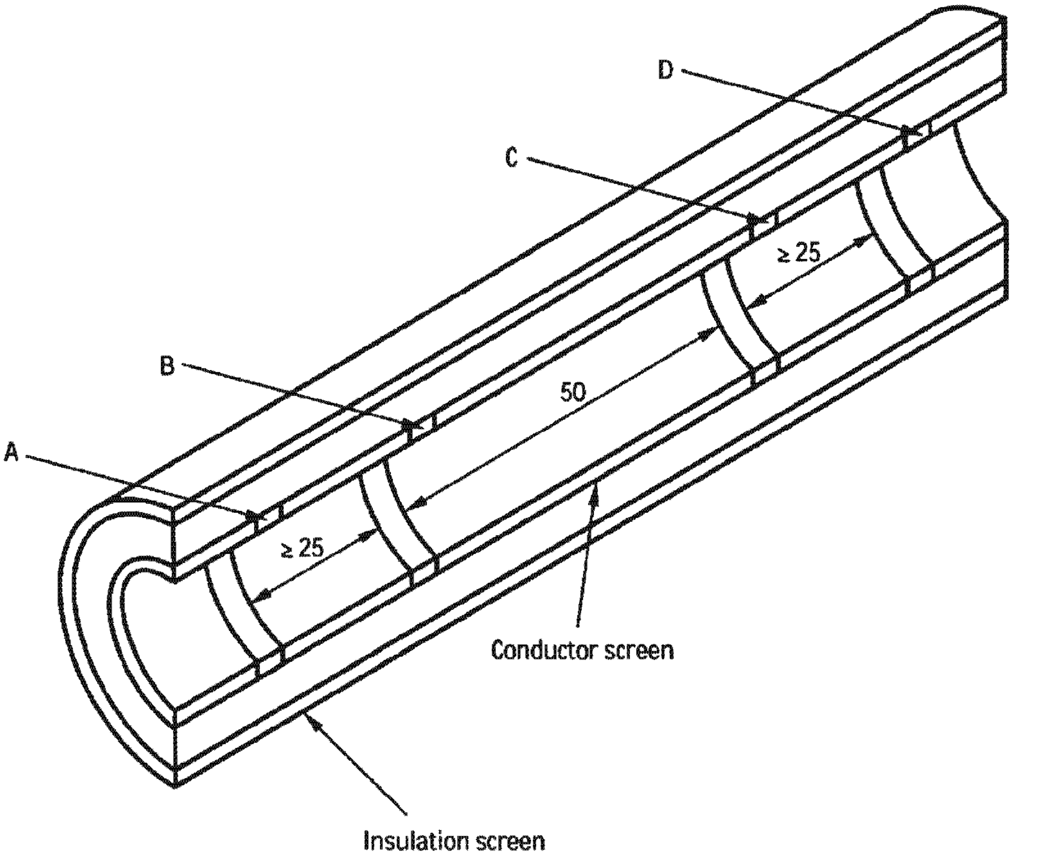
Make connections to the electrodes by means of suitable clips, avoiding damage to the screen. In testing with 5 mm strips, ensure that when making the measurements on one side of the test piece, the clips are insulated from the electrodes on the other side (see Figure G.3).

A similar precaution is necessary when testing the conductor screen on a sample taken from circular core to avoid contact with the screen on the outside of the core.

Place the assembly in an oven pre-heated to (90 ± 2) °C and after an interval of at least 30 min, measure the resistance between the electrodes B and C by means of a circuit with the power not exceeding 100 mW.

After taking the electrical measurements, measure optically the diameter over the conductor screen and insulation (see Figure G.2), the width of the conductor screen and insulation screen (see Figure G.3) and the thickness of the conductor screen and insulation screen (see Figures G.1, G.2 and G.3) in all cases taking the average of six measurements. Measure the distance between the two potential electrodes B and C.

All dimensions are in millimetres

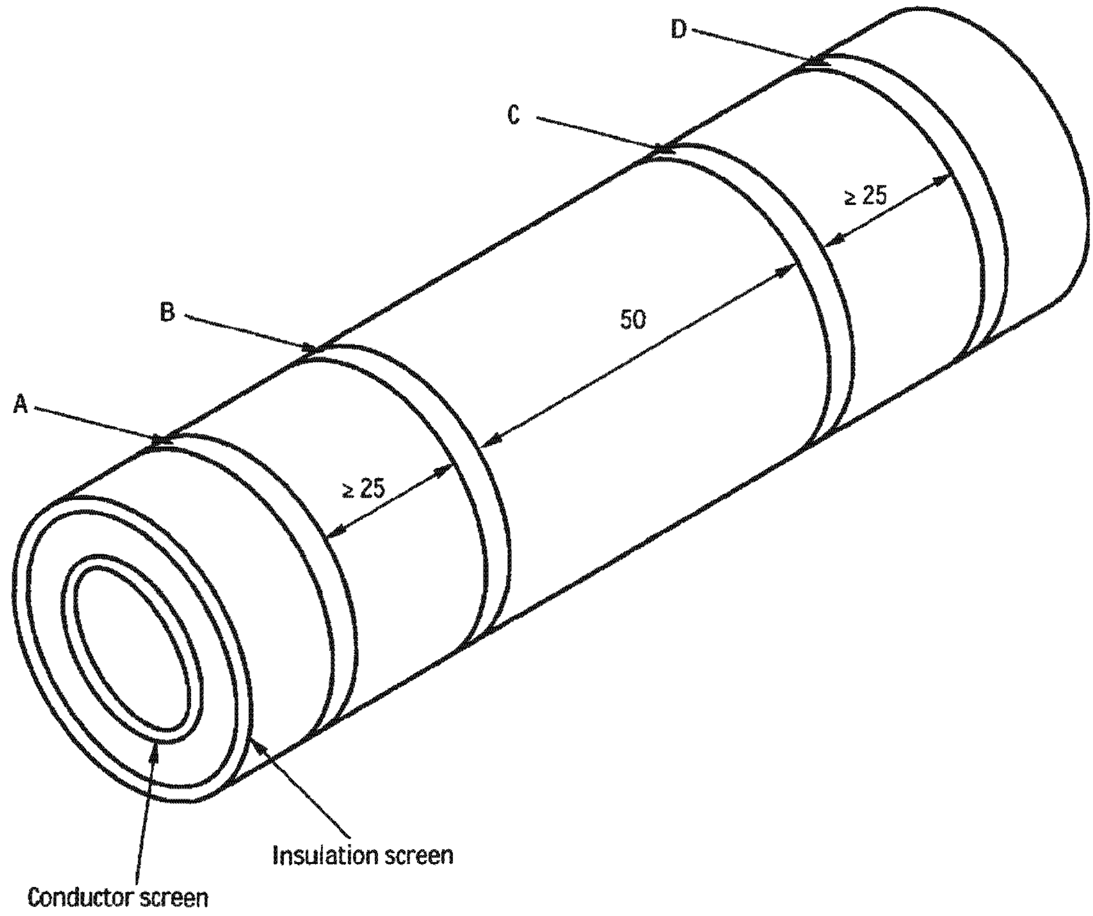


B and C are potential electrodes

A and D are current electrodes

Figure G.1 — Test piece and arrangement of electrodes for measurement of resistivity of conductor screen of circular core

All dimensions are in millimetres

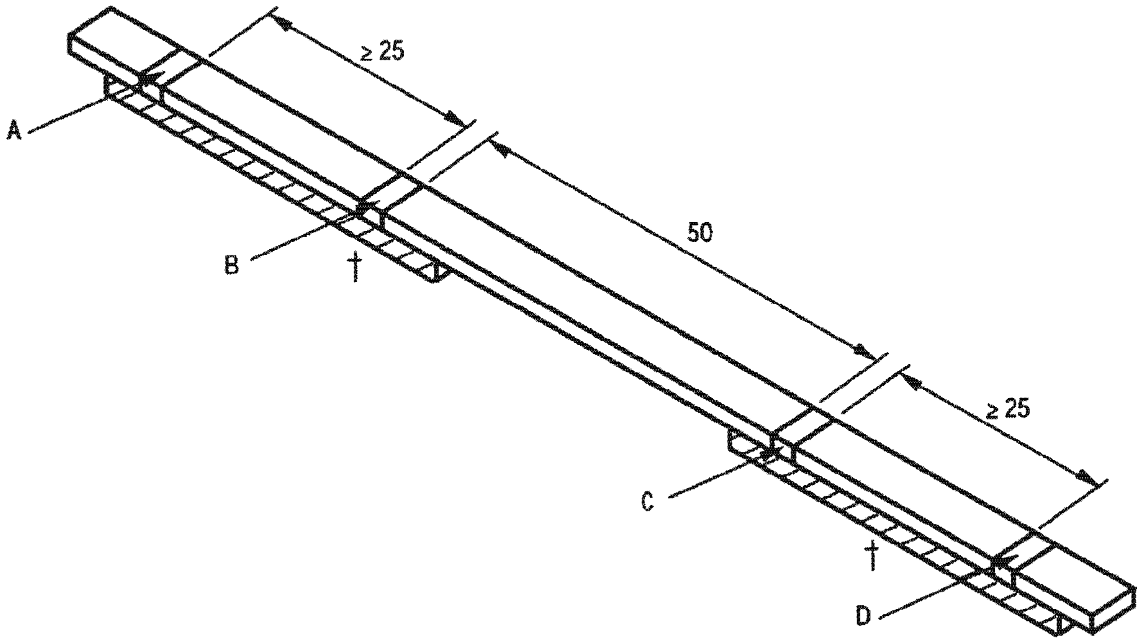


B and C are potential electrodes

A and D are current electrodes

Figure G.2 — Test piece and arrangement of electrodes for measurement of resistivity of insulation screen of circular core

All dimensions are in millimetres



A, B, C and D are silver plated electrodes

† Insulating strips

Figure G.3 — Arrangement of test piece, electrodes and insulating strips for measurement of resistivity of conductor and insulation screens of shaped core

G.3 Calculations

G.3.1 *Conductor screen of circular core*

Calculate the resistivity ρ (in Ω·m) of the conductor screen of a circular core (see Figure G.1) from the following equation:

$$\rho = \frac{R \times \pi \times (D - T) \times T}{2L}$$

where

- R is the resistance measured (in Ω);
- L is the distance measured between potential electrodes (in m);
- D is the diameter over the conductor screen (in m);
- T is the average thickness of the conductor screen (in m).

G.3.2 *Insulation screen of circular core*

Calculate the resistivity, ρ (in Ω·m), of the insulation screen of a circular core (see Figure G.2) from the following equation:

$$\rho = \frac{R \times \pi \times (D + T) \times T}{L}$$

where

- R is the resistance measured (in Ω);
- L is the distance measured between potential electrodes (in m);
- D is the diameter over the insulation (in m);
- T is the average thickness of the conductor screen (in m).

G.3.3 Conductor and insulation screen of shaped core

Calculate the resistivity, ρ (in Ω·m), of the conductor and insulation screen of shaped core (see Figure G.3) from the following equation:

$$\rho = \frac{R \times W \times T}{L}$$

where

R is the resistance measured (in Ω);

L is the distance measured between potential electrodes (in m);

W is the average width of the screen (in m);

T is the average thickness of the screen (in m).

Annex H (normative)
Wet compatibility test

Samples of the semi-conducting carbon loaded tape layer and steel wire shall be taken from a complete cable and immersed for 7 days in a test cell as shown in Figure H.1.

The cell shall contain a minimum volume of 500 ml of 0.1M NaCl solution. The total surface area of the tape below the surface of the liquid shall be 500 mm^2 and the ratio of the surface area of the tape to the steel shall be 1:2.5. The temperature of the electrolyte shall be maintained between 15 °C and 25 °C. The test samples shall be connected through a 10 Ω resistor.

Dimension in millimetres

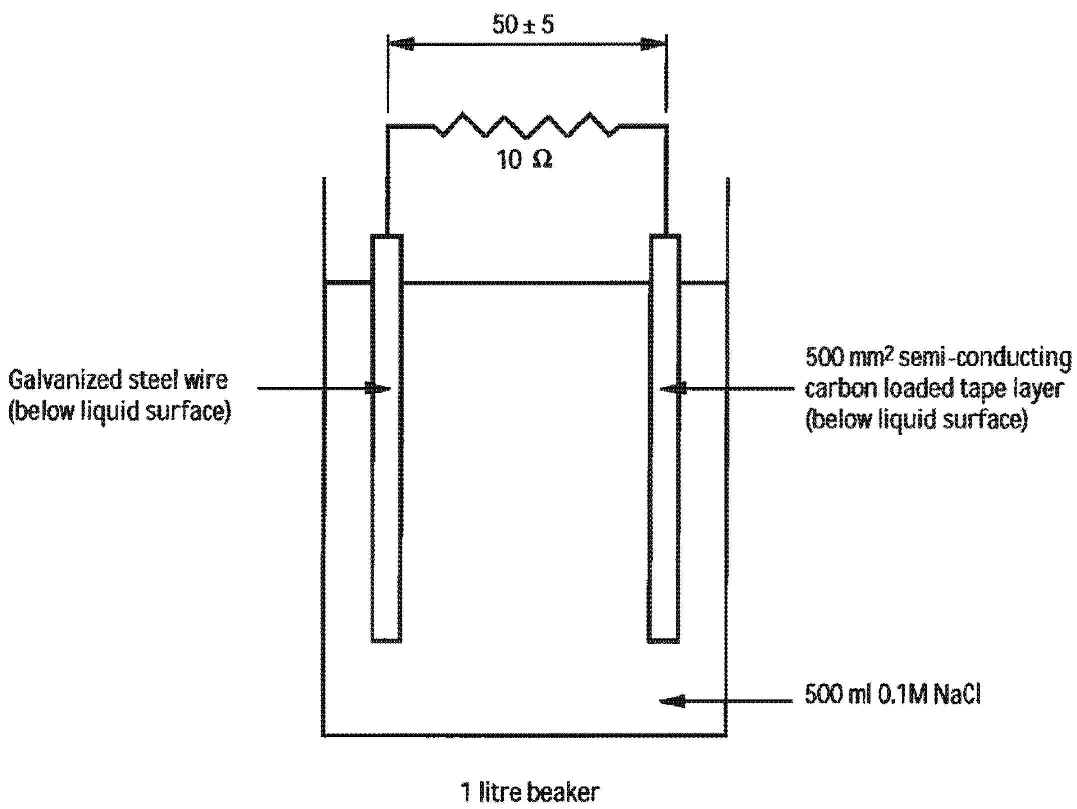


Figure H.1 — Electrochemical test of semi-conducting carbon loaded tape layer

Annex I *Spare*

Annex J (normative)
Abrasion test

Lay the sample of cable straight and horizontal on a firm base. In the middle part of the sample, place a length of low carbon steel (mild steel) angle horizontally, at right angles to the cable, with its angle edge resting on the cable and with its arm symmetrical about the vertical plane. Ensure that the outer radius of curvature of the angle edge is not less than 1 mm and not greater than 2 mm (see Figure J.1).

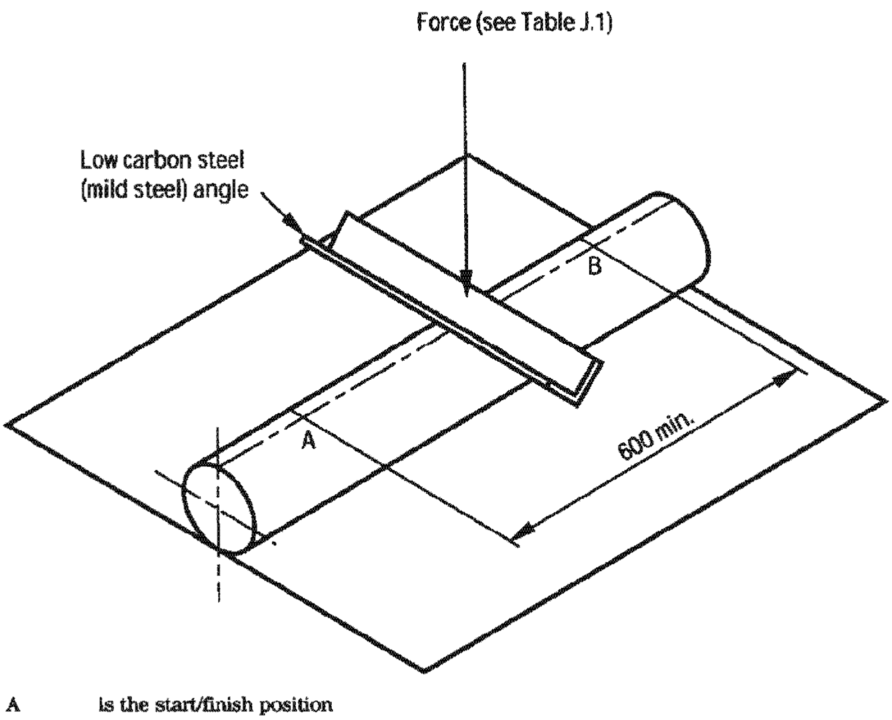
Vertically load the steel angle, above the point of contact, to give a force in accordance with Table J.1.

Table J.1 — Vertical force on cable during abrasion test

Overall measured diameter of cable		Force
Greater than or equal to mm	Less than mm	N
20	30	35
30	40	65
40	50	105
50	60	155
60	70	210
70	—	270

Drag the steel angle horizontally along the cable for a distance not less than 600 mm at a speed of between 150 mm/s and 300 mm/s. Reverse the direction of movement at the end of each pass to give 50 passes, 25 in each direction, over the 600 mm test path.

Dimension in millimetres



A is the start/finish position
B is the start/finish position
A–B is the minimum test path length

Figure J.1 — Abrasion test

Annex K (normative)
Test for shrinkage of sheath on cable

K.1 General

This test shall be carried out to determine the shrinkage of sheath during heat treatment. The test shall be carried out in accordance with BS EN 60811-1-3 modified in accordance with **K.2** to **K.5**.

K.2 Selection of samples

Take one sample of each cable to be tested about 300 mm in length and at least 500 mm away from the end of the cable length.

K.3 Preparation of test piece

Within an interval of not more than 5 min from the time of cutting the sample, mark a test length of (200 ± 5) mm on the middle part of the test piece. Measure the distance between the marks to an accuracy of 0.5 mm.

Prepare the test piece by removing the sheath from both ends of the sample up to positions between 2 mm and 5 mm away from the marks.

Bind the armour wires at both ends.

K.4 Procedure

Perform the test in an air oven in accordance with BS EN 60811-1-3. Support the test piece by means of a freshly prepared talc bath. The combined volume of test apparatus and test piece shall not exceed 10 % of the volume of the oven. Preheat the oven with the test apparatus in place for a minimum of 2 h at 80 °C before the test piece is introduced.

Support the test piece horizontally on the surface of the talc bath. Ensure that there is sufficient depth of talc so that the test piece does not touch the bottom of the bath. Spread the talc evenly, without compacting it, at the start of the test, so as to permit free movement of the sheath.

Introduce the test piece into the test oven, and maintain it at a temperature of (80 ± 2) °C for 4 h. At the end of this period, remove the apparatus with the test piece in place, and allow it to cool to ambient temperature.

Re-measure the distance between the two marks on the test piece to an accuracy of 0.5 mm.

K.5 Evaluation of results

Calculate the difference in the distance between the marks before the heat treatment and after the heating and cooling, and record the shrinkage as a percentage of the distance between the marks before the treatment.

Annex L (normative)
Impulse voltage test

L.1 Test assembly

The test assembly shall be situated indoors in reasonably still air and away from direct sunlight. No arcing horns shall be fitted to the sealing ends.

The main components of the test assembly are an impulse generator, a voltage divider, an impulse wave monitor and the cable sample to be tested.

L.2 Procedure

Connect one core of the cable to be tested to the impulse generator with an associated voltage divider and oscillograph system. Adjust the circuit values of the impulse generator to produce an impulse wave conforming to BS 923-1 and BS EN 60060-2, except that the wavefront may have any duration from 0.5 µs to 5.0 µs. If using an oscilloscope, make oscillograms in short and long time sweeps to record the wavefront and wavetail duration of the test impulse wave. If using a digital measuring system, measure the timing of the wave. Leave the circuit values of the impulse generator unaltered for the remainder of the test period.

Apply to the test cable a loading current of a value estimated to produce the required conductor temperature. Keep this current constant until the cable sheath temperatures have been steady (i.e. with a variation not greater than 2 °C after due allowance has been made for ambient temperature variations) for a minimum of 2 h. Calculate the maximum conductor temperature from a consideration of the conductor current and resistance, the maximum sheath temperature and the design value of cable thermal resistance. Alternatively, the conductor temperature may be established by any similar method such as measuring the actual temperature of an identical sample along with its sheath temperatures. Ensure that the calculated or measured conductor temperature is within the range 95 °C to 100 °C. If not, adjust the loading current as required, until the sheath temperatures are constant.

During the 2 h steady temperature period, perform a calibration of the impulse generator as follows.

Connect a sphere gap across the test assembly. For each setting of the sphere gap, adjust the impulse generator charging voltage to give 50 % sparkover of the gap, and make oscillograms of the impulse voltage.

Perform this procedure for at least three different gap settings using the positive polarity of the impulse voltage and select the settings so that their 50 % sparkover voltages, as given in BS 358, are about 55 %, 75 % and 95 % of the required impulse withstand voltage.

Draw a curve relating charging voltage to sphere gap sparkover voltage and extrapolate this curve to determine the charging voltage necessary to obtain the specified positive withstand voltage level.

Calculate the voltage divider ratio by consideration of the maximum sphere gap sparkover voltage and the corresponding impulse voltage oscillogram. Alternatively, the voltage divider ratio can be measured using a meter specifically designed for this purpose. Use this value of the voltage divider ratio for all the oscillograms made in the course of the series of tests using positive polarity.

With the sphere gap setting increased and the cable maintained at the required temperature, subject one core of the test cable to a series of 10 positive impulses at the voltage specified in Table 24. Ensure that the time interval between successive impulses is just sufficient to fully charge the impulse generator.

Immediately after the application of the 10 positive impulses, recalibrate the generator for negative polarity under the conditions already described, and then apply a series of 10 negative impulses of the same specified voltage to one core of the test cable.

Make oscillograms of at least the first and tenth in each sequence of 10 impulses, including base and voltage calibration lines and a timing wave. Alternatively, if a digital measuring system is utilized, then the print outs shall include the peak voltage and wave timings.

Repeat the impulse tests on any other cores of the cable.

Annex M (normative)
Insulation resistance constant test on oversheath

M.1 Procedure

Immerse a length of a least 5 m of completed cable for at least 12 h in water at (20 ± 5) °C, leaving a length of about 250 mm at each end projecting above the water. Maintain the temperature of the water at (20 ± 1) °C for the 30 min immediately preceding the test. Apply a voltage of between 80 V and 500 V d.c. between the armour and the water. Measure the insulation resistance 1 min after the application of the voltage.

M.2 Calculation of results

Calculate the insulation resistance constant (K value) in MΩ·km from the following equation:

$$K = \frac{lR}{1\,000 \log_{10} D/d}$$

where

- D is the diameter over sheath (in mm);
- d is the diameter over armour (in mm);
- l is the immersed length of cable (in m);
- R is the insulation resistance of the length of cable (in MΩ).

Annex N (informative)
Guide to use

N.1 Aim

The aim of this annex is to inform users of characteristics and limitations of electric cables and thereby to minimize their misuse.

It is assumed that the design of installation and the specification, purchase and installation of cables in accordance with this British Standard is entrusted to suitable skilled and competent people.

In cases of doubt as to the suitability of cables in this British Standard for a particular use, further specific information should be obtained from the manufacturer.

N.2 Cable selection and design

N.2.1 The products described in this British Standard are intended to be used for the supply of electrical energy up to the rated voltage indicated on the cable. **A.2** lists the voltage ratings of the cables specified in this standard. These voltages should not be exceeded.

N.2.2 These cables are intended for use at a nominal power frequency range of 49 Hz to 61 Hz.

N.2.3 There are several aspects which need to be taken into account relating to the capability of the cable to withstand the worst anticipated fault condition of the system, as follows.

a) A solidly or directly earthed system in general implies that the earth fault current is at least equal to the values of the three-phase or phase-to-phase fault current.

b) When an earth fault current is specified, it is necessary to ensure that the phase conductor also has this capability.

c) Some work on spiking of cables has been undertaken by the British cable industry and it shows that, in general, the spiking capability of the screen(s) is less than their through fault capacity. The manufacturer's advice should be sought if in doubt.

d) It is essential that connections at joints and terminations onto metallic elements carrying fault currents to earth have at least equal capacity.

N.2.4 The possible effects of transient over-voltages should be recognized as they can be detrimental to cables.

N.3 Environmental/application

N.3.1 Reasonable protection against mechanical damage, appropriate to the choice of cable and the installation conditions, should be provided.

N.3.2 Cables can be harmed by exposure to corrosive products or solvent substances, including petroleum based vapours.

N.3.3 Cables specified in this British Standard are not specifically designed for use for the following:

a) as self-supporting aerial cables;

b) as submarine cable or for laying in water-logged conditions;

c) where subsidence is likely, unless special precautions are taken to minimize damage;

d) where any exposure to excessive heat is involved.

N.3.4 If the cables specified in this standard are exposed to localized heat, solar radiation or high temperature ambient conditions, this reduces the current carrying capacity.

N.3.5 The standard sheathing components supplied on these cables do not provide protection against damage by rodents, termites, etc.

N.3.6 Loaded cables can have a surface temperature which requires protection to be provided against accidental contact.

N.4 Installation

N.4.1 Precautions should be taken to avoid mechanical damage to the cables before and during installation (see annex C).

N.4.2 Exceeding the manufacturer's recommended maximum pulling tensions can result in damage to the cable.

N.4.3 If cables are to be installed in ducts, the correct size of duct should be used.

N.4.4 The type of jointing and filling compounds employed should be chemically compatible with the cable materials.

N.4.5 The cable support system should be such as to avoid damage or danger under normal or fault conditions.

N.4.6 Cables specified in this British Standard are designed for fixed installations only; they are not for use as, for example, trailing or reeling cables.

N.4.7 Repeated over-voltage testing can lead to premature failure of the cable, see **C.8**.

N.4.8 The selection of cable glands, accessories and any associated tools should take account of all aspects of intended use.

N.4.9 Care should be exercised with single-core cables to ensure that the bonding and earthing arrangements are adequate to cater for circulating currents in the armour.

N.5 Storage and handling of drums

N.5.1 Cable drums should be regularly inspected during storage to assess their physical condition.

N.5.2 Battens, where applied, should not be removed from the drums until the cable is about to be installed.

N.5.3 When handling drums, reasonable precautions should be taken to avoid injury. Due regard should be paid to the weight, method and direction of rolling, lifting, protruding nails and splinters.

N.5.4 Care should be taken to avoid deterioration of drums or their becoming a hazard to the general public.

N.5.5 The cable manufacturer should be consulted for detailed guidance as to the safe handling of cable drums.

N.6 Scrap cable — incineration

Incineration of scrap cable should only be undertaken by a licensed contractor. For further information, the Environment Agency should be contacted.

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IEC 60695-5-2:1994, *Fire hazard testing — Part 5: Assessment of potential corrosion damage by fire effluent — Section 2: Guidance on the selection and use of test methods.*

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[2] INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE). Paper no. 69, CP88-PWR[6].

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