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British Standard Specification for Performance requirements for cables required to maintain circuit integrity under fire conditions

Spécification concernant les prescriptions auxquelles doivent satisfaire les câbles devant maintenir l'intégrité des circuits en cas d'incendie

Bestimmungen für Prüfanforderungen von Kabeln und isolierten Leitungen, die im Brandfalle die Betriebsfähigkeit der Stromkreise bewahren sollen

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Foreword

This British Standard has been prepared under the direction of the General Electrotechnical Engineering Standards Committee to specify performance requirements and provide test methods to enable designers of installations to make an assessment of the fire performance characteristics of various types of cable, particularly with regard to maintaining circuit integrity for a period after commencement of a fire. A number of alternative time and temperature parameters are given to allow the designer to select those considered to be the most appropriate for the intended use. No attempt is made to specify any additional mechanical protection which may be desirable for such cables under particular installation conditions, nor to deal with cable terminations or connected equipment which require separate but parallel consideration in relation to the duty to be performed.

It is emphasized that the fire tests do not assess a fire hazard, nor can the results of the fire tests alone guarantee safety. They only provide information to assist in the assessment of the suitability of a cable for a given application.

It has been assumed in the drafting of this British Standard that the execution of its provision is entrusted to appropriately qualified staff and experienced people, for whose guidance it has been prepared.

At the time of publication of this British Standard there is no corresponding international standard. In preparing the standard, however, use has been made of IEC Publication 331 of the International Electrotechnical Commission (IEC) 'Fire-resisting characteristics of electric cables'.

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

British Standard Specification for

Performance requirements for cables required to maintain circuit integrity under fire conditions

1. Scope

This British Standard specifies performance requirements and gives test methods for mechanical and fire tests applicable to cables rated at voltages not exceeding 450/750 V and for mineral-insulated cables complying with BS 6207 : Part 1. The cables are intended to be used for wiring and interconnection where it is required to maintain circuit integrity under fire conditions for longer periods than cables having conventional insulations such as rubber and PVC.

This standard specifies those requirements of the cables related to characteristics required to enable circuit integrity to be maintained under fire conditions.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2. Definitions

For the purposes of this British Standard the definitions given in BS 4727 apply, together with the following:

2.1 rated voltage U_0 . The power-frequency voltage to earth for which the cable is designed.

2.2 rated voltage U . The power-frequency voltage between conductors for which the cable is designed.

2.3 routine test. A test to be conducted on all manufactured lengths.

2.4 sample test. A test made by the manufacturer on samples of completed cable, or components taken from a completed cable, at a frequency adequate to verify that the finished product meets the design specification.

2.5 type test. A test required to be 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, and that is of such a nature that after it has been made it need not be repeated unless changes are made in the cable materials or design which might change the performance characteristics.

3. Voltage designation

3.1 The cable shall be designated by the rated voltages U_0 and U expressed in the form U_0/U , unless otherwise specified in the appropriate cable standard.

3.2 The rated voltages recognized for the purposes of this standard are 300/500 V and 450/750 V and those applicable to mineral insulated cables as specified in BS 6207 : Part 1.

NOTE. In an a.c. system, the rated voltage of a cable should be at least equal to the nominal voltage of the system for which it is intended. This condition applies both to the value U_0 and the value U .

In a d.c. system, the rated voltage of a cable should be not less than two-thirds of the nominal voltage of the system for which it is intended.

It should be noted in regard to both the above, that it is possible for the operating voltage of a system to exceed permanently the nominal voltage of the system by 10 %.

4. Tests

CAUTION. The tests given in this standard involve the use of dangerous voltages and temperatures. Suitable precautions should be taken against shock, burning, fire and explosion risks that may be involved and against any noxious fumes that may be produced.

Cables shall meet the requirement of the tests as shown by the letter 'x' in table 1. When specified by the purchaser at the time of enquiry or order, cables shall also meet the requirements shown by the letter 'o' (optional).

The tests shall be applied to cables having two or more insulated conductors, whether or not the cables incorporate other metallic elements such as armour, screen or circuit protective conductor. The tests shall also be applied to cables having one insulated conductor provided that the cable incorporates at least one other metallic element. The tests shall not be applied to cables having one insulated conductor but no other metallic element.

Table 1. List of applicable tests

Clause reference	Test description	Category of test	Mineral insulated cables complying with requirements of BS 6207 : Part 1	Other cables with overall diameter < 20 mm	Other cables with overall diameter > 20 mm
6.1	Conductor resistance test <i>Voltage tests on completed cable</i>	Sample	x (as BS 6207 : Part 1)	x	x
6.2.1, A.1 and A.2	Full length test	Routine	x (as BS 6207 : Part 1)	x	x
6.2.2, A.1 and A.3	Test in water	Sample	x (as BS 6207 : Part 1)	x	x
	<i>Tests for bending characteristics</i>				
7, B.1 and B.3	Bend test at ambient temperature	Type	x (as BS 6207 : Part 1)	x	—
7, B.2 and B.3	Bend test at 0 °C	Type	—	x	—
	<i>Tests for resistance of cable to impact</i>				
8.1 and appendix C	Test for resistance to impact at ambient temperature	Type	—	x	x
8.2	Test for resistance of sheath to cold impact	Type	—	x	x
9	<i>Test for electric cables under fire conditions</i>	Type	x (as BS 6207 : Part 1)	x	x
	<i>Tests for fire resistance characteristics</i>				
10.1, D.1 and D.2	Resistance to fire alone	Type	x	x	x
10.2, D.1 and D.3	Resistance to fire with water	Type	o	o	o
10.3, D.1 and D.4	Resistance to fire with mechanical shock	Type	o	o	o

'x' means the test is applied.

'—' means the test is not applied.

'o' means the test is optional.

5. Categories of cable

Cables shall be categorized by a letter symbol or series of symbols according to the requirements for fire resistance characteristics which they meet, the test temperatures selected (see D.2 and D.4) and the duration of the test for resistance to fire alone (see D.2).

The first letter symbol (or symbols) shall be as follows.

Resistance to fire alone (see D.2)	Symbol
650 °C for 3 h	A
750 °C for 3 h	B
950 °C for 3 h	C
950 °C for 20 min (short duration)	S

Where an optional test is applied to further categorize the cable, this letter shall be followed by one or more of the following letter symbols.

Resistance to fire with water (see D.3)

W

Resistance to fire with mechanical shock (see D.4)

650 °C

X

750 °C

Y

950 °C

Z

Thus, a cable meeting the performance requirements of 10.1 at 950 °C for 3 h and 10.3 at 750 °C, but not 10.2, would be category CY, or a cable meeting the requirements of 10.1 at 650 °C for 3 h and 950 °C for 20 min and also 10.2, and 10.3 at 650 °C would be category ASWX.

The listing of the test methods indicated above does not imply that cables exist to meet all the permutations of categories possible.

6. Electrical requirements for completed cable

6.1 Conductor resistance test. The d.c. resistance of each conductor measured on a sample of cable at least 1 m in length, after correction for ambient temperature, shall be not more than the value specified in the appropriate table of BS 6360 : 1981 for the type and size of conductor used.

6.2 Voltage tests on completed cable

6.2.1 Full length test. When a manufactured length of completed cable is tested as described in A.1 and A.2, no breakdown of the insulation shall occur during the test.

6.2.2 Test in water. When a sample of completed cable is tested as described in A.1 and A.3.1, no breakdown of the insulation shall occur during the test.

When a sample of completed cable, having a metallic layer or a non-insulated circuit protective conductor, is tested as described in A.1 and A.3.2, no breakdown of the insulation shall occur during the test.

7. Bending characteristics

When a sample of cable is tested either at ambient temperature (see B.1 and B.3) or at 0 °C (see B.2 and B.3) as described in appendix B, the sheath of the sample of cable shall be free from splits and no breakdown of the insulation shall occur during the test.

8. Resistance of cable to impact

8.1 Resistance to impact at ambient temperature.

There shall be no breakdown of the insulation of any of the samples when they are tested as described in appendix C.

8.2 Resistance of sheath to cold impact. When cables are tested for resistance to cold impact at a temperature of

-15 ± 2 °C using the test method described in appendix D of BS 6746 : 1976, the sheaths of at least five out of the six test pieces shall not show any crack when examined with normal or corrected vision without magnification.

9. Test requirements for electric cable under fire conditions

A sample of cable shall be tested in accordance with BS 4066 : Part 1 and shall meet the requirements of that standard.

10. Fire resistance characteristics

10.1 Resistance to fire alone. When a cable sample is tested as described in D.1 and D.2, no fuse shall be ruptured nor any lamp extinguished during the period of the test. If the sample fails to comply with this requirement, two further samples shall be prepared and tested and both shall comply with this requirement.

10.2 Resistance to fire with water. When a cable sample is tested as described in D.1 and D.3, no fuse shall be ruptured nor any lamp extinguished during the period of the test. If the sample fails to comply with this requirement, two further samples shall be prepared and tested and both shall comply with this requirement.

10.3 Resistance to fire with mechanical shock. When a cable sample is tested as described in D.1 and D.4, no fuse shall be ruptured nor any lamp extinguished during the period of the test. If the sample fails to comply with this requirement, two further samples shall be prepared and tested and both shall comply with this requirement.

Appendix A

Voltage tests on completed cable

A.1 Test conditions and voltage. Carry out the tests described in A.2 and A.3 at a temperature of $20 \pm 5^\circ\text{C}$ using an alternating voltage approximately of sinewave form, having a frequency in the range 49 Hz to 61 Hz, the ratio peak value/r.m.s. value being equal to $\sqrt{2}$ with a tolerance of $\pm 7\%$.

A.2 Full length test. Test each manufactured length of twin and multicore cable without immersion in water. Apply the test voltage, increasing this gradually and maintaining it at the full r.m.s. value given in table 2 for 5 min between each conductor in turn and all the others connected together and also connected to the circuit protective conductor, drain wire and metallic layer, if any.

A.3 Test in water

A.3.1 Immerse a sample of cable, 20 m in length, in water for at least 24 h, the ends of the cores protruding sufficiently above the water level to prevent damage due to leakage current along the surface of the cable when the required voltage is applied between the conductor and the water. Apply the test voltage, increasing the voltage gradually and maintaining it at the full r.m.s. value given in table 2 for 15 min, between each conductor in turn and all the others connected together and also connected to the circuit protective conductor, drain wire and metallic layer, if any, and to the water; also apply the test voltage between all the conductors connected together and the water.

A.3.2 If the cable has a metallic layer or a non-insulated circuit protective conductor, carry out the following additional test while the sample is still immersed. Disconnect the circuit protective conductor, drain wire and the metallic layer from the water and connect them together. Apply a voltage of 1 kV for 5 min between these and the water.

Table 2. Test voltages for completed cable

Rated voltage of cable	Test voltage (r.m.s.)
V	V
300/500	2000
450/750	2500

Appendix B

Tests for bending characteristics

B.1 Bending test at ambient temperature. Take a sample of cable and subject it to the bending test in accordance with the test method given in B.3 at a temperature of $20 \pm 5^\circ\text{C}$.

B.2 Bending test at 0°C . Take a sample of cable and, together with the test mandrel, cool it for 2 h at 0°C . Then immediately subject it to the bending test in accordance with the test method given in B.3.

B.3 Test method

B.3.1 Apparatus. A test mandrel having a diameter $12 D \pm 5\%$ where D is the external diameter of the completed cable.

B.3.2 Procedure. Take a cable sample having a length at least five times the mandrel diameter and not less than 1500 mm if the test for resistance to fire with water is later to be carried out (see D.3.2). Mount the test mandrel on a horizontal or vertical axis about which it is free to rotate. Lay out the cable sample straight on a level surface and secure one cable end to the test mandrel through a swivel connection. Draw a reference line along the top of the cable parallel to its longitudinal axis.

Rotate the mandrel steadily so that all the cable is wound on in a closely wrapped coil, preventing the cable from twisting during the operation. Then rotate the mandrel in the opposite direction so that the cable is unwound and again laid straight on the level surface. Rotate the cable through 180° around its longitudinal axis and repeat the winding and unwinding processes.

Apply the test voltage, increasing the voltage gradually and maintaining it at the full r.m.s. value given in table 2 for 1 min, between each conductor in turn and all the other conductors connected together and also connected to the circuit protective conductor, drain wire and metallic layer, if any.

Appendix C

Test for resistance to impact at ambient temperature

Cables shall be tested for resistance to impact at a temperature of $20 \pm 5^\circ\text{C}$ using the apparatus illustrated in figure 1, both with a chisel edged intermediate piece and a radiused intermediate piece.

Take six samples of cable, each approximately 500 mm long, and remove 100 mm of each sheath from each end to allow the cores to be separated. Place the six samples successively in position on the impact test apparatus and allow the 500 g hammer to fall from a height of 250 mm, three samples being tested with the chisel edged intermediate piece and three with the radiused intermediate piece.

Then apply the test voltage, increasing the voltage gradually and maintaining it at the full r.m.s. value given in table 2 for 1 min, to each of the samples, between each conductor in turn and all the others connected together and also connected to the circuit protective conductor, drain wire and metallic layer, if any.

Appendix D

Tests for fire resistance characteristics

D.1 Test conditions. Carry out the tests in a suitable chamber provided with the means of disposing of noxious gases resulting from the burning and with draught shields fitted near the burner, if found necessary.

D.2 Resistance to fire alone**D.2.1 Apparatus**

D.2.1.1 General. The test rig for verifying resistance to fire alone consists of the following:

- (a) a cable supporting system, as described in D.2.1.2;
- (b) a continuity checking arrangement, as described in D.2.1.3;
- (c) a source of heat, as described in D.2.1.4.

D.2.1.2 Cable supporting system. The cable is held horizontally by means of suitable clamps at each end of the sheathed or protected portion. The middle portion of the cable is supported by two metal rings placed approximately 300 mm apart and these as well as any other metal parts of the supporting apparatus are earthed. The cable supporting arrangement is shown in figure 2.

D.2.1.3 Continuity checking arrangement. During the test a current is passed through all cores of the cable and this is provided by a three-phase star-connected transformer or three single-phase transformers (or one single phase transformer if testing a single core-cable) of sufficient capacity to maintain the test voltage up to the maximum leakage current allowable, i.e. to 3 A. At the opposite end of the cable a lamp (with ballast resistor if necessary) is connected to each core with a power rating such that each core carries a current of approximately 0.25 A at the rated voltage of the cable.

D.2.1.4 Source of heat. The recommended source of heat is a 610 mm long tube-type gas burner which produces a line of closely spaced flames using propane or other gas with a forced air supply, but other equipment may be used for the tests provided that the temperature and time test conditions are achieved.

An unearthed thermocouple not more than 2 mm in diameter suitable for the temperature (e.g. platinum-iridium) is inserted in the flame at the end close to the gas inlet with the thermocouple parallel to the burner and situated 75 mm above it.

D.2.2 Flame temperature and duration of test. The flame temperature used and the duration of the test shall be selected from the following categories:

- category A $650 \pm 40^\circ\text{C}$ for 3 h
- category B $750 \pm 40^\circ\text{C}$ for 3 h
- category C $950 \pm 40^\circ\text{C}$ for 3 h
- category S $950 \pm 40^\circ\text{C}$ for 20 min.

D.2.3 Sample. The sample to be tested shall be a piece of the completed cable not less than 1200 mm long, with 100 mm of sheath and outer coverings removed from each end. At the ends of the cable the conductors shall be suitably prepared for electrical connections in accordance with the manufacturer's recommendations.

D.2.4 Procedure. Mount the sample of cable in the clamps and adjust the metal supporting rings as described in D.2.1.2.

Connect the transformer or transformers to the conductors at one end of the cable, excluding any conductor that is specifically identified as intended for use as a neutral or protective conductor. For single, twin or three conductor cables, connect each conductor to a separate phase of the transformer output with a 3 A fuse or circuit breaker in each phase. For cables with more than three conductors divide the conductors into three groups, ensuring that adjacent conductors are in different groups, as far as possible. Connect the conductors in each group in parallel and connect each group to a separate phase of the transformer output, with a 3 A fuse or circuit breaker in each phase. Alternatively, place a 3 A fuse or circuit breaker in series

with each conductor. The alternative circuit arrangements for a four conductor cable, are shown in figure 11.

In cases of dispute the circuit arrangement shown in figure 11(b) shall be the reference method. At the transformer end of the sample, earth the neutral conductor, the protective conductor and any drain wire and metallic layer. At the other end of the cable, connect one terminal of a lamp as described in D.2.1.3 to each phase conductor and the other terminal to the neutral conductor if there is one, or otherwise to the protective conductor if there is one, or otherwise to any metallic layer.

Adjust the apparatus so that the cable may later be lowered into position with the minimum of readjustment.

Switch on the electricity supply and adjust the voltage between phases to the rated voltage U (or in the case of a single-core cable to the rated voltage to earth U_0).

With the thermocouple in position, light the burners and adjust the gas and air supplies until the test temperature for the appropriate category in accordance with D.2.2 is steadily registered.

Remove the thermocouple and lower the cable into position, so that it is parallel with the burner and the lower surface of the cable is 75 mm above the burner. Continue the test for the duration for the appropriate category in accordance with D.2.2.

D.3 Resistance to fire with water**D.3.1 Apparatus**

D.3.1.1 General. The test rig for verifying resistance to fire with water consists of the following items:

- (a) a cable supporting system as described in D.3.1.2;
- (b) a continuity checking arrangement as described in D.3.1.3;
- (c) a source of heat as described in D.3.1.4;
- (d) a water spray as described in D.3.1.5.

D.3.1.2 Cable supporting system. The cable is attached to a metal support consisting of two strips of steel 25 mm wide by means of metal clips as shown in figure 3, the spacing of the clips being approximately 200 mm. This assembly with the cable attached is supported in the test frame as shown in figures 4 and 5 and this frame is earthed.

D.3.1.3 Continuity checking arrangement. During the test a current is passed through all cores of the cable and this is provided by a three-phase star-connected transformer or three single-phase transformers (or one single phase transformer if testing a single-core cable) of sufficient capacity to maintain the test voltage up to the maximum leakage current allowable, i.e. to 3 A. At the opposite end of the cable a lamp (with ballast resistor if necessary) is connected to each core with a power rating such that each core carries a current of approximately 0.25 A at the rated voltage of the cable.

D.3.1.4 Source of heat. The source of heat is a propane or natural gas burner system arranged so as to burn approximately 400 mm of the cable sample. The gas burners are adjusted to give a luminous flame having a temperature of $650 \pm 40^\circ\text{C}$ positioned as shown in figures 4 and 5 so that the flame impinges on the cable sample.

NOTE. A suitable arrangement consists of four separate burners each having an orifice 36 mm long and 5 mm wide ($\pm 5\%$).

The temperature of the flame is measured using an unearthed thermocouple not more than 2 mm in diameter suitable for the temperature (e.g. platinum-iridium) placed in the flame at the position the lower surface of the cable sample will occupy during the test.

The heat flow rate is measured by the following procedure. Fit a thermocouple at one end of a mild steel bar $3 \text{ mm} \pm 5\%$ in diameter and more than 300 mm long, so that the temperature at the end of the rod can be measured. Hold the end with the thermocouple attached in the flame so that the end of the rod is between 40 mm and 50 mm from the burner. The heat flow rate shall be such that the temperature of the steel rod reaches 400°C in not less than 20 s and not more than 40 s.

D.3.1.5 Water spray. A sprinkler head as shown in figure 6* is fixed to the test frame as shown in figures 4 and 5, and uses a water supply at a pressure between 250 kPa and 300 kPa with a rate of water application in the vicinity of the cable sample not less than $0.25 \text{ L}/(\text{m}^2 \cdot \text{s})$.

D.3.2 Sample and sample treatment. The sample to be tested shall be a piece of completed cable at least 1500 mm long, which has been subjected to the bending test at ambient temperature, with 100 mm of the sheath or outer covering removed from each end. At the ends of the cable the conductors shall be suitably prepared for electrical connections in accordance with the manufacturer's recommendations.

D.3.3 Procedure. Connect the transformer or transformers to the conductors at one end of the cable, excluding any conductor that is specifically identified as intended for use as a neutral or protective conductor. For single, twin or three conductor cables, connect each conductor to a separate phase of the transformer output with a 3 A fuse or circuit breaker in each phase. For cables with more than three conductors divide the conductors into three groups, ensuring that adjacent conductors are in different groups, as far as possible. Connect the conductors in each group in parallel and connect each group to a separate phase of the transformer output, with a 3 A fuse or circuit breaker in each phase. Alternatively, place a 3 A fuse or circuit breaker in series with each conductor. The alternative circuit arrangements, for a four conductor cable, are shown in figure 11. In cases of dispute the circuit arrangement shown in figure 11(b) shall be the reference method. At the transformer end of the sample, earth the neutral conductor, the protective conductor and any drain wire and metallic layer. At the other end of the cable connect one terminal of a lamp as described in D.3.1.3 to each phase conductor and the other terminal to the neutral conductor if there is one, or otherwise to the protective conductor if there is one, or otherwise to any metallic layer.

Light the burners and adjust the flame temperature to $650 \pm 40^\circ\text{C}$ by means of regulator valves in the supply, with the burner needle valves fully open.

Extinguish the flames by closing the needle valves controlling the gas flow to the burners, leaving the position of the regulator valves in the supply unchanged.

Attach the cable sample to the steel support as described in D.3.1.2 and place the assembly in position on the test frame (see figure 4).

Switch on the electrical supply and adjust the voltage between phases to the rated voltage U (or in the case of a single-core cable to the rated voltage to earth U_0).

Open the needle valves fully and re-ignite the burner.

After 15 min of burning, turn on the water supply to the sprinkler head to give a spray of water over the burned area of the cable sample.

Continue the flame and water spray for a further 15 min:

D.4 Resistance to fire with mechanical shock

D.4.1 Apparatus

D.4.1.1 General. The test rig for verifying resistance of cables to fire with mechanical shock consists of the following items:

- (a) a vertical wall on to which the cable is mounted, comprising a board of heat resisting incombustible material fastened to steel runners, as described in D.4.1.2;
- (b) a transformer or transformers with fuses and electric lamps for indicating that continuity is maintained, as described in D.4.1.3;
- (c) a shock producing device, as described in D.4.1.4;
- (d) a source of heat, as described in D.4.1.5.

A general arrangement of the test rig is shown in figure 7. A slotted angle framework is a suitable means of supporting the components in their relative positions.

D.4.1.2 The wall and its mounting. The wall consists of a board of heat resisting non-combustible material fastened rigidly to two horizontal steel runners, one at the top of the board and the other at the bottom. The board is approximately 900 mm long, 300 mm deep and 9 mm thick and of a mass of between 10 kg and 15 kg. Each runner is made from standard 25 mm square steel tube and is 1 m long. It is important that the top runner is fastened to the board so that its upper face is flush with the upper edge of the board. Each runner has a horizontal hole drilled into it at each end outside the board, the exact position of each hole and its diameter being determined from the particular supporting bush used and the requirements of the supporting framework. The wall is fastened to the framework by four bonded rubber bushes approximately 25 mm diameter and 15 mm thick as shown in figure 8.

D.4.1.3 Continuity checking arrangement. During the test a current is passed through all cores of the cable and this is provided by a three-phase star-connected transformer or three single-phase transformers (or one single phase transformer if testing a single-core cable) of sufficient capacity to maintain the test voltage up to the maximum leakage current allowable, i.e. to 3 A. At the opposite end of the cable a lamp (with ballast resistor if necessary) is connected to each core with a power rating such that each core carries a current of approximately 0.25 A at the rated voltage of the cable.

D.4.1.4 Shock producing device. The shock producing device consists of a mild steel round bar $25 \text{ mm} \pm 5\%$ diameter and $600 \text{ mm} \pm 5\%$ long. The rod is freely pivoted about an axis parallel to the wall, which is in the same horizontal plane as, and 200 mm away from, the upper edge of the wall. The axis divides the rod into two unequal sections of length 200 mm and 400 mm respectively, the longer section impacting the wall. The rod drops under its own weight from an angle of 60° to the horizontal to strike the top of the wall at its midpoint once every 30 s (see figure 7).



*There is at present no British Standard for this sprinkler jet. A draft standard is under preparation that this will eventually lead to a British Standard to which cross reference can be made.