

Specification for

General requirements for aircraft electrical cables (second series)

Committees responsible for this British Standard

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- Association of Manufacturers allied to the Electrical and Electronic Industry (BEAMA Ltd)
- British Airways
- British Cable Makers Confederation
- British Rubber Manufacturers' Association
- Civil Aviation Authority (Airworthiness Division)
- Electronic Components Industry Federation
- Ministry of Defence
- Society of British Aerospace Companies Limited

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Foreword

This new edition of this British Standard has been prepared under the direction of the Aerospace Standards Policy Committee and supersedes BS G 230:1984 which is withdrawn. It does not reflect a full revision of the standard which will be undertaken in due course.

This edition embodies the text of amendment No 1 (AMD 5482) and amendment No 2 (AMD 6253). It also introduces revised definitions, a test for tensile strength and elongation of insulation, changed requirements for marking and formulae for the calculation of conductor resistance in an appendix.

It updates the requirements of BS G 212 and applies to aerospace series cable specifications published since 1984. The retrospective application of this standard to the requirements of aerospace series cable specifications published prior to 1984 is not possible, and BS G 212 has been retained in the aerospace series for this purpose.

This standard forms the basis on which a series of individual cable specifications, e.g. BS G 232, has been prepared. The individual specifications should therefore be considered as the definitive standards.

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

Formulae for calculating braiding details are given in Appendix A and manufacturer's identification marks are given in Appendix B.

WARNING. This British Standard calls for the use of substances and 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.

Relative thermal life and temperature rating given in Appendix C has been reproduced from ASTM D 3032-80, with permission, and formulae for calculating conductor resistance are given in Appendix D.

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 50, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies requirements and describes methods of test common to aerospace series electrical cable specifications.

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 following definitions apply.

2.1

airframe cable

cable suitable for open wiring and engine compartments without additional protection

2.2

cable

an assembly consisting of conductor, insulation and, where applicable, screen and jacket

2.3

concentric conductor

an assembly comprising several strands, all arranged in the form of a spiral, in regular concentric layers. The direction of lay of the strand, passing from one strand layer to the next layer, is either alternate or identical. The lay for the various layers may be different or identical

2.4

bunched conductor

an assembly of several strands, all arranged in the form of a spiral, in the same direction and with the same lay

2.5

rope stranded conductor

an assembly comprising a number of concentric or bunched conductors, arranged in the form of a spiral and in regular concentric layers, the different layers being laid in opposite directions

2.6

conductor

the conducting element of a cable upon which the electrical rating is based

2.7

conductor size

the number used to define the gauge size of the conductor

NOTE This number approximates to the American Wire Gauge Number.

2.8

core

an assembly of a conductor and dielectric or insulation that form part of a complete single or multi-conductor cable

2.9

dielectric

that material surrounding the conductor which provides the acceptable level of electrical insulation

2.10

insulation

that part of the cable surrounding the conductor consisting of dielectric and, where applicable, sheath

2.11

interconnect cable

cable suitable for use in areas with some protection, such as behind panels or bulkheads

2.12

jacket

the outermost covering of a multi-core cable or a screened cable

2.13

multi-core cable

a cable consisting of two or more cores and/or other elements laid together helically

2.14

plated strand

a strand that is covered with a thin metallic coating in order to improve the performance or termination

2.15

rope stranded

an assembly consisting of a number of elements arranged in concentric layers, the layers being arranged in concentric lay

2.16

screen

a conductive covering applied over the cables or cores to reduce the electro-magnetic interference

2.17

screened cable

a cable having a screen

2.18

screened and jacketed cable

a screened cable having an overall jacket

2.19

sheath

a protective covering added to the core to improve its mechanical or fluid resistive properties

NOTE It may also be added to provide a suitable surface for printing.

2.20
solid conductor

a conductor consisting of a single strand

2.21
strand

cylindrical metallic element of uniform cross-sectional area used to form the conductor, or braid of a screened cable

3 Classification and colour coding

NOTE Details of conductors, insulation, screens, glass braids and jackets are given in the individual cable specifications. The formulae for calculating the filling factor and lay factor of screens and glass braids are given in Appendix A.

3.1 Classification. The cables in an individual range shall be classed according to the number of cores they possess, e.g.:

- class 1: single core
- class 2: two core
- class 3: three core
- class 4: four core

3.2 Colour coding

3.2.1 General. Where applicable, the colours shall be recognizable as those given in BS 6746C.

3.2.2 Class 1 cables and sheaths. Class 1 cables and sheaths shall be white or straw.

3.2.3 Classes 2, 3 and 4. Each core of a multi-core cable shall be colour coded as given in Table 1, e.g.:

- two core: red, blue
- three core: red, blue, yellow
- four core: red, blue, yellow, green

One of the following methods shall be used to colour identify the cables.

- a) The cable insulation surface shall be completely coloured to show the base colour.
Where a second colour is required, this shall be in the form of a helical stripe approximately 0.75 mm wide applied with a lay length of approximately 12 times the cable diameter.
- b) The base colour shall be applied in a helical stripe not less than 1.5 mm wide with a lay length of approximately 12 times the cable diameter.
Where a second colour is required, this shall be applied in a helical stripe of the same lay length, but approximately 0.75 mm wide.

4 Designation and marking

4.1 Designation. For the purpose of references on drawings and orders, the cables shall be designated by a part number composed as follows:

Part number			
GXXX	XX	X	XXXX
Specification number	Type number	Class number	Size number

4.2 Marking. Cables shall be marked with their part number together with the following additional information which shall be clearly separated from the part number.

Details of origin		
XX	XX	XX
Country of origin	Manufacturer	Year of manufacture

This information shall be permanently and legibly printed. It shall appear on the cable in a contrasting colour and shall be repeated at a spacing of 150 mm to 300 mm. The axis of the characters shall be either horizontal or perpendicular to the axis of the cable for sizes 10 and smaller cables, but shall be horizontal to the axis of the cable for sizes 8 and larger cables. The height of the characters on cable sizes 10 to 24 shall be approximately two-thirds of the maximum cable diameter, and on cable sizes 8 to 0000 shall be as applied to the size 10 cables. All letters shall be capitals.

Single-screened and jacketed cables shall be marked on the core. Multi-core cables shall be marked on the red core only.

The cable size shall correspond to the conductor size stated in the individual cable specification.

The code letters for the country of origin of the cable shall be “GB” for cables manufactured in the United Kingdom.

The manufacturer shall not mark the cable with his name or address but with code letters in accordance with the list of manufacturers’ identification marks for aircraft electrical cables given in Appendix B.

The year of manufacture shall be identified using the appropriate code from Table 2.

Table 1 — Colour code for multi-core cable

Core number	Base colour	Second colour
1	Red	—
2	Blue	—
3	Yellow	—
4	Green	—
5	Black	—
6	Violet	—
7	Orange	—
8	Brown	—
9	Pink	—
10	Grey	—
11	Grey	Red
12	Grey	Blue
13	Grey	Yellow
14	Grey	Green
15	Grey	Black
16	Grey	Violet
17	Grey	Orange
18	Grey	Brown
19	Grey	Pink
20	Red	Blue
21	Red	Yellow
22	Red	Green
23	Red	Black
24	Red	Violet
25	Red	Orange
26	Red	Brown
27	Red	Pink
28	Blue	Yellow
29	Blue	Green
30	Blue	Black
etc.		

Table 2 — Code for identification of year of manufacture

1991	F or 91
1992	92
1993	93
1994	94
1995	95
1996	96
1997	97
1998	98
1999	99
2000	00

All manufacturers shall use the same code for the current year, which shall be the year in which the insulation was applied.

4.3 Circuit identification. Cable manufacturers shall give details of a satisfactory method of hot stamp circuit identification marking for application by customers.

5 Packaging and labelling

The cable shall be supplied on reels or drums.

NOTE 1 The lengths should be as specified in the contract or order.

NOTE 2 Cable should not be supplied in coils unless specified in the contract or order.

Each reel or drum shall bear a durable label upon which the following particulars shall be plainly and permanently printed:

- name of manufacturer;
- designation of cable (see 4.1);
- formation of conductor, e.g. 37/0.25 mm;
- date of manufacture, i.e. year and month;
- lot number, release reference number or contract number, or all;
- actual length or lengths (in sequence on reel or drum), in metres.

The label shall be attached permanently to the side of the reel or drum by adhesive or staples, or shall be a tie-on label with one side blank.

NOTE If the manufacturer so desires, the information may be hand printed provided an indelible ink is used and the characters are legible.

6 Tests

6.1 General. The manufacturer shall produce evidence to the satisfaction of the Approving Authority¹⁾ that the cable complies with the individual cable specification. Such evidence shall include a Declaration of Design and Performance based upon the format given in BS 3G 100-1 but suitably modified to permit specific declarations against all the performance requirements of the individual cable specification.

If any changes are made in the techniques or materials used in the production of the cables, the manufacturer shall inform the Approving Authority.

NOTE Following such changes the Approving Authority may require a repetition of Qualification Approval tests.

¹⁾ The Approving Authority is either:

- for UK civil aviation products, the Civil Aviation Authority or their accredited representative; or
- for UK military products, information is available from the Procurement Executive, Ministry of Defence, Directorate General of Defence Quality Assurance, Directorate of Standardization, Kentigern House, 65 Brown Street, Glasgow G2 8EX.

Four types of test are specified, as follows.

a) *Qualification approval.* Qualification approval tests selected from **6.2** to **6.41** in accordance with the individual cable specification shall be made on separate specimens from a sample selected by the manufacturer from each group of cable types and sizes specified in the individual cable specification. A sample shall be regarded as being representative of all cables in its group, provided that they are made by the same process and with the same materials within the group from which it is selected. The samples shall be selected from a production batch.

Typical circuit identification markings shall be applied to all specimens using the recommended method (see **4.3**) before testing.

b) *Production quality tests.* Production quality tests selected from **6.2** to **6.41** in accordance with the individual cable specification shall either be made on each 100 km of cable or at least once on each two months' production, whichever is the smaller, unless otherwise specified in the individual cable specification.

NOTE The quantity of cable may consist of different sizes and types but the sample should be representative of the different sizes and types being produced.

c) *Inspection lot tests.* Inspection lot tests selected from **6.2** to **6.41** in accordance with the individual cable specification shall be made on each inspection lot.

NOTE An inspection lot is all that material associated with a given sample.

Dispatch shall not be made until the lot tests are satisfied.

d) *Production routine tests.* Production routine tests selected from **6.2** to **6.41** in accordance with the individual cable specification shall be made on every length of cable.

Tests shall be conducted on finished cable or its extracted component parts unless otherwise stated in a particular test or in the individual cable specification.

6.2 Test 1. Appearance and identification of finished cable. When a visual examination of the finished cable is carried out, the cables shall present a smooth appearance and shall be marked in accordance with **4.2**.

6.3 Test 2. Mass per unit length of finished cable. When a minimum length of 1 m per cable size of finished cable is weighed, the mass per unit length, expressed in kg/km, shall not be greater than that specified in the individual cable specification.

6.4 Test 3. Conductor composition

6.4.1 Method. Count the number of constituent strands and measure the diameter of each strand using a micrometer.

6.4.2 Requirement. The number of strands per conductor and the strand diameter shall comply with BS G 231.

6.5 Test 4. Visual examination of strands. When a visual examination of the coated strands used for the conductor and metal braids is made, the strands shall be clean, bright and free from surface irregularities.

6.6 Test 5. Insulation thickness and concentricity

6.6.1 Method. Measure the thickness of the insulation and the centring of the conductors in the insulation at three different points on the reel to be tested, at least 1.0 m apart.

Carry out the measurements using either an optical micrometer, a measuring microscope or any equivalent instrument. Measure the radial thickness of the insulation at its minimum and maximum points.

6.6.2 Requirement. The minimum value of the radial thickness shall comply with the individual cable specification and shall be not less than 70 % of the measured maximum thickness.

6.7 Test 6. Core and cable outer

diameters. When the core and cable minimum and maximum outer diameters are measured in two perpendicular directions located at the same point along the cable, the diameters shall comply with the individual cable specification.

NOTE The use of a shadowgraph is recommended for measuring these diameters.

6.8 Test 7. Tensile strength and elongation at break of copper or copper alloy conductors

6.8.1 Method. Carry out the test in accordance with **4.1.1** of BS G 231.

6.8.2 Requirement. The tensile strength and elongation at break of the strand or conductor shall comply with **4.1.2** of BS G 231.

6.9 Test 8. Tensile strength and elongation at break of aluminium or aluminium alloy conductors

6.9.1 Method. Conduct the test in accordance with **4.1.1** of BS G 231 but for this test, take not less than 10 strands from size 8 to 2 conductors, and not less than 20 strands from sizes 0 and larger. Take the sample strands at random from the conductor.

6.9.2 Requirements. The tensile strength and elongation at break of the strand or conductor shall comply with the individual cable specification. In addition, the strand or conductor shall not break when wound round a mandrel of its own diameter forming a close helix of turns, unwrapped six turns, and again closely re-wrapped in the same direction as the first wrapping.

6.10 Test 9. Strand plating continuity

6.10.1 Method. Take three strands, not less than 150 mm in length, from an uninsulated conductor previously straightened by hand. Degrease the strands without damage, then wipe using a clean dry cloth. Ensure that any strands cleaned in this manner are not touched by hand. Immerse the strands for 30 s in a solution of sodium polysulphide of density 1.142 g/cm^3 at 20°C , then wash carefully in distilled water. In addition, immerse silver and nickel coated strands for 15 s in hydrochloric acid solution of density 1.088 g/cm^3 at 20°C and then wash carefully in distilled water. Examine the strands under a magnification of $\times 30$.

6.10.2 Requirement. No adherent or distinctly visible black spots shall be observed. Any blackening occurring less than 15 mm from each end shall be disregarded.

6.11 Test 10. Strand plating adherence

6.11.1 Method. Take three strands, not less than 150 mm in length, from a conductor previously straightened by hand and which has been removed from a finished insulated construction. Wind one strand of the conductor around itself, using half the specimen length as a mandrel so as to form ten adjacent turns. Examine under a magnification of $\times 100$.

6.11.2 Requirement. The plating shall not exhibit any detachment or cracks.

6.12 Test 11. Strand plating thickness. When checked by a method that is acceptable to the Approving Authority, the thickness of silver and nickel plating shall comply with BS G 231.

The thickness of tin plating shall not be checked.

6.13 Test 12. Electrical resistance of copper or copper alloy conductors. When the electrical resistance of the conductor is measured and referred to 20°C in accordance with BS G 231, it shall comply with the individual cable specification.

NOTE The maximum values of resistance (for plated copper conductors only) given in BS G 231 have been calculated using the formulae given in Appendix D.

6.14 Test 13. Electrical resistance of aluminium or aluminium alloy conductors.

When the electrical resistance of the conductor is measured and referred to 20°C , it shall comply with the individual cable specification.

6.15 Test 14. Solderability

6.15.1 Test 14(a). Method 1²⁾ (not applicable to size 10 and larger)

6.15.1.1 Principle. A prepared specimen is vertically suspended from a sensitive balance in such a manner that it is immersed to a set depth in a bath of molten solder at a controlled temperature. The resulting vertical forces of buoyancy and surface tension acting upon the specimen are detected by a transducer and converted into a signal that is continuously recorded as a function of time on a high-speed chart recorder.

6.15.1.2 Apparatus. The apparatus comprising a balance, transducer, chart recorder and solder bath shall comply with the following characteristics.

- The response time of the chart recorder shall be such that its return to centre zero on removal of a maximum load shall be accomplished within 0.3 s, with an overshoot corresponding to not more than 1 % of the maximum load.
- The recording system shall have a number of sensitivity settings, the most sensitive corresponding at least to a maximum deflection from centre being produced when a 200 mg mass is suspended from the specimen holder.
- The chart speed shall not be less than 10 mm/s.
- Electrical and mechanical noise recorded in the trace shall not exceed the equivalent of 4.10^{-5} N peak to peak.
- The deflection of the writing device shall be directly proportional to the force being measured over the full scale to an accuracy of better than 95 %.
- The stiffness of the spring system of the balance shall be such that a load of 10^{-2} N causes a vertical displacement of the specimen suspension not exceeding 0.1 mm.
- The dimensions of the solder bath shall be such that no portion of the specimen is less than 15 mm from the wall, and the depth of the bath shall be not less than 15 mm.
- The bath temperature shall be controllable to an accuracy of ± 1.5 % up to a maximum of 350°C .

²⁾ A similar method is being discussed within the International Electrotechnical Commission (IEC). If on completion this work is adopted as a British Standard, this standard will be amended to comply with it.

i) The immersion depth of the lowest point on the specimen shall be adjustable to any specified position between 2 mm and 5 mm with a maximum error of ± 0.2 mm.

j) The speed of immersion and withdrawal shall be 20 ± 5 mm/s.

k) The dwell time at the maximum immersion depth shall be adjustable.

6.15.1.3 Preparation of specimens. Prepare the specimens as follows.

a) *Cable conductors.* Remove at least 150 mm from the end of the cable and discard. Cut five specimens of approximately 30 mm length from the remaining cable. Strip the specimens of insulation to expose a length of 15^{+0}_{-5} mm of conductor, taking care to ensure that no part of the surface of the exposed conductor becomes contaminated, especially by contact with the fingers. Minimize and correct any disturbance of the strands.

b) *Screens.* Take five specimen strands from the completed cable. Ensure that no part of the strand becomes contaminated, especially by contact with the fingers.

6.15.1.4 Procedure. Mount the specimen in a suitable holder. Immerse the whole of the surface of the specimen to be tested in a flux at room temperature as specified in the individual cable specification. Immediately drain off excess flux by standing the specimen vertically on clean filter paper for 1 s to 5 s.

Fill the solder bath with solder of the type specified in the individual cable specification and raise to the temperature specified therein. Suspend the specimen vertically with its cut end 20 ± 5 mm above the surface of the molten solder for 30 ± 15 s to allow most of the flux solvent to evaporate. During this drying period, scrape the surface of the molten solder with a blade of suitable material to remove oxides, and adjust the suspension and chart recorder trace to the desired zero position.

Immerse the specimen in the molten solder at a speed of 20 ± 5 mm/s to a depth of 4 ± 1 mm and hold in this position for not less than 10 s and then withdraw. Obtain a trace of force versus time from the start of lowering until the specimen returns to the start position.

NOTE A typical trace is shown in Figure 1. The wetting time is taken to be the time difference between t_2 and t_1 .

6.15.1.5 Requirement. The wetting time shall not exceed the value given in the individual cable specification.

6.15.2 Test 14(b). Method 2 (not applicable to size 10 and larger)

NOTE The purpose of this test is to prove the plating quality.

6.15.2.1 Method. Test the cable conductors and screen in accordance with method 1 (solder bath at 235°C) of test Ta of BS 2011-2.1T:1981. The immersion times are 5 s for sizes 26 to 16 inclusive and 10 s for sizes 14 and 12, with an immersion depth of 12 mm. A non-activated flux is used and the specimens are examined under a magnification of $\times 2$.

6.15.2.2 Requirements. The solder coating shall be smooth, free of lumps and continuous. In addition, there shall be evidence of good wetting and bonding between the strands.

6.16 Test 15. Conductor strand adhesion

6.16.1 Method. Select at random eight specimens, approximately 150 mm in length, from a 4 m length of previously untested cable that has been removed carefully without undue flexing from the cable drum.

Initiate a stripping action 50 mm from one end of the specimen using a calibrated hand stripping tool. Without kinking or otherwise deforming the conductor, move the insulation slug endwise until approximately 20 mm of the conductor is exposed. Remove the specimen from the stripping tool. Grip the insulation with the fingers at both ends of the exposed strands and rotate one end so as to untwist the exposed strands until they are parallel with the conductor axis. The strands will “birdcage” as a result of this action. Do not touch the strands during the untwisting process.

Carry out the appropriate procedure as follows.

a) If the conductor is of unidirectional lay construction, gently probe the strands using a thin steel probe, such as a fine needle, aided by a magnification of $\times 10$, to determine whether they are fused together by metallic bonding, or simply laying side by side. Pairs or groups of strands that cannot be separated along the entire 20 mm length of exposed conductor without forcing the probe between the individual strands are considered to be adhered.

b) If the conductor is of true concentric lay construction, the direction of lay of each layer will be reversed, and only the outer layer of strands will untwist. In this case proceed as specified for unidirectional lay conductors until the evaluation of the outer layer has been completed. Carefully sever and fold back the birdcaged strands. Again grip the insulation and untwist the inner layer of strands, and continue with the evaluation until all strands have been examined.

c) If the conductor is of rope stranded construction, select three outer members for the test. Carefully remove them from the conductor and proceed as specified for unidirectional lay conductors.

6.16.2 Requirements. The individual strands of the conductor shall separate freely and there shall be no evidence of bonding of the strands.

6.17 Test 16. High voltage

6.17.1 Test 16(a). Immersion

6.17.1.1 Method. Immerse the specimens, each 15 m in length, in a solution consisting of 1 000 g of distilled water, 30 g of sodium chloride and 2 g of wetting agent. The temperature of the solution is between 15 °C and 25 °C. After immersion for 1 h, apply a voltage as specified in the individual cable specification at a frequency of 40 Hz to 60 Hz between the conductor of the cable and an electrode in contact with the liquid for 5 min.

6.17.1.2 Requirement. No electrical breakdown of the insulation shall occur.

6.17.2 Test 16(b). Dry spark

6.17.2.1 Method. Subject all cable produced at its final reeling or in the stage of manufacture as specified in the individual cable specification to the spark test described in BS 5099 except that the spark test voltage is as specified in the individual cable specification. In addition, on screened cables, apply a spark test at the voltage specified in the individual cable specification between the metal braid and a suitable electrode on the outside of the cable.

6.17.2.2 Requirement. Electrical flaws occurring in the cable shall be removed by cutting out at least 300 mm of the cable on each side of the point of failure.

6.17.3 Test 16(c). Dry impulse

6.17.3.1 Apparatus

6.17.3.1.1 Electrode head, as shown in Figure 2. The wave form of the voltage supplied to the electrode head shall consist of a sharp rise pulse followed by a highly damped wave train. The sharp rise of the impulse wave front shall reach 90 % of the specified peak value in less than 10 µs and shall reach peak value in less than 20 µs. Fluctuations of the actual peak value, due to variations of input power into the generator, shall not exceed ± 2 % of the specified peak value. The peak value shall not show more than a 5 % reduction in the event of an increase of capacitance load to 50 pF, during operation, from an initial load of 25 pF between electrode and instrument ground. The pulse duration, including the damped portion of the wave, shall be between 40 µs and 50 µs. The pulse repetition rate of the electrode shall be a minimum of 170 pulses/s and a maximum of 500 pulses/s. Visible or audible corona shall be evident in the electrode structure when operating at the specified voltage.

Connected to the electrode head there shall be a peak reading instrument voltmeter indicating continually the potential of the electrode with or without a grounded test wire in the chamber. The peak reading voltmeter shall show full deflection at a peak value not exceeding 25 kV and shall have an accuracy of ± 3 % of the specified operating value. This meter shall be capable of maintaining calibration for an adequate period, preferably a minimum of one month.

When using the electrode head, there shall be guides external to the electrode head to provide axial centering of the cable in the chamber. The guides shall be such as to centre the cable in the electrode head within 0.06 mm (0.0025 in) or 25 % of the cable diameter, whichever is greater, without damage to the cable and without obstructing free access of air to the electrode head.

There shall be a failure detection circuit to give a visible or audible indication of insulation failure, automatically de-energize the electrode head and stop progress of the cable through the electrode. The detection circuit shall be sufficiently sensitive to indicate a fault when the electrode is arced to ground through a 0.5 MΩ resistor and shall be capable of detecting a fault which lasts for the duration of only one impulse. The high voltage, when turned off by the failure detection circuit, shall remain off until reset manually.

The impulse test equipment shall be calibrated by means of a peak detecting electronic voltmeter connected directly between the electrode head and ground. The impulse generator shall be energized and the voltage control of the impulse generator shall be adjusted until the reading on the calibration voltmeter is the specified potential, at which point the reading on the instrument voltmeter shall be observed and recorded. This calibration shall be repeated at each specified peak potential. The pulse wave form shall be monitored by means of an oscilloscope connected to the electrode head at suitable test points.

NOTE Calibration may be accomplished without a test wire in the electrode head, in which case the voltage control on the impulse generator may require a different setting for each cable size in order to give the desired reading on the instrument voltmeter; or the calibration may be made with a load of 20 pF to 60 pF. The equipment may also be calibrated against an oscilloscope with a calibrated and compensated attenuator. The chosen method should have an accuracy of $\pm 2\%$.

6.17.3.2 Procedure. Pass all cable produced at its final reeling or in the stage of manufacture as specified in the individual cable specification through the centering guides and the electrode head. The conductor or screen, as applicable, is grounded. With the electrode energized to the peak potential specified in the individual cable specification, pass the cable through the chamber at such a speed that every part of the cable is subjected to at least three impulses of the test potential while within the electrode head. Ensure that the number of impulses that any part of the cable is subjected to, including set up, does not exceed 1 000.

6.17.3.3 Requirement. Electrical flaws occurring in the cable shall be removed by cutting out at least 300 mm of the cable on each side of the point of failure.

6.17.4 Test 16(d). Screened and multi-core cables; voltage test on completed cable

6.17.4.1 Method. Subject all cables, in the dry state, to the voltage specified in the individual cable specification for 1 min between each core and all the other cores connected together.

NOTE For screened cables, the screen is considered as the core.

6.17.4.2 Requirement. Electrical flaws occurring in the cable shall be removed by cutting out at least 300 mm of the cable on each side of the point of failure.

6.18 Test 17. Insulation resistance

6.18.1 Method. Immerse the specimens in the solution specified in test 16(a) (see **6.17.1**) with the specimen ends protruding at least 150 mm above the surface. Ensure that the immersed length (l) is at least 1 m. Record this length. After 1 h of immersion at test temperatures $20 \pm 2^\circ\text{C}$ and $95 \pm 2^\circ\text{C}$ respectively, apply a voltage of 500 ± 50 V d.c. between the conductor and the solution for a period of 1 min.

After the application of this voltage, determine the insulation resistance R_k (in Ω) for a 1 km length at $20 \pm 2^\circ\text{C}$ and $95 \pm 2^\circ\text{C}$ using the following formula:

$$R_k = \frac{Rl}{1000}$$

where

R is the resistance of the immersed length;

l is the immersed length.

6.18.2 Requirement. The insulation resistance shall be not less than the following:

- a) 500 M Ω for a 1 km length at $20 \pm 2^\circ\text{C}$;
- b) 1 M Ω for a 1 km length at $95 \pm 2^\circ\text{C}$.

6.19 Test 18. Surface resistance

6.19.1 Method. Apply two electrodes in tinned copper wire or metal foil about the centre of each specimen (see Figure 3). The distance between the inside edges is 25 mm. Ensure that the electrodes provide good electrical contact with the surface of the specimens. Allow a sufficient length of wire to connect the cables entering the chamber (see Figure 4). Solder the electrode wires to the cables so that their ends are at least 25 mm from the inner walls of the chamber. Clean the specimens to eliminate any contamination and subsequently handle with maximum care to avoid further contamination of the portion between the electrodes.

The environmental conditions of the chamber are as follows:

relative humidity	: $95 \pm 5\%$
ambient temperature	: $20 \pm 5^\circ\text{C}$

Ensure that the insulation resistance measured between opposite output cables is at least 10^6 M Ω before the sample is connected.

Maintain the assembly in the above conditions for a period of 96 h.

At the end of this period, apply a voltage of 500 ± 50 V d.c. to the electrodes for 1 min and measure the resistance between them. Calculate the surface resistance by multiplying the values obtained in this manner by the diameter of the specimen in millimetres.

Apply a voltage of 2 500 V r.m.s. at a frequency of between 40 Hz and 60 Hz for 1 min between the electrodes.

6.19.2 Requirements. No arcing, smoke emission, burning marks, crazing, etc. shall occur. After a rest period of between 15 min and 20 min, the surface resistance shall again be measured and the values obtained shall be multiplied by the diameter of the specimens in millimetres and shall, in each case, be at least equal to 12 500 M Ω /mm.

6.20 Test 19. Accelerated ageing

6.20.1 Method. Remove 25 mm of the covering from each end of a 750 mm length specimen. Bend the control portion of the specimen at least halfway around a cylindrical mandrel having a diameter as specified in the individual cable specification. Apply a tensile force as specified in the individual cable specification to each end of the conductor attached in such a manner that the portion of the insulation and covering between the conductor and mandrel is in compression. Place the prepared specimen and mandrel in an air circulating oven for the times and temperatures specified in the individual cable specification.

After the heat cycle, allow the specimen to cool to a temperature of 20 ± 5 °C and maintain this temperature for at least 1 h. Remove the applied tension. Withdraw the cable from the mandrel and straighten before subjecting it to the room temperature bend test (see 6.25) and the high-voltage immersion test (see 6.17.1).

NOTE A non-stick barrier may be required on the mandrel to prevent adhesion of the cable to the mandrel.

6.20.2 Requirements. The cable shall withstand the room temperature bend test and the high-voltage immersion test.

6.21 Test 20. Thermal endurance. When tested in accordance with Appendix C, the thermal life and temperature rating shall be as specified in the individual cable specification.

6.22 Test 21. Adherence of insulation on conductor (not applicable to size 8 and larger)

6.22.1 Method. Cut the insulation around the whole periphery of each specimen 5 mm and 30 mm from one end. Strip the insulation from both ends to leave a 25 mm length of insulation on the conductor. Insert the conductor into a calibrated hole (i.e. conductor diameter + 0.05 mm) and subject to a gradually increasing tensile force, F , until it slides within the insulation (see Figure 5). The pulling rate is 100 ± 10 mm/min.

6.22.2 Requirements. Using normally employed stripping tools, it shall be possible to strip a 10 mm length of insulation without difficulty from each end of each specimen.

On completion of the test described in 6.22.1, the minimum values of the adherence forces shall be not less than the values specified in the individual cable specification.

6.23 Test 22. Delamination and shrinkage

6.23.1 Method. Take one specimen, 300 mm in length, from the finished cable and cut at its ends so that the conductor is flush with the insulation at both ends. Store the specimen in an air circulating oven at a temperature and for the time and number of cycles required by the individual cable specification. Allow the specimen to return to room temperature.

6.23.2 Requirements. The length of conductor exposed at either end shall be measured and shall not exceed the values given in the individual cable specification. Any delamination of layers either along the insulation or at the ends shall be considered a defect.

6.24 Test 23. Delamination and insulation blocking

6.24.1 Method. Wind one cable specimen around a mandrel of a diameter as specified in the individual cable specification in two superimposed layers, each consisting of six to eight cable turns. Wind the cable in such a way that succeeding turns are in close contact with one another and under a tension as specified in the individual cable specification. Fix the free end of the cable to the mandrel to prevent unwinding or loosening of the turns or layers. Place the assembly in an air circulating oven for a time and at a temperature as specified in the individual cable specification. Withdraw the assembly from the oven and cool for at least 1 h at room temperature.

6.24.2 Requirements. It shall be easy to unwind the cable from the mandrel and the turns shall easily separate from each other. Any delamination of the layers either along the insulation or at the ends shall be considered a defect.

6.25 Test 24. Room temperature bend

6.25.1 Method. Attach one end of a specimen to a horizontal mandrel and subject the other end to a tensile force. The mandrel diameter and the force are as specified in the individual cable specification. Rotate the mandrel until at least two turns of the specimen are wound onto it then rotate it in the opposite direction in a similar manner so that the compressed surface in the first winding becomes the stretched surface in the second. Perform the cycle twice.

6.25.2 Requirement. On completion of this test, the specimen shall withstand the high-voltage immersion test (see 6.17.1).

The cable insulation shall exhibit neither crazing nor cracking.

6.26 Test 25. Cold bend (not applicable to size 4 and larger)

6.26.1 Method. Attach one end of a specimen of suitable length to a horizontal mandrel and subject the other end to a tensile force. The mandrel diameter and the force are as specified in the individual cable specification. Place the assembly in a chamber at a temperature and for a time as specified in the individual cable specification. Rotate the mandrel at a rate of at least 12 r/min until at least two turns of the specimen are wound onto it. Rotate the mandrel in the opposite direction in a similar manner, so that the compressed surface in the first winding becomes the stretched surface in the second. Perform the cycle twice.

6.26.2 Requirements. After being allowed to return to room temperature, the cable insulation shall exhibit neither crazing nor cracking. On completion of this test, the specimen shall withstand the high-voltage immersion test (see 6.17.1).

6.27 Test 26. Dynamic cut-through (not applicable to size 8 and larger)

6.27.1 Apparatus

6.27.1.1 Tensile tester (or equivalent apparatus) operating in a compression mode and equipped with a means to record the force necessary to drive the cutting edge through the insulation of a finished cable specimen (see Figure 6). The tester is also equipped with a chamber that allows the test to be performed after stabilization at elevated temperatures, and a low-voltage detection circuit designed to stop the tester when the edge cuts through the cable insulation and contacts the conductor.

6.27.2 Procedure. Carry out the test at the temperature specified in the individual cable specification. Move the cutting edge through the insulation at the constant rate of loading specified in the individual cable specification until contact with the conductor occurs. Perform four tests on each specimen. Move the specimen forward a minimum of 25 mm and rotate 90° clockwise between each test.

6.27.3 Requirements. The cut-through shall be the average of the four tests, and shall not be less than the average value given in the individual cable specification.

6.28 Test 27. Notch-propagation resistance

6.28.1 Method. Remove 25 mm of insulation from each end of the 500 mm finished cable specimens. At the approximate centre of each specimen, cut a notch in the insulation to a depth equivalent to 30 % of the minimum radial thickness shown in the individual cable specification. Cut the notch with a commercial grade steel safety razor mounted in a suitable guide to control the depth of the notch (see Figure 7). Wrap the specimens 360° around a mandrel of three times the nominal outside diameter of the finished cable as shown in the individual cable specification with the notch on the outside of the bend.

6.28.2 Requirement. On removal from the mandrel the specimens shall withstand the high-voltage immersion test (see 6.17.1).

6.29 Test 28. Flammability

6.29.1 Test 28(a). Method 1

WARNING NOTE. Care should be exercised in making this test as toxic fumes may be given off during combustion. It is recommended that the test chamber be placed in a fume cabinet that will allow evacuation of gaseous products of combustion at the end of the test.

6.29.1.1 Apparatus

6.29.1.1.1 Test chamber, measuring roughly 700 mm high × 500 mm wide × 300 mm deep, enclosed at the top, open at the front and situated in a draught-free environment but with sufficient air to provide normal combustion.

6.29.1.2 Preparation of test specimens. Cut the specimens, approximately 900 mm in length, consecutively from the same coil and freely expose them in an atmosphere of 50 ± 5 % relative humidity at a temperature of 20 ± 5 °C for a period of not less than 16 h. Keep the specimens in the conditioning chamber until just prior to testing.

Mount the specimens in a test chamber as shown in Figure 8 and hold tight at an angle of 60° to the horizontal, parallel to, and approximately 150 mm from the front end of the test chamber.

Mark the specimens in two places, 200 mm and 600 mm from the upper edge of the lower clamp.

NOTE The former defines the mid-point of application of the flame (flame centre datum) and the latter provides a datum point for measurement after test.

6.29.1.3 Procedure. Adjust a bunsen burner to produce a flame with an inner blue cone approximately one-third of the overall flame height. Insert a bare copper wire of diameter 0.7 ± 0.025 mm and having a free length of not less than 100 mm into the flame, the end of the wire being immediately above the tip of the inner cone³⁾. Finally adjust the burner so that the wire starts to melt within 4 s to 6 s of being inserted into the flame. Alternatively, a 0.8 mm to 0.81 mm diameter wire may be used in which case adjust the burner so that the wire starts to melt within 7 s to 9 s.

Mount the burner under the 200 mm mark, perpendicular to the specimen and at an angle of 30° to the vertical plane of the specimen as shown in Figure 8.

Apply the flame to the specimen so that the tip of the inner cone is immediately below the flame centre datum mark (200 mm) for a period of time depending on the size and type of the cable as specified in the individual cable specification. Remove the flame immediately at the end of the application time.

6.29.1.4 Requirements. During the test no flaming particles shall fall from the specimen and after the source of flame is removed the cable shall comply with the following.

- a) It shall cease to burn within 15 s.
- b) The total length burned or charred shall not exceed 75 mm. Breaking of cable specimens of sizes 24 and smaller shall not be considered a failure provided the specimens comply with the aforementioned requirements.

NOTE The burn length is the total length burnt or charred, measured from the farthest evidence of damage in the downward direction to the farthest evidence of damage in the upward direction. It is determined by subtracting the total unburnt length from the original length of 600 mm.

6.29.2 Test 28(b) Method 2

WARNING NOTE. Care should be exercised in making this test as toxic fumes may be given off during combustion. It is recommended that the test chamber be placed in a fume cabinet that will allow evacuation of gaseous products of combustion at the end of the test.

6.29.2.1 Method. Carry out the test in a chamber similar to that used in 6.29.1, using specimens measuring 450 mm in length. Remove 50 mm of insulation from one end of the specimen and mount it as shown in Figure 9. Apply a 38 mm high yellow flame from a bunsen burner to the specimen at the junction of the insulation and the bare conductor in such a manner that the lower end of the insulation is located 19 mm into the flame. The duration of the flame is as specified in the individual cable specification. At the end of the specified time remove the burner from below the specimen. Record the burn length and the time of burning after removal of the flame for each specimen, then calculate the mean measurements. Disregard any light discoloration of the insulation.

6.29.2.2 Requirements. During the test no flaming particles shall fall from the specimens and after the source of flame is removed, the mean measurements shall be such that:

- a) the cable shall cease to burn within 15 s;
- b) the total length of the cable that is burnt or charred shall not exceed 90 mm.

NOTE The burn length is the distance from the original junction of the insulation and the bare conductor, indicated by the bend made in the conductor, to the farthest point of damage. (Damage is indicated by exposed conductor or charred insulation.)

6.30 Test 29. Resistance to fluids

WARNING NOTE. Some test fluids may have a critical flash point temperature. Testing should always be undertaken in a suitable bomb calorimeter if that temperature is exceeded.

Some test fluids may themselves, or in combination with the specimen, be toxic. Due consideration should be given to this possibility before commencing the test.

6.30.1 Method. Bend the specimens, each measuring not less than 600 mm, into single "U" loops of a diameter approximately 10 times the diameter of the cable. Immerse each specimen in one of the fluids listed in Table 3 with the ends 150 mm above the surface of the fluid and maintain at the temperature specified in Table 3 for not less than 20 h. Remove the specimens from the fluid and allow to cool at room temperature in free air for 1 h.

³⁾ For initial setting-up purposes an overall flame height of approximately 75 mm may be found suitable.

Table 3 — List of test fluids

Contaminant fluid group		Test fluid	Test temperature ($\pm 2^\circ\text{C}$)
Fuels	Kerosene (turbine)	ISO 1817 test liquid F	70 ^a
	Gasoline (piston engine)	ISO 1817 test liquid B	40 ^a
Hydraulic fluids	Mineral oil based	NATO H-520; (OM-18) ^b	70
	Phosphate ester based (synthetic)	ISO 1817 test liquid 103	70
	Silicone based	Dimethyl silicone, 10 mm ² /s (cSt) at 25 °C (ZX42; NATO S1714)	70
Lubricating oils	Ester based (synthetic)	ISO 1817 test liquid 101	150
Solvents and cleaning fluids		Propan-2-ol (isopropyl alcohol) (see BS 1595)	50 ^a
		1,1,1-Trichloroethane (see BS 4487)	50
De-icing and anti-freeze fluids		Kilfroast ABC, DTD 900/4907	50
Sullage		4 $\pm$ 0.1 % Formaldehyde plus 1 $\pm$ 0.1 % o-Cresol (general purpose reagent) in water	23
NOTE For information on the availability of the liquids given in this table, write to Customer Information, BSI, Linford Wood, Milton Keynes MK14 6LE.			
^a This temperature exceeds the critical flash point temperature. Expert advice should be taken on the conduct of the test.			
^b NATO H-515 may be used as an alternative if desired.			

6.30.2 Requirements. On completion of the test the cable shall comply with the following:

- a) there shall be no crazing or delamination of the insulation and covering;
- b) marking shall remain legible;
- c) the change in colour shall be slight;
- d) variation of the overall diameter shall not exceed 5 %.

Each specimen shall withstand the room temperature bend test (see 6.25) and the high-voltage immersion test (see 6.17.1).

NOTE Where the Approving Authority requires cables to be tested in additional fluids to those given in Table 3, these should be stated in the order.

6.31 Test 30. Scrape abrasion (not applicable to size 8 and larger)

6.31.1 Apparatus (see Figure 10)

6.31.1.1 Device, designed to abrade the surface of the insulation parallel to the longitudinal axis of the cable over a length of 10 ± 1 mm at a frequency of 55 ± 5 cycles/min.

6.31.1.2 Test rig, fitted with a counter and an automatic stop that will operate on contact between the abrading edge and the conductor.

6.31.2 Procedure. Carry out the test at the temperature described in the individual cable specification. Securely attach the cable specimen, measuring approximately 750 mm in length, to the mounting by means of a cable clamp. Subject the abrading edge to the force specified in the individual cable specification.

Subject each specimen to four tests, moving it forward 100 mm between tests while rotating through an angle of 90° , always in the same direction.

6.31.3 Requirements. The insulation shall withstand the number of cycles as specified in the individual cable specification, one cycle consisting of one abrading edge movement in each direction.

NOTE The scrape abrasion resistance is the number of complete cycles required for the abrading edge to completely abrade through the insulation and to stop the equipment.

6.32 Test 31. Overload resistance

WARNING NOTE. Care should be exercised in carrying out this test as toxic fumes may be given off during the test.