

Specification for general requirements for aircraft electrical cables (second series)

ICS 49.060

Committees responsible for this British Standard

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British Cable Makers' Confederation
Civil Aviation Authority
Federation of the Electronics Industry
Ministry of Defence
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Foreword

The revision of this British Standard has been prepared by Subcommittee ACE/6/2, Aerospace-Cables, on behalf of Technical Committee ACE/6, Aerospace avionic, electrical and fibre optic technology. It supersedes BS 2G 230: 1991 which is withdrawn.

This edition embodies the text of amendment No 1 (AMD 7066) and the draft amendment No 2. It introduces revised titles for tests, revised requirements for tests and introduces additional tests. The revised tests bring the specification into line with proposed future European Standards that will, in due course, supersede some of the tests listed herein. This edition also takes into account developments in the revision of ISO 2635: 1979 which will be reflected in a future revision of BS G 231:1997. However, smoke production under current overload conditions is addressed in the text for overload resistance.

This revision of the standard does not include requirements or tests for the determination of smoke density or toxicity as European Standards for these tests are still under development at time of preparation of this standard.

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

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

Formulae for calculating braiding details are specified in annex A and revised manufacturer's identification marks are specified in annex 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 specified in annex C has been reproduced from ASTM D 3032-80, with permission, and formulae for calculating conductor resistance are specified in annex D.

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 79 and a back cover.

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1 Scope

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

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 903-A16:1987, *Physical testing of rubber — Determination of the effect of liquids* (ISO 1817)

BS 1595-1:1986, *Propan-2-ol (isopropyl alcohol) for industrial use — Specification for Propan-2-ol (isopropyl alcohol)*

BS 2011-2.1T:1981, *Environmental testing — 1T. Test T. Soldering*

BS 2782-5: Method 540B:1982, *Methods of testing plastics — Methods of exposure to laboratory light sources (xenon arc lamp, enclosed carbon arc lamp, open-flame carbon arc lamp, fluorescent tube lamps)*

BS 3591:1985, *Specification for industrial methylated spirits*

BS 5099:1992, *Specification for spark testing of electric cables*

BS 6746C:1993, *Colour chart for insulation and sheath of electric cables*

BS 3G 100-1:1973, *Specification for general requirements for equipment for use in aircraft. Identification and declarations*

BS 3G 100-2.3.12:1991, *Specification for general requirements for equipment for use in aircraft — All equipment — Environmental conditions — Fluid contamination*

BS 3G 100-2.3.13:1973, *Specification for general requirements for equipment for use in aircraft — All equipment — Resistance to fire in designated fire zones*

BS 3G 100-3:1979, *Specification for general requirements for equipment for use in aircraft — All equipment — Characteristics of aircraft electrical power supplies*

BS 4G 229:1996, *Schedule for environmental conditions and test procedures for airborne equipment* (Implementation of ISO 7137)

BS 3G 231:1997, *Specification for conductors for general-purpose aircraft electrical cables and aerospace applications*

BS G 250:1994, *Specification for identification marking of electric cables* (Implementation of ISO 2574)

BS 3G 230:2000

BS G 258:1995, *Glossary of terms for electrical cables and cable harness* (implementation of ISO 8815)

BS G 262:1998, *Aircraft. Declaration of design and performance for aircraft equipment. Standard form* (ISO/TR 224:1998)

BS 2L 93:1971, *Specification for plate of aluminium-copper-magnesium-silicon-manganese alloy (solution treated, controlled stretched and precipitation treated)* (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)

BS EN ISO 3166, *Codes for the representation of names of countries and their subdivisions — Country subdivision codes*

ASTM D 3032-80, *Hookup wire insulation*

Mil-C-5809, *General specification for aircraft circuit breaker trip-free*

Mil-T-43435-B, *Specification for tape lacing and tying*

3 Definitions

For the purposes of this British Standard, the definitions given in BS G 258:1995 apply, together with the following.

3.1

individual cable specification

technical specification, product standard or a combination of the two (e.g. as used in the case of European Standards) which define specific requirements relating to a cable product type

3.2

approving authority

body which is recognized by the CAA, for civil aviation products, or MOD, for military products, (or their accredited representatives), which can confer approval for a product to be used on aircraft built in the UK

4 Classification and colour coding

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

4.1 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.

4.2 Colour coding

4.2.1 General

Where applicable, the colours shall be recognizable as those specified in BS 6746C.

4.2.2 Class 1 cables and sheaths

Class 1 cables and sheaths shall be white in accordance with BS G 250 (ISO 2574).

4.2.3 Classes 2, 3 and 4

Each core of a multi-core cable shall be colour coded as specified in BS G 250 (ISO 2574).

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.

5 Designation and marking

5.1 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

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. Multicore cables shall be marked on the red core only.

NOTE The cable size designation refers to the size of the conductor within it as 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 a name or address but with code letters in accordance with the list of manufacturers' identification marks for aircraft electrical cables specified in annex B.

The year of manufacture shall be identified using the appropriate code from BS G 250 (ISO 2574).

NOTE All manufacturers should use the same code for the current year, which shall be the year in which the insulation was applied. The year code is that for the year in which the insulation was applied.

5.2 Circuit identification

Cable manufacturers shall give details of a satisfactory method of hot stamp circuit identification marking for application by customers on cables having a total insulation thickness of 0.254 mm (0.010 in) or greater.

NOTE It is recommended that cables having less than 0.254 mm (0.010 in) in total insulation should not be marked by any aggressive method.

6 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:

- a) name of manufacturer;
- b) designation of cable (see 5.1);
- c) formation of conductor, e.g. 37/0.25 mm;
- d) date of manufacture, i.e. year and month;
- e) lot number, release reference number or contract number, or all;
- f) 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 The information may be hand printed provided an indelible ink is used and the characters are legible.

7 Tests

7.1 General

The manufacturer shall produce evidence to the satisfaction of the Approving Authority, that the cable conforms to the individual cable specification. Such evidence shall include a Declaration of Design and Performance in accordance with the format specified in BS G 262 but suitably modified for claims of compliance with 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 1 Following such changes, the Approving Authority may require a repetition of Qualification Approval tests.

Four types of test are specified, as follows.

- a) *Qualification approval*. Qualification approval tests selected from 7.2 onwards 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 5.2) before testing.
- b) *Production quality tests*. Production quality tests selected from 7.2 onwards 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 2 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 7.2 onwards, in accordance with the individual cable specification shall be made on each inspection lot.

NOTE 3 An inspection lot is all the material associated with a given sample.

Dispatch shall not be made until cables have achieved pass results on completion of the selected tests.

- d) *Production routine tests*. Production routine tests selected from 7.2 onwards 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.

7.2 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.

7.3 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 be not greater than that specified in the individual cable specification.

7.4 Test 3. Conductor composition

7.4.1 Method

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

7.4.2 Requirement

The number of strands per conductor and the strand diameter shall conform to BS G 231.

NOTE The number of strands per conductor and the strand diameter may conform to the requirements of BS ISO 2635, which is in preparation at time of writing of this standard.

7.5 Test 4. Visual examination of strands

When visually examined, the coated strands used for the conductor and metal braids shall be clean, bright and free from surface irregularities.

7.6 Test 5. Insulation thickness and concentricity

7.6.1 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.

7.6.2 Requirement

The minimum value of the radial thickness shall conform to the individual cable specification and shall be not less than 70 % of the measured maximum thickness.

7.7 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 conform to the individual cable specification.

NOTE The use of a shadow-graph is recommended for measuring these diameters.

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

7.8.1 Method

Carry out the test in accordance with 6.1.1 of BS G 231.

7.8.2 Requirement

The tensile strength and elongation at break of the strand or conductor shall conform to **6.1.2** of BS G 231.

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

7.9.1 Method

Conduct the test in accordance with **6.1.1** 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.

7.9.2 Requirements

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

7.10 Test 9. Strand plating continuity

7.10.1 Method

Take three strands, not less than 150 mm in length, from an uninsulated conductor previously straightened by hand. Degrease the strands without damaging them, then wipe them 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 polysulfide of density 1.142 g/cm^3 at $20 \text{ }^\circ\text{C}$, then wash them 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 $20 \text{ }^\circ\text{C}$ and then wash them carefully in distilled water. Examine the strands under a magnification of $\times 30$.

7.10.2 Requirement

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

7.11 Test 10. Strand plating adherence

7.11.1 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 them under a magnification of $\times 100$.

7.11.2 Requirement

The plating shall not exhibit any detachment or cracks.

7.12 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 conform to BS G 231.

NOTE The thickness of tin plating does not have to be checked.

7.13 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 conform to the individual cable specification.

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

7.14 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 conform to the individual cable specification.

7.15 Test 14. Solderability**7.15.1 Test 14(a). Method¹⁾ (not applicable to size 10 and larger)****7.15.1.1 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.

7.15.1.2 Apparatus**7.15.1.2.1 General**

The apparatus comprising a balance, transducer, chart recorder and solder bath shall conform to the following characteristics.

7.15.1.2.2 Balance, having a spring system of stiffness such that a load of 10^{-2} N shall cause a vertical displacement of the suspended specimen of not more than 0.1 mm.

¹⁾ 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 conform to it.

7.15.1.2.3 *Transducer*

7.15.1.2.4 *Chart recorder*, having the following characteristics.

- a) The chart recorder shall have a response time such that its return to zero on removal of a maximum load is within 0.3 s, with an overshoot corresponding to not more than 1 % of the maximum load.
- b) The chart recorder shall have a number of sensitivity settings, the most sensitive of which shall correspond to at least a maximum deflection from centre when a 200 mg mass is suspended from the specimen holder.
- c) The chart speed shall be not less than 10 mm/s.
- d) The electrical and mechanical noise recorded in the trace shall not exceed the equivalent of $4 \cdot 10^{-5}$ N peak to peak.
- e) 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 %.

7.15.1.2.5 *Solder bath*, having the following characteristics.

- a) 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.
- b) The bath temperature shall be controllable to an accuracy of ± 1.5 % up to a maximum of 350 °C.
- c) 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 $\pm 0,2$ mm.
- d) The speed of immersion and withdrawal of the specimen shall be (20 ± 5) mm/s.
- e) The dwell time at the maximum immersion depth shall be adjustable.

7.15.1.3 *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.

7.15.1.4 Procedure

Mount the specimen in a 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 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 the specimen. 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 .

7.15.1.5 Requirement

The wetting time shall not exceed the value specified in the individual cable specification.

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

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

7.15.2.1 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. 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 $\times 2$.

7.15.2.2 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.

7.16 Test 15. Conductor strand adhesion**7.16.1 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 “bird-cage” 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.

7.16.2 Requirements

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

7.17 Test 16. High voltage

7.17.1 Test 16(a). Immersion

7.17.1.1 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 shall be 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.

7.17.1.2 Requirement

No electrical breakdown of the insulation shall occur.

7.17.2 Test 16(b). Dry spark

7.17.2.1 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, for screened cables, apply a spark test at the voltage specified in the individual cable specification between the metal braid and an electrode on the outside of the cable.

7.17.2.2 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.

7.17.3 Test 16(c). Dry impulse

7.17.3.1 Apparatus

An electrode head, as shown in Figure 2, is required. 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 μ s and shall reach peak value in less than 20 μ s. 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 μ s and 50 μ s. 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.

A peak reading instrument voltmeter shall be connected to the electrode head to indicate 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 (see 7.17.3.2). This meter shall be capable of maintaining calibration for an adequate period, preferably a minimum of one month.

The apparatus shall have guides external to the electrode head to provide axial centring of the cable in the chamber when the electrode is in use. 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.

The apparatus shall incorporate 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 M Ω 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.

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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 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 using an oscilloscope with a calibrated and compensated attenuator. The chosen method should have an accuracy of $\pm 2\%$.

7.17.3.2 Procedure

Pass all cable produced at its final reeling or in the stage of manufacture as specified in the individual cable specification through the centring 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.

7.17.3.3 Requirement

Electrical flaws occurring at points along the length of the cable shall be removed by cutting out and discarding at least 300 mm of the cable on each side of the point of failure.

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

7.17.4.1 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 also considered as a core.

7.17.4.2 Requirement

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

7.18 Test 17. Insulation resistance

7.18.1 Method

Immerse the specimens in the solution specified in test 16(a) (see 7.17.1) 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:

$$R_k = \frac{RL}{1\,000} \quad (1)$$

where

R the resistance of the immersed length
 L is the immersed length.

7.18.2 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 $(95 \pm 2)^\circ\text{C}$.

7.19 Test 18. Surface resistance

7.19.1 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: $(20 \pm 5)^\circ\text{C}$

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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.

7.19.2 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 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.

7.20 Test 19. Accelerated ageing

7.20.1 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 mandrels is in compression (see Figure 23). 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 7.25) and the high-voltage immersion test (see 7.17.1).

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

7.20.2 Requirements

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

7.21 Test 20. Thermal endurance

When tested in accordance with annex C, the thermal life and temperature rating shall be as specified in the individual cable specification.

7.22 Test 21. Adherence of insulation on conductor

NOTE This test is not applicable to size 8 and larger

7.22.1 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 it to a gradually increasing tensile force F until it slides within the insulation (see Figure 5). The pulling rate is (100 ± 10) mm/min.

7.22.2 Requirements

Using normally employed stripping tools, it shall be possible to strip a 10 mm length insulation without difficulty from each end of each specimen. On completion of the test described in 7.22.1, the minimum adherence values specified in the individual cable specification shall be met.

7.23 Test 22. Delamination and shrinkage

7.23.1 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.

7.23.2 Requirements

The length of conductor exposed at either end shall be measured and shall not exceed the values specified in the individual cable specification. There shall be no delamination of layers either along the insulation or at its ends.

7.24 Test 23. Delamination and insulation blocking

7.24.1 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.

7.24.2 Requirements

The cable shall unwind freely from the mandrel and the turns shall separate cleanly from each other. There shall be no delamination of layers either along the insulation or at its ends.

7.25 Test 24. Room temperature bend test

7.25.1 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.

7.25.2 Requirement

On completion of this test, the specimen shall withstand the high-voltage immersion test (see 7.17.1). The cable insulation shall exhibit neither crazing nor cracking.

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

7.26.1 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. 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 revolutions/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.

7.26.2 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 7.17.1).

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

7.27.1 Apparatus

A tensile tester (or equivalent apparatus) shall operate in a compression mode and be 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 shall also be equipped with a chamber that allows the test to be performed after stabilization at elevated temperatures, and a low voltage detection circuit shall stop the tester when the edge cuts through the cable insulation and contacts the conductor.

7.27.2 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 it 90° clockwise between each test.

7.27.3 Requirements

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

7.28 Test 27. Notch-propagation resistance

7.28.1 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 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.

7.28.2 Requirement

On removal from the mandrel the specimens shall withstand the high-voltage immersion test (see 7.17.1).

7.29 Test 28. Flammability

7.29.1 Test 28(a). Method 1

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

7.29.1.1 Apparatus

A 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.

7.29.1.2 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 them 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 200 mm mark defines the mid-point of application of the flame (flame centre datum) and the 600 mm provides a datum point for measurement after test.

7.29.1.3 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 cone²⁾. 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.

7.29.1.4 Requirements

During the test no flaming particles shall fall from the specimen and after the source of flame is removed the cable shall conform to the following.

- a) It shall cease to burn within 3 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 conform to the extinguishing time and the total charred length specified.

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.

7.29.2 Test 28(b) Method 2

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

7.29.2.1 Method

Carry out the test in a chamber similar to that used in 7.29.1, 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.

²⁾ For initial setting-up purposes an overall flame height of approximately 75 mm may be found suitable.

7.29.2.2 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.)

7.30 Test 29. Resistance to fluids

WARNING NOTE. Some test fluids may have a critical flash point temperature. Testing should always be undertaken in a bomb calorimeter if that temperature is exceeded. Some test fluids may themselves, or in combination with the specimen, be toxic and it is recommended that the tests should be performed within a fume cupboard.

7.30.1 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 1 with the ends 150 mm above the surface of the fluid and maintain at the temperature specified in Table 1 for not less than 20 h. Remove the specimens from the fluid and allow them to cool at room temperature in free air for 1 h.

7.30.2 Requirements

On completion of the test the cable shall conform to the following:

- a) there shall be no crazing or delamination of the insulation and covering;
- b) marking shall remain legible;
- c) all colour shall remain recognizable;
- d) variation of the overall diameter shall not exceed 5 %. Each specimen shall withstand the room temperature bend test (see 7.25) and the high-voltage immersion test (see 7.17.1).

NOTE The Approving Authority may require cables to be tested in additional fluids to those specified in Table 1.

Table 1 — List of test fluids

Contaminant fluid group		Test fluid	Test temperature (± 2 °C)
Fuels	Kerosene (turbine)	BS 903-A16 (ISO 1817) test liquid F	70 ^{a)}
	Gasoline (piston engine)	BS 903-A16 (ISO 1817) test liquid B	40 ^{a)}
Hydraulic fluids	Mineral oil based	NATO H-520; (OM-18) ^{b)}	70
	Phosphate ester based (synthetic)	BS 903-A16 (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)}
De-icing and anti-freeze fluids		Kilfrost ABC, DTD 900/4907	50
Sullage		(4 \pm 0.1) % Formaldehyde plus (1 \pm 0.1) % o-Cresol (general purpose reagent) in water	23
^{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.			

NOTE For information on the availability of the liquids specified in this table, write to BSI Customer Services, 389 Chiswick High Road, London W4 4AL.

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

7.31.1 Apparatus (see figure 10)

7.31.1.1 Device, designed to abrade the surface of the insulation parallel to the longitudinal axis of the cable over a length of (10 \pm 1) mm at a frequency of (55 \pm 5) cycles/min.

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

7.31.2 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 it through an angle of 90°, always in the same direction.

7.31.3 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.

7.32 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.

7.32.1 Introduction

The purpose of this test is to check that there is no smoke emission at an overload level raising the conductor to a temperature T_1 and that, at a further overload raising this conductor to a temperature T_2 , neither ignition nor destruction of the insulation occurs. Temperatures T_1 and T_2 are specified in the individual cable specification.

7.32.2 Method

Carry out the test in still air at an ambient temperature of $(20 \pm 5)^\circ\text{C}$. Suspend a cable specimen, approximately 5 m in length, so that at least the central 3 m section is horizontal and unsupported. Suspend a weight from one end of the cable in order that no sagging will occur throughout the test. Apply an electric current to the conductor and measure the voltage drop over the central 3 m portion.

NOTE A matt black or a black and white horizontally-striped background should be used to identify the appearance of any smoke.

From the current and voltage values, calculate the resistance of the wire conductor R_t . The temperature T (in $^\circ\text{C}$) of the wire conductor is determined from the change in resistance, using the following formula:

$$T = 20 + 250 \left(\frac{R_t}{R} - 1 \right) \quad (2)$$

where

R_t is the resistance (in Ω) of the conductor at temperature T ;

R is the resistance (in Ω) of the conductor at 20°C ;

T is the temperature of the conductor (in $^\circ\text{C}$).

Adjust the current so that the conductor temperature stabilizes at the temperature T_1 . Maintain this temperature for 30 min. After this period raise the current so that the conductor temperature reaches T_2 . Maintain this temperature for 15 min.

7.32.3 Requirements

At temperature T_1 there shall be no indication of visible smoke, or smell or appreciable colour change.

At temperature T_2 there shall be no indication of:

- a) spontaneous combustion;
- b) splitting of the insulation;
- c) baring of the conductor.

After cooling from temperature T_2 to ambient temperature there shall be no indication of separation and/or embrittlement of the insulation.

7.33 Test 32. Delamination (not applicable to size 8 and larger)

7.33.1 Apparatus

Obtain two torsion clamps, axially aligned face to face and spaced at a distance of approximately 250 mm such that the specimen is held taut. One of the clamps shall be capable of rotation through 360° on either side of the specimen centre line, so as to impart torsion and torsion release effects to the taut specimen. The other clamp shall be capable of moving parallel to the specimen centre line to keep it taut by means of the force specified in the individual cable specification; it shall be fixed so that it cannot rotate .

7.33.2 Procedure

Age the specimen, measuring approximately 300 mm in length, for 50 h in a chamber raised to temperature T_2 as specified in the individual cable specification. After cooling to room temperature, place the specimen in the torsion clamps, the length between clamps being (250 ± 6) mm and hold taut under the force specified in the individual cable specification.

NOTE 1 The ends of the specimen can be protected from accidental damage by binding them with tape or by other means, provided that no part of the torque is absorbed by the protection.

Place the assembly in a chamber raised to temperature T_1 as specified in the individual cable specification and carry out the torsion tests at this temperature. Complete 100 torsion cycles in this manner at the rate of 5 cycles/min to 6 cycles/min.

NOTE 2 Each torsion cycle consists of rotating the specimen through 360° in one direction and then 720° in the opposite direction and again through 360° in the original direction which returns the specimen to the zero position.

Remove the equipment from the heating chamber, cool to room temperature and then remove the specimen from the clamps. Examine the specimens by normal corrected vision.

7.33.3 Requirements

Any delamination of the layers, either along the insulation or at the ends shall be considered as a defect. Each specimen shall then withstand the high-voltage immersion test described in 7.17.1 except that the specimen length shall be approximately 300 mm, and the ends of the 'U' bend of radius 50 mm protrude above the level of the solution by 50 mm.

7.34 Test 33. Fire resistance

Carry out the test in accordance with 3.13 of BS 3G 100-2-3:1973.

7.35 Test 34. Air-excluded ageing (applicable to silicone rubber insulations only)

7.35.1 Method

Place the specimen, measuring 100 mm in length, in a metal tube measuring 120 mm internal length and of internal diameter 30 mm. Seal the ends of the metal tube using a screw cap at one end and a soldered plug at the other.

Place the sealed tube in an oven at (180 ± 5) °C for 336 h. At the end of this time, remove the metal tube from the oven and allow to return to room temperature. Remove the specimen from the metal tube and bend into a 'U' loop having a diameter six times the specified overall diameter of the cable.

7.35.2 Requirements

The cable coverings shall show no signs of cracking, splitting or reversion.

7.36 Test 35. Climatic

Carry out the test in accordance with the individual cable specification.

7.37 Test 36. Identification durability (not applicable to size 8 and larger)

7.37.1 Method

Clamp the specimen into the scrape abrasion test rig (see Figure 10) with the printed identification uppermost. Use an abrading edge of (0.65 ± 0.01) mm in diameter. The length of stroke and speed of the rubbing member are the same as for the scrape abrasion test (see 7.31). Conduct the test at the temperature stated in the individual cable specification. Monitor the test throughout and as soon as a line is scored through the printing, stop the machine and record the number of cycles.

7.37.2 Requirements

The total force applied to the rubbing member and the number of cycles recorded shall be as specified in the individual cable specification.

7.38 Test 37. Cable to cable abrasion

7.38.1 Method

Mount the specimens in a test rig as shown in Figure 11. Activate the movable member of the fixture by a vibration test exciter or other suitable device. Adjust the exciter to produce a sinusoidal mode at 10 cycles/s and a total displacement of 6.35 mm. Adjust the tension by attaching a 0.5 kg, 1.0 kg and 2.5 kg mass to the free end of the cable, an unused specimen being used for each mass. Install an electrical detector to indicate when both conductors are exposed.

7.38.2 Requirement

The insulation shall withstand the number of cycles as specified in the individual cable specification.

7.39 Test 38. Pliability

7.39.1 Test 38(a). Method 1 (not applicable to size 8 and larger)

NOTE This test measures the ease with which the cable bends and accepts a permanent set.

7.39.1.1 Preparation of specimens

Cut the cable specimens, each approximately 200 mm long, consecutively from the same coil. Suspend each specimen vertically for 24 h in an oven with a mass attached to its free end. The applied mass and oven temperature are as stated in the individual cable specification. Immediately after removal from the oven, store the specimens at the temperature and relative humidity for the period of time specified in the individual cable specification.

7.39.1.2 Procedure

Test the specimens using the rig shown in Figure 12, the diameter of the mandrel in the test rig being that specified in the individual cable specification. Gradually apply a mass to the cable at the position shown in Figure 12 sufficient to bend the cable downwards through $(90 + 0, -1)$. Ensure that the specimen remains in this position for 5 min and record the mass. After this time, remove the mass and allow the specimen to recoil towards its original position. At a time 5 min after removal of the mass, record the recoil distance.

7.39.1.3 Requirements

The mass required to bend the cable through $(90 + 0, -1)^\circ$ and the recoil distance shall not exceed the values stated in the individual cable specification.

On completion of this test, the specimen shall withstand the high-voltage immersion test (see 7.17.1).

7.39.2 Test 38(b). Method 2 (not applicable to size 8 and larger)

NOTE This test measures the ease with which a cable bends into an arc.

7.39.2.1 Apparatus

7.39.2.1.1 Test rig, as shown in Figure 13, comprising:

- a) a sensitive balance;
- b) a stiff wire loop 150 mm long, and balance mass;
- c) a cable clamp that is capable of rotation, together with a means of measuring this rotation.

7.39.2.1.2 Two copper wires, approximately 0.6 mm diameter

7.39.2.2 Preparation of test specimens

Cut the cable specimens, each approximately 200 mm long, consecutively from the same coil. Lay the specimens on a flat surface so that the natural set of the cable can be seen and draw an ink line along the cable on the outer periphery. Suspend each specimen vertically in an oven at the temperature and for the period specified in the individual cable specification, each specimen having a mass, as specified therein, attached to the free end. Immediately after removal from the oven, store the specimens at 75 % relative humidity and (20 ± 5) °C for a period of 24 h.

7.39.2.3 Procedure

Loop the two copper wires around the cable, 12 mm from one end, and twist them together. Place the twisted ends of the wires at right angles to, and in the same plane as, the natural bend of the cable. Straighten the cable and clamp in the test rig, with the ink line underneath, so that the twisted wires are 75 mm from the clamp edge. With the balance on its knife edges and the balance pointer at zero, adjust the cable to touch the wire loop and record the protractor reading. Rotate the cable clear of the wire loop. Place a mass on the scale pan and bring down the cable on to the wire loop. Rotate the clamp slowly and record the rotation reading immediately the balance pointer reads zero. Immediately lift the specimen from the wire loop. Repeat the cycle of operations with an increased mass on the scale pan, so that a graph of load against angle of rotation can be plotted using the average results for three specimens.

7.39.2.4 Requirements

The rotation in degrees to counter-balance given mass, obtained from the smooth curve, shall be not less than that stated in the individual cable specification.

7.40 Test 39. Colour fastness to light

7.40.1 Method

Subject a sample of cable to the test for colour fastness to artificial light in accordance with BS 2782:Method 540B, with the following provisions:

- a) ensure that the temperature of the test enclosure does not exceed 40 °C;
- b) exercise no humidity control;
- c) ensure that any printing faces the light source.

Record the number of the blue-dyed wool standard that corresponds to the first detectable fading of the cable specimen, together with any tendency of the printing to become illegible.

7.40.2 Requirements

Any printing shall remain legible, and the colour shall be recognizable as the untested cable colour.

The blue-dyed wool standard that corresponds to the first detectable fading of the cable specimen shall not be less than blue standard no. 5.

7.41 Test 40. Current rating

7.41.1 General

Current rating tests shall be carried out on all new designs of cable and each cable manufacturer shall show conformance to the current rating data³⁾ in the individual cable specification.

NOTE The ratings in the individual cable specifications are based on commercial frequencies. If the cables are used to the limit of the maximum frequency declared, corrections for skin effect may be necessary.

Current ratings shall cover the long term and the short term and shall be presented for each size of cable in the form of a stepped current versus time curve to log/log scales.

³⁾ For the cable manufacturer, these figures should be regarded as minimal. For the cable user, these figures should be regarded as maxima.

Before the commencement of the tests, measure the conductor resistance at 20 °C. When the current ratings have been established, correct the measured values for maximum specified conductor resistance at 20 °C by multiplying by

$$\sqrt{(R/R_{max})} \quad (3)$$

where

R is the measured value;

R_{max} is the specified maximum conductor resistance at 20 °C. Current ratings shall be determined by test for the largest and the smallest of the sizes in the individual cable specification, and for alternate intermediate sizes.

NOTE 1 Ratings for sizes not tested, provided the conductor material is the same, may be obtained by interpolation.

NOTE 2 A formula is specified in the individual cable specifications to modify the ratings when cables are used in an ambient temperature different from that upon which the tests were based.

This formula normally provides a de-rating factor where the cable is used in an ambient temperature within less than 40 °C of its maximum conductor working temperature. It should be used with caution as an up-rating factor where the ambient temperature is more than 40 °C below the maximum conductor temperature, and should not normally be used where the difference between the two temperatures is greater than 60 °C.

7.41.2 Long-term ratings

Long-term current ratings shall be those at which, for the cable construction specified and for the temperature rise allowed above the stated ambient temperature, the maximum stabilized conductor temperature permitted by the individual cable specification is not exceeded. Long-term current ratings shall be determined for the following periods:

- a) continuous;
- b) 5 min \pm 5 s;
- c) 1 min \pm 2 s; and for each of the following conditions:
- d) single cable in free air;
- e) three-bunched cables of the same size and carrying the same current in free air.

NOTE Larger bunches are not considered because in an actual aircraft bundle some cables will be unloaded or only lightly loaded and will act as a heat sink.

7.41.3 *Short-term rating*

Short-term current ratings shall be those for which the maximum temperature reached by the conductor is just below that at which there is evidence of damage to the cable. Short-term current ratings shall be determined for the following periods:

- a) (0.35 ± 0.025) s;
- b) (2.0 ± 0.2) s;
- c) (10.0 ± 0.5) s;
- d) (60.0 ± 2.0) s; and for each of the following conditions:
- e) single cable in free air;
- f) three-bunched cables of the same size and carrying the same current in free air.

7.41.4 *Apparatus*

NOTE Apparatus is shown diagrammatically in Figure 14.

7.41.4.1 *Oven*, of large volume relative to the cable specimens, and capable of being set to any temperature between 20 °C and the maximum specified for the individual cable, with means, where necessary, of circulating the air inside the oven and of venting fumes safely to the outer atmosphere. The air surrounding the cable shall be static during the application of the current.

7.41.4.2 *Constant current, 50 Hz to 60 Hz a.c. or d.c. power supply*, capable of loading the largest cables for the shortest times necessary, together with a switching mechanism capable of switching the energizing currents with the least delay time.

7.41.4.3 *Means of accurately monitoring the temperature within the oven.*

7.41.4.4 *Thermocouple*, for measuring the temperature of the conductor of the cable specimens, with a response time of less than 200 ms and a wire diameter of approximately 0.15 mm. The thermal mass of the couple and associated leads shall be kept to a practical minimum in order to reduce heat sink effects.

The thermocouple is placed under the cable insulation against the conductor. The conductor temperature is measured on the same time-base as voltage and current. Alternatively, the conductor temperature may be derived from the change of resistance calculated from the voltage drop across the specimen.

NOTE The latter method is usually more accurate on smaller cable sizes whereas the use of a thermocouple is usually more accurate on size 12 and larger.

7.41.4.5 Measuring and recording equipment, to monitor voltage and current accurately, together with a time-base accurate to ± 10 ms.

The voltage is measured at the pick-off points shown in Figure 14. Current and voltage drop is measured throughout the test and recorded against a time-base. For the cable manufacturer, these figures should be regarded as minima. For the cable user, these figures should be regarded as maxima.

7.41.5 Preparation of test specimens

Cable specimens are of such a length that a temperature gradient is not present at the ends, and in any case the specimens are not less than 1 m in length. They are supported horizontally in the oven without subjecting them to tension. For the purpose of rating three-bunched cables, tie the bunch of cables with a lacing cord at intervals of approximately 75 mm.

7.41.6 Procedure for long-term rating tests

NOTE As these tests are non-destructive, the same cable specimens may be used for successive time-ratings for a given size of particular cable.

Pass the test current through the specimen for the time specified in **7.41.2** such that the maximum stabilized conductor temperature specified in the individual cable specification is not exceeded. Determine the test current empirically for the given size of cable and for the specified time period. In the case of continuous ratings, pass the test current through the specimen until the conductor temperature stabilizes at the maximum stabilized conductor temperature.

7.41.7 Requirement

The current shall be not less than the value specified in the individual cable specification.

7.41.8 Procedure for short-term rating tests

NOTE Separate groups of specimens should be used for different time-ratings and, additionally, for any one time-rating, of each size of cable.

Pass the test current through each specimen nine times with sufficient time between tests to allow the specimen to cool to ambient temperature. Determine empirically the approximate test current necessary to produce the onset of damage, after nine applications of the test current for the given size of cable for the time specified in **7.41.3**. Carry out further tests, each of nine applications of the test current, on separate specimens of the same size of cable, with a spread of current magnitudes just below the value already shown to produce damage until the point of no damage is reached. Carry out a further test, also of nine applications of the test current, at the no-damage level to confirm this current. If no damage occurs during the confirmatory test, this current is the declared rating, for the specified time period for that particular size and type of cable. If damage occurs during the confirmatory test, further tests are made, at reduced currents, until the foregoing condition is met.

Use the same procedure to determine the ratings for the other specified times for that size of the particular cable, and similarly again for the other sizes of the cable.

7.41.9 Requirements

The current shall be not less than the value specified in the individual cable specification. The “no-damage” condition shall be checked by submitting the specimens to the room temperature bend test (see 7.25).

7.42 Test 41. Toxicity

The Approving Authorities interest in toxicity has been recognized but no technically meaningful test has been found to date which has proved applicable to this standard.

NOTE Pending the development of such a test, the materials from which cables are manufactured should present the minimum hazard from toxic fumes and smoke when submitted to the overload resistance test (see 7.32). Individual cable specifications have defined temperatures T_1 and T_2 for test 31 (see 7.32) at values which determine the resistance to failure at levels which may be deemed to satisfy non-substantive requirements, e.g. materials should not present a smoke or toxicity hazard.

7.43 Test 42. Resistance to wet arc tracking

7.43.1 Preparation of sample

Cut seven lengths of size 20 cable, each approximately 400 mm long, consecutively from one length of cable and strip each of the ends of insulation to permit electrical connection. Clean each length of cable with a clean cloth moistened with propan-2-ol fluid. Damage two of the lengths of cable by inflicting a cut around the total circumference at the mid point of the length, taking care to ensure that the cut penetrates to the conductor around the full circumference and has a width of 0.5 mm to 1.0 mm.

Lay up the seven cables as follows.

- a) Lay the two damaged cables adjacent each other with four others around a centre seventh cable.
- b) Displace the damaged cables longitudinally such that a separation of (10 ± 0.5) mm of undamaged insulation is provided. This is called the test zone.
- c) Ensure that all cables are straight and geometrically parallel and restrained by ties such that they are in continuous contact at least within the test zone.
- d) The tie material should be of a fire retardant type conforming to United States Defense Department Standard Mil-T-43435-B type IV, Finish D size 3.
- e) Position ties (4 ± 1.0) mm away from each side of the test zone and then at 15 mm to 20 mm spacing towards the ends of the specimen as shown in Figure 16.
- f) Number the cables 1 to 7 as shown in Figure 16 such that the faulted cables are number 1 and 6 and the centre cable is number 7. Cables 2, 3, 4, 5 and 7 are designated as Group A and cables 1 and 6 as Group B.

7.43.2 *Electrical connections*

Connect the seven cables of a test sample within a circuit as shown in Figure 15. This will provide a three phase supply to the six outer cables, numbers 1 to 6 of the loom, in an ABC, ABC sequence. Connect the centre cable, No. 7, to neutral (see Figure 16).

Use a three phase supply derived from a rotary machine of not less than 5 kVA rating delivered at 200 V line to line, 400 Hz, within characteristic limits conforming to BS 3G 100-3.

The resistance of the supply feeders between generator and circuit breakers shall be ballasted to give a value of 1 Ω (sensibly non-inductive), the power rating of the cables and resistor shall be such as to withstand electrical short circuits of the load. A rating of not less than 200 W is recommended. Thermal breakers shall conform to specification Mil-C-5809 or equivalent and be rated at 7.5 amps.

Employ an automatic shut down circuit which will remove the three phase input power to the test circuit 10 s after the occurrence of:

- a) any thermal circuit breaker opening; or
- b) any cable becoming open circuit.

Ensure that automatic shut down also inhibits further flow of electrolyte to the sample.

Make provision to manually override the shut down circuit. Connect the ends of cables 1 to 6 which are remote from the input power to 20 watt loads, including the power necessary to supply indicator lamps. Cable No. 7 provides the common neutral for these circuits.

NOTE All cable to load connections should be arranged so as not to be affected by any excess electrolyte flowing down the laid up cables.

7.43.3 *Electrolyte*

Use of solution in distilled or de-ionized water of 2 % by mass of ammonium chloride and (0.1 ± 0.01) % by mass of iso-octylphenolpolyethoxyethanal, the polyethoxy chain to contain approximately 10 ethoxy units (triton x-100). Exceptionally, in the circumstances specified in 7.43.5, the surfactant may be changed to ammonium perfluoroalkane carboxylate, e.g. 3M FC 126 or FC 143, at a concentration of (0.1 ± 0.01) % by mass.

Employ an electrolyte delivery system which provides a constant rate of (100 ± 10) mg/min and dispenses drops from an 18 gauge needle cut-off square.

NOTE The needle wall thickness should be selected such that the specified flow rate will be delivered at approximately 6 drops per minute

7.43.4 Test configuration

Tests shall be performed at an ambient temperature of (23 ± 5) °C.

Support the loom in free air inclined at an angle of 10° to the horizontal with the electrical input connections at the higher end and with the cables forming the test zone uppermost. Position the delivery system so that the electrolyte contacts the loom from a height of (10 ± 2) mm above the uppermost cables in the loom at a point which will position droplets into the upper cut or no more than 2 mm towards the higher end of the specimen. Ensure that drops strike the cable loom at the top centre of the circumference are such that they fall into the crevice between cable numbers 1 and 6 (see Figure 16).

7.43.5 Procedure

NOTE This test can produce severe electrical arcing and associated ejection of molten metal. Precautions should be taken, including the provision of a transparent screen to protect personnel.

Electrically energize the loom and start the flow of electrolyte at a rate of (100 ± 10) mg/min. Particular care should be taken to ensure that the electrolyte flows between the damage sites as evidenced by steaming of the electrolyte and the development of scintillation. Should this not occur and failure of cable to wet be determined then the alternative surfactant described in **7.43.3** may be employed.

Run the test continuously for a period of 8 hours or until an automatic shut down occurs, whichever is the sooner. Following an automatic shutdown adopt the following procedure.

After not less than 3 min nor more than 10 min and with all thermal circuit breakers closed, reapply power to the specimen with the automatic trip circuit deactivated and with no further flow of electrolyte. Apply power for the time necessary for any fault condition to fully develop but do not reset the thermal circuit breakers.

Test a total of five test specimens with a new specimen employed for each test. Prior to each test series check all thermal breakers for correct operation at twice the rated current (15 A) and replace them as necessary.

7.43.6 Test report

The test report shall include details of the following:

- a) the identity of the cable type and details of the origin and release certification. Such certification shall enable traceability of the cable to a production batch.
- b) the characteristics of the power source.
- c) the identity of the 7.5 A thermal circuit breakers and the results of calibration checks at a current of 15 A.
- d) precise details of activity during the test including the operation of individual circuit breakers, observations made when power is reapplied following circuit trip and the timing of all significant events.
- e) video recording of test activity or photographs of test specimens taken after the test showing the extent of damage and indicating to which end of the specimen power was applied.
- f) damage to the insulation including the length of char.
- g) any other requirements defined in the individual cable specification.

7.43.7 Requirements

The individual cable specification shall define the extent of damage which may be accepted to Group A cables as a result of a test series. In any case, neither Group A nor B cables shall ignite to the extent that they would fail the after burn char length requirements of the flammability test (see 7.29.1.4).

7.44 Test 43. Resistance to dry arcing**7.44.1 Introduction**

A primary aim of the method is to present failure effects which are representative of those seen in service when cables are damaged by abrasion such that electrical arcing occurs. The behaviour of cables (wires) which are not involved in the initial arc is of prime concern and the test requires that collateral damage is assessed and quantified. Commentators and experimenters report that whilst failure effects observed using 115 V 400 Hz a.c. are not necessarily the same as those given by 28 V d.c. power, there is no evidence to suggest that a failure could be produced with 28 V d.c. which would escape detection with the 115 V 400 Hz power. Only 115 V 400 Hz supplies are specified in this procedure.

7.44.2 Principle

7.44.2.1 The test requires a reciprocating blade to be placed in contact with two cables having defined insulation damage, that are members of a seven cable test specimen. This test specimen is electrically powered and the aluminium blade provides an electrical path to neutral. Undamaged cables are known as Group A and the two initially damaged cables are known as Group B (see 7.44.4.1).

7.44.2.2 The extent of damage to cables which may be accepted as a result of a test series is specified in the individual cable specification and is usually specified as the number of cables required to survive.

7.44.2.3 A test series will contain a total of 45 Group A initially undamaged cables. A typical specification might require that, after testing, not more than a total of 15 such cables are damaged.

7.44.3 Specimen requirements

Cable to be tested shall be of traceable origin (see 7.44.9.1(a)) and shall satisfactorily withstand the high voltage dielectric test defined in the individual product specification.

7.44.4 Preparation of specimen

7.44.4.1 Cut seven separate lengths of size 20 cable consecutively from one length of cable, and strip each of the ends of insulation to permit electrical connection. Clean each length of cable with a clean cloth moistened with propan-2-ol fluid. Damage two of the lengths of cable by making a cut around the total circumference at the mid point of the length, taking care to ensure that the cut penetrates to the conductor around the full circumference and that the cut has a width of (1 ± 0.3) mm.

7.44.4.2 Lay up the seven cables as follows.

- a) Lay up the two damaged cables (numbers 1 and 2) with the five undamaged cables (numbers 3 to 7) in a six around one configuration as shown in Figure 18, ensuring that the two cuts are aligned.
- b) Ensure that all cables are straight and geometrically parallel, and restrained by ties such that they are in continuous contact for at least a 75 mm continuous length around the mid point of the loom length. This is called the test zone.

NOTE The tie material should be of PTFE glass lacing tape conforming to Mil-T-43435B type IV, finish D size 3.

- c) Position the ties at 15 mm to 20 mm spacing within the test zone, with the insulation damage equidistant between ties.

7.44.4.3 For circuit verification purposes assemble a seven wire bundle as described in 7.44.4.2, replacing cables number 1 and 2 by a single unbroken cable which extends to and from the test zone. This cable will enable a short circuit to be presented across phases A and B.

7.44.5 *Electrical apparatus*

7.44.5.1 Connect the seven cables of the test sample within a circuit as shown in Figure 19. This will provide a three phase supply to the six outer cables, numbers 1 to 6 of the loom, in an ABC, ABC sequence. Connect the centre cable (number 7) to neutral (see Figure 17).

7.44.5.2 Derive the three phase supply from a rotary machine of not less than 15 kV A rating delivered at 200 V line to line, 400 Hz within characteristic limits conforming to BS G 229 (ISO 7137).

7.44.5.3 Ballast the resistance of the supply feeders between generator and circuit breakers to give a value of 1 Ω (sensibly non-inductive), and ensure that the power rating of the cables and resistor are able to withstand the electrical short circuits of the load. A rating of not less than 200 W is recommended. Ensure that the thermal breakers conform to specification Mil-C-5809 or equivalent and are rated at 7.5 A.

7.44.5.4 Use an automatic shut down circuit which can, if armed, remove the blade from the specimen and disconnect the three phase input power to the test circuit (10 ± 2) s after either of the following occurs:

- a) any thermal circuit breaker opening; or
- b) any cable becoming open circuit.

Make provision to manually override the individual shut down circuit functions.

7.44.5.5 Connect each end of cables number 1 to 6 which are remote from the input power to 20 W loads, including the power necessary to supply indicator lamps. The common neutral for these circuits is provided by cable number 7 as shown in Figure 17.

7.44.6 Mechanical apparatus

Construct an apparatus (shown diagrammatically in Figure 20) which includes the following minimum provisions:

- a) a lightweight, freely pivoting test fixture to hold the blade at a 90° angle to the specimen and to exert an adjustable force on the specimen;
NOTE Generally, a mounting on 50 mm centres will hold the individual wires of the specimen in close proximity.
- b) electrical terminations to provide a ready means of connecting test specimens into the circuit as shown in Figure 21;
- c) an aluminium blade conforming to material specification BS 2L 93 (T6) and Figure 21;
- d) a mechanism to provide an oscillating stroke of (5.5 ± 0.5) mm excursion at a frequency of 30 Hz;
- e) adjustment of the blade carrier to give a downward force at the blade, adjustable between (50 ± 5) g;
- f) a mechanical stop to limit the fall of the oscillating blade to within an accuracy of 0.2 mm measured at the point of contact;
- g) means of separating the blade from the specimen, both manually and automatically;
- h) an electrical connection of the aluminium blade to the neutral of the test power supply;
- i) a transparent enclosure to protect personnel from ejected molten metal.

NOTE Eye protection should be provided, and the work area should be ventilated.

7.44.7 Procedure

NOTE The nature of this procedure is such that video recording or photographs of test activity are necessary for accurate reporting.

7.44.7.1 Mount the verification specimen (see 7.44.4.3) in the test apparatus and connect electrically. Apply power up to a maximum of 15 s and check that only the circuit breakers in phases A or B or both operate. No other generator system protection shall operate. Switch off the power and remove the specimen from the apparatus.

7.44.7.2 Adjust the test apparatus to allow the blade to fall one half of one cable diameter below the point of initial contact with a test specimen positioned as described in 7.44.7.3.

7.44.7.3 Mount the test specimen in the test apparatus such that the blade contact position on the specimen is between clamps positioned approximately 25 mm to each side. Make the electrical connections with cables number 1 and 2 uppermost. Position the test fixture and aluminium blade such that the blade contacts the exposed conductor of cables number 1 and 2 when in the lowered position, and adjust the blade to give a downward load of (50 ± 5) g.

7.44.7.4 Excite the actuating mechanism and with the blade oscillating across the bare conductors, apply electrical power to the specimen.

NOTE 10 s after the detection of electrical failure the blade will be automatically separated from the cable bundle and electrical power will be switched off (see 7.44.5.4).

7.44.7.5 In not less than 3 min nor more than 10 min, and with all thermal circuit breakers closed, reactivate the circuit with the aluminium blade removed and with the automatic trip circuit deactivated. Apply power for the time necessary for any fault condition to fully develop. Do not reset the thermal circuit breakers a second time.

7.44.7.6 Test a total of nine specimens with a new specimen employed for each test.

7.44.7.7 Prior to each test series check all thermal breakers for correct operation at 200 % rated current (15 A) and replace as necessary.

7.44.8 Examination

7.44.8.1 Carefully remove the test specimen from the apparatus and photograph the cable bundle.

7.44.8.2 Examine visually and record the damage to the insulation including the length of char.

7.44.8.3 With minimal mechanical disturbance to the test specimen, carry out the insulation resistance test (see 7.18) in turn for each of the cables which appear to have survived the test.

NOTE In this application, the minimum length of 1 m of cable required by 7.18 is waived.

7.44.8.4 Measure the immersed length of each cable, and calculate the insulation resistance R_k (in Ω) for a 1 km length at (20 ± 2) °C only and record the result for each cable.

7.44.9 Test report

7.44.9.1 The test report shall include details of the following:

- a) identity of the cable type and details of the origin and release certification permitting traceability to a production batch;
- b) characteristics of the power source;
- c) identity of the 7.5 A thermal circuit breakers and the results of calibration checks at a current of 15 A;

NOTE Comparison of cable performance obtained in different test sites may be assisted by the measurement of current flow within the verification specimen (see 7.44.7.1) together with a record of phase voltages.

d) precise details of activity during the test including:

- 1) operation of individual circuit breakers;
- 2) observations made when power is reapplied following circuit trip;
- 3) timing of all significant events;

e) results of the examinations made under 7.44.8;

f) any other requirements defined in the individual cable specification.

7.44.9.2 Include a video recording of the test activity and photographs of test specimens taken after test showing the extent of damage and indicating to which end of the specimen power was applied.

7.44.10 Requirements

The individual cable specification shall define the extent of damage which may be accepted to Group A cables as a result of a test series. In any case, neither Group A or B cables shall ignite to the extent that they would fail the after burn char length requirements of the flammability test (see 7.29.1.4).

7.45 Test 44. Tensile strength and elongation of insulation

7.45.1 Equipment

Use a power driven tensile testing machine of such capacity that the load required for the test is between 15 % and 85 % of the maximum of the scale.

The machine shall maintain a constant rate of separation of the specimen jaws during the test. The jaw grips shall be of the axially self-aligning type. They shall also be of mechanically self-tightening design or of the air pressure clamping type such that the specimen is gripped without slipping but is not damaged. The machine shall be equipped with a means of measuring and recording the load applied to the specimen and a means of measuring and recording the distance between the bench marks on the specimen as the specimen is stretched.

7.45.2 Specimen preparation

Each test specimen shall be an undamaged tube of material approximately 100 mm in length, obtained by careful removal of the conductor from a length of insulated cable. Where several layers are involved they shall be pulled separately or together as indicated in the individual cable specification.

Fiducial marks for the purpose of measuring elongation shall be placed on each specimen. The marks shall be equidistant from the centre of the specimen and perpendicular to its long axis. The marks shall be (20 ± 0.25) mm apart.

NOTE The cross-sectional area of the specimen tube may be determined by any convenient means.

7.45.3 Conditioning

Any special conditioning requirements for the specimens shall be stated in the individual cable specification.

7.45.4 Procedure

Set the initial jaw separation to 50.0 mm and place the specimen centrally in the jaws of the test machine. Set the rate of jaw separation to the value stated in the individual cable specification and start the machine.

Note the applied force and distance between the bench marks when rupture occurs.

7.45.5 Calculations

Tensile strength is the force at rupture divided by initial cross-sectional area.

$$\text{Ultimate elongation \% is } \frac{(D - 20)}{20} \times 100 \quad (4)$$

where

D is the distance in millimetres between bench marks at rupture.

7.45.6 Requirements

The values of tensile strength and ultimate elongation shall be not less than those stated in the individual cable specification.

7.46 Test 45. Test for hydrolysis**7.46.1 Method**

Prepare a PTFE mandrel the diameter of which is 10 times (0, -5) % the maximum specified outer diameter of the cable under test. Wind five turns of cable round the mandrel, ensuring that the cable is in close contact with the mandrel and with each adjacent turn for all five turns. Secure the cable in position on the mandrel, for example by tying the two free ends together.

Mount the specimen in a test chamber meeting the requirements of BS 2011-2.1 Ca:1977, at the temperature defined in the individual cable specification and (93 +2, -3) % rh. The specimen shall be heated to the test temperature before the humidity is raised in order to prevent condensation on the specimen. Maintain the specified temperature and humidity in the test chamber for the period specified in the individual cable specification.

Remove the specimen from the test chamber and maintain at (23 ± 2) °C and (50 ± 5) % rh for a minimum of 1 h.

Carry out the room temperature bend test (Test 24).

7.46.2 Requirement

The specimen shall conform to requirements of Test 24.

7.47 Test 46. Test for flexure endurance**7.47.1 Method**

Clamp a minimum of three samples of the test specimen in a fixture as shown in Figure 22. Use the mandrel size and weight listed in Table 2.

Connect each of the specimen conductors to an electrical circuit that will provide an indication when the individual conductors break.

Rotate the cable through a 180° arc at a uniform rate of (18 ± 2) cycles per minute. A cycle is defined as movement from the vertical to 90° left then to 90° right and return to the vertical. Record the number of cycles for the conductor(s) to break.

7.47.2 Examination

Observe the condition of the insulation. Record any instances when the insulation cracks or breaks before the conductor.

Table 2 — Flexure endurance

Cable size (AWG)	Mandrel diameter (mm)	Weight (kg)	Mandrel spacing (mm)
20	25 + 1	0.9 ± 0.025	Specimen diameter

7.47.3 Requirements

The individual cable specification shall define the minimum number of cycles required before the conductor will break.

7.48 Test 47. Sheath durability

7.48.1 Applicability

This test is applicable only to cable types where the sheath (outer coat or top coat) forms part of the insulation.

7.48.2 Method

Select five specimens of size 006 wire for testing. Subject the specimens to test 30, scrape abrasion, using a load as specified in the individual cable specification.

7.48.3 Requirement

The average number of scrape cycles required to abrade through a sample of 5 specimens, exposing the underlying material shall be not less than 25, unless otherwise specified in the individual cable specification.

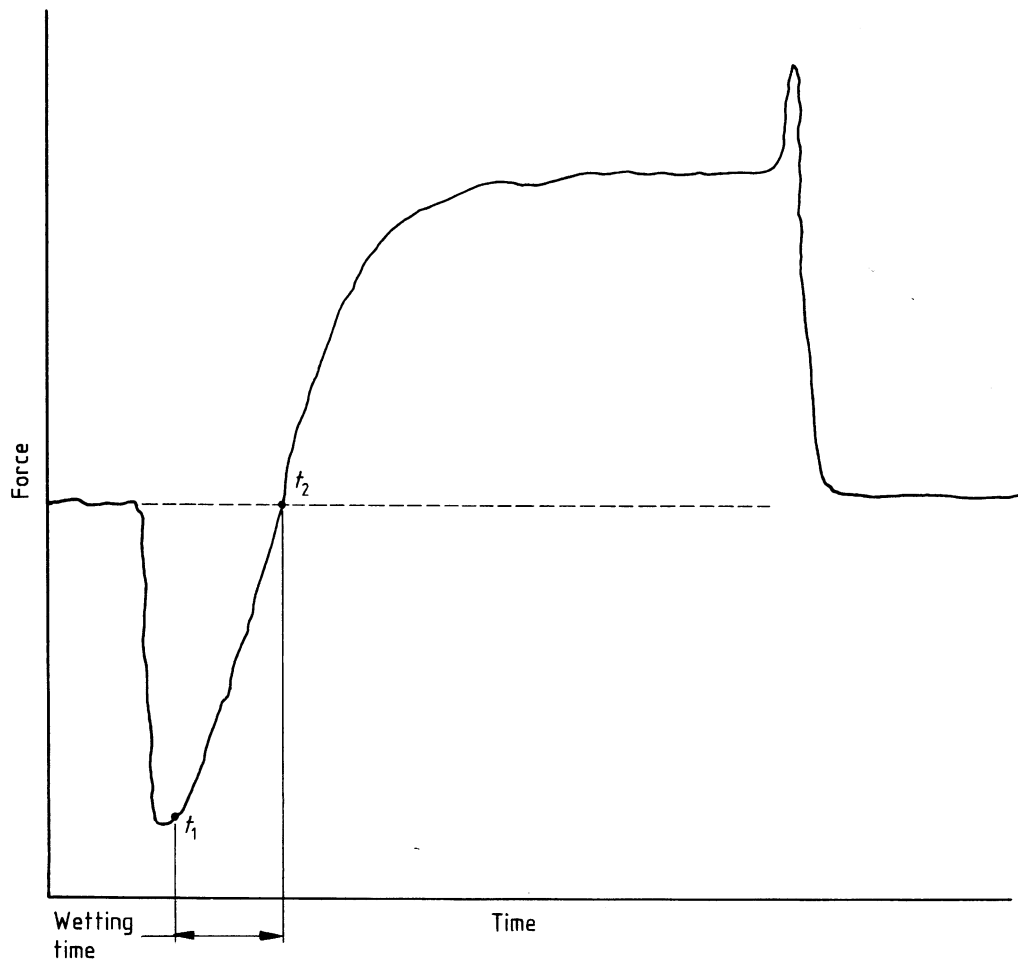


Figure 1 — Typical force/time trace for solderability test

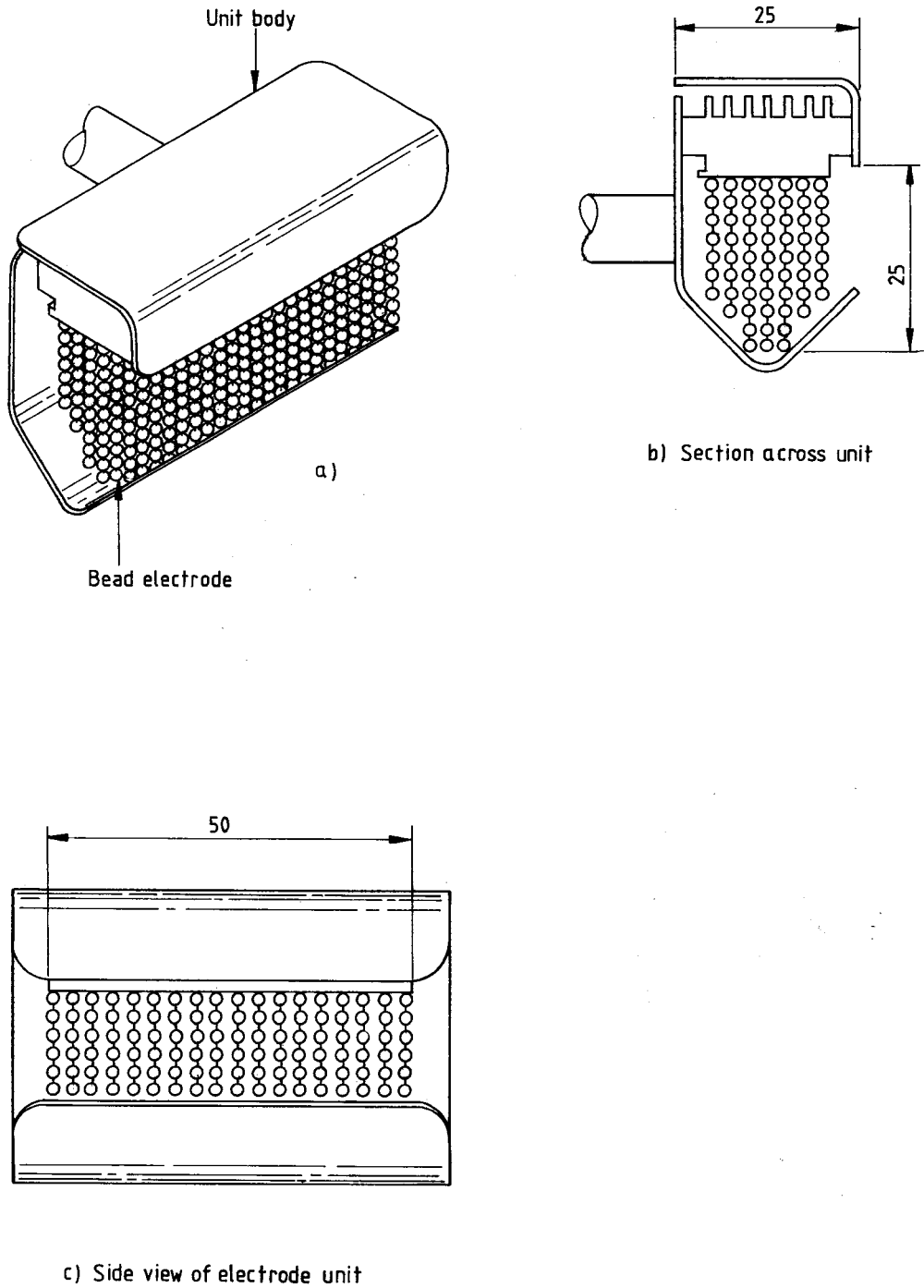


Figure 2 — Miniature bead-chain electrode head for dry impulse test

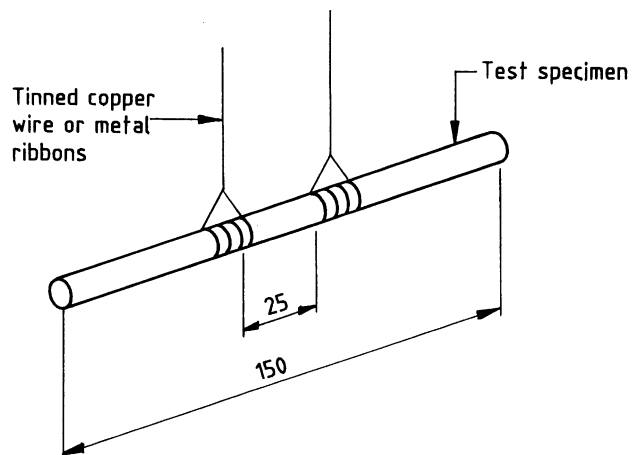


Figure 3 — Preparation of specimen for surface resistance test

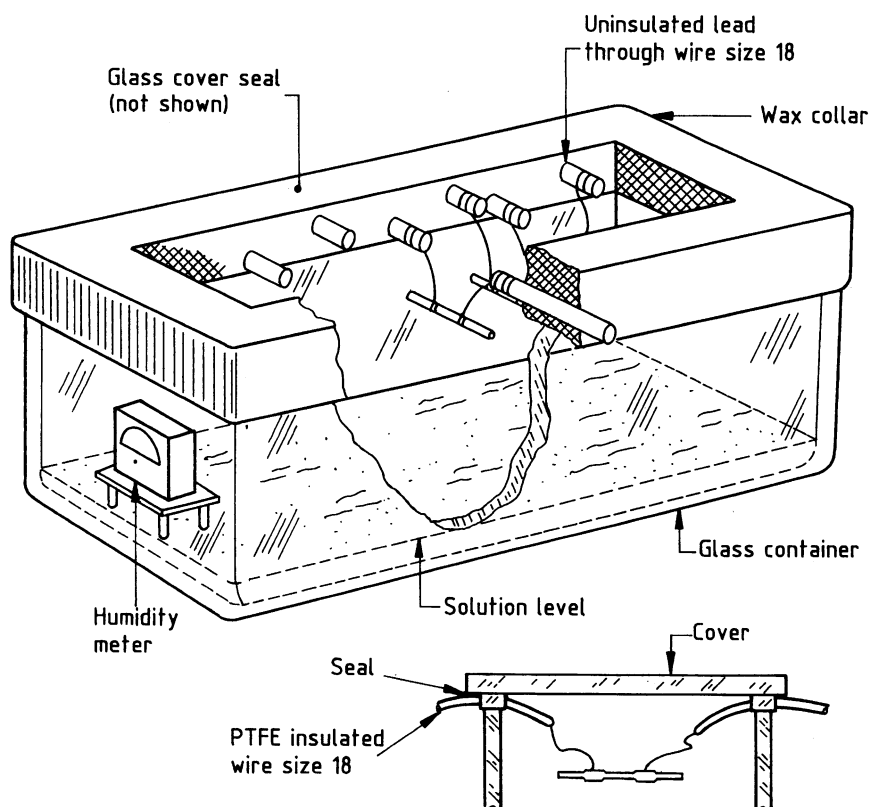


Figure 4 — Chamber for surface resistance test

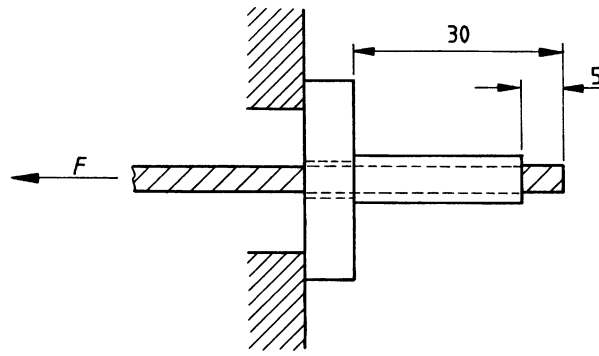
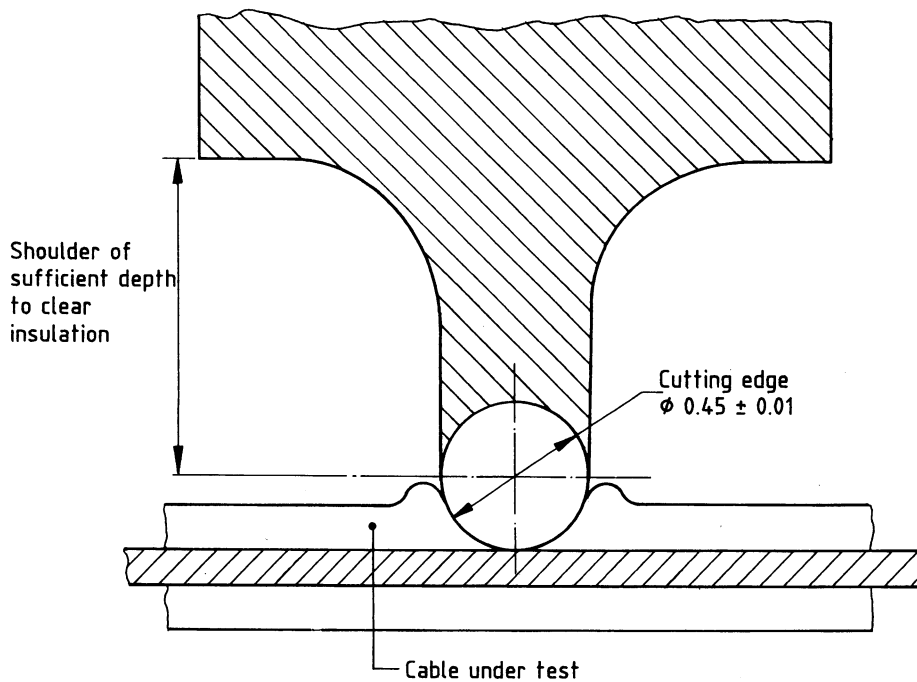


Figure 5 — Adherence of insulation test



NOTE. An example of a cutting edge is a sewing needle, chrome plated, sharps size 11, or a tungsten carbide rod finished with a 350 grit wheel.

Figure 6 — Typical cutting edge for dynamic cut-through test

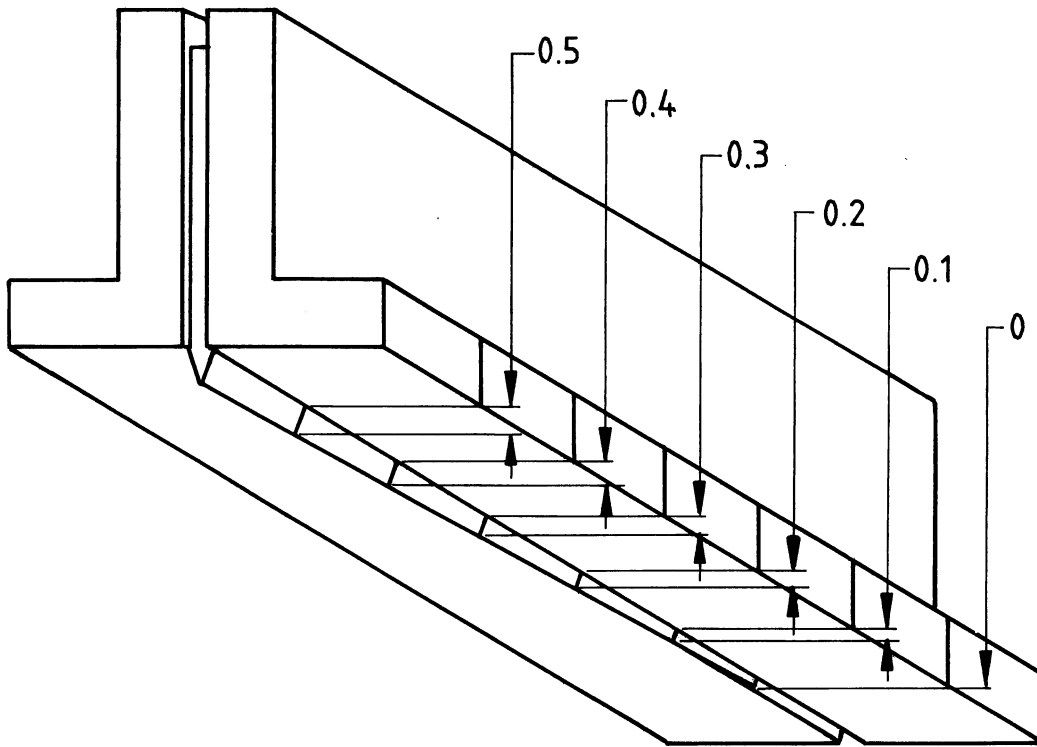


Figure 7 — Notch-propagation test blade holder

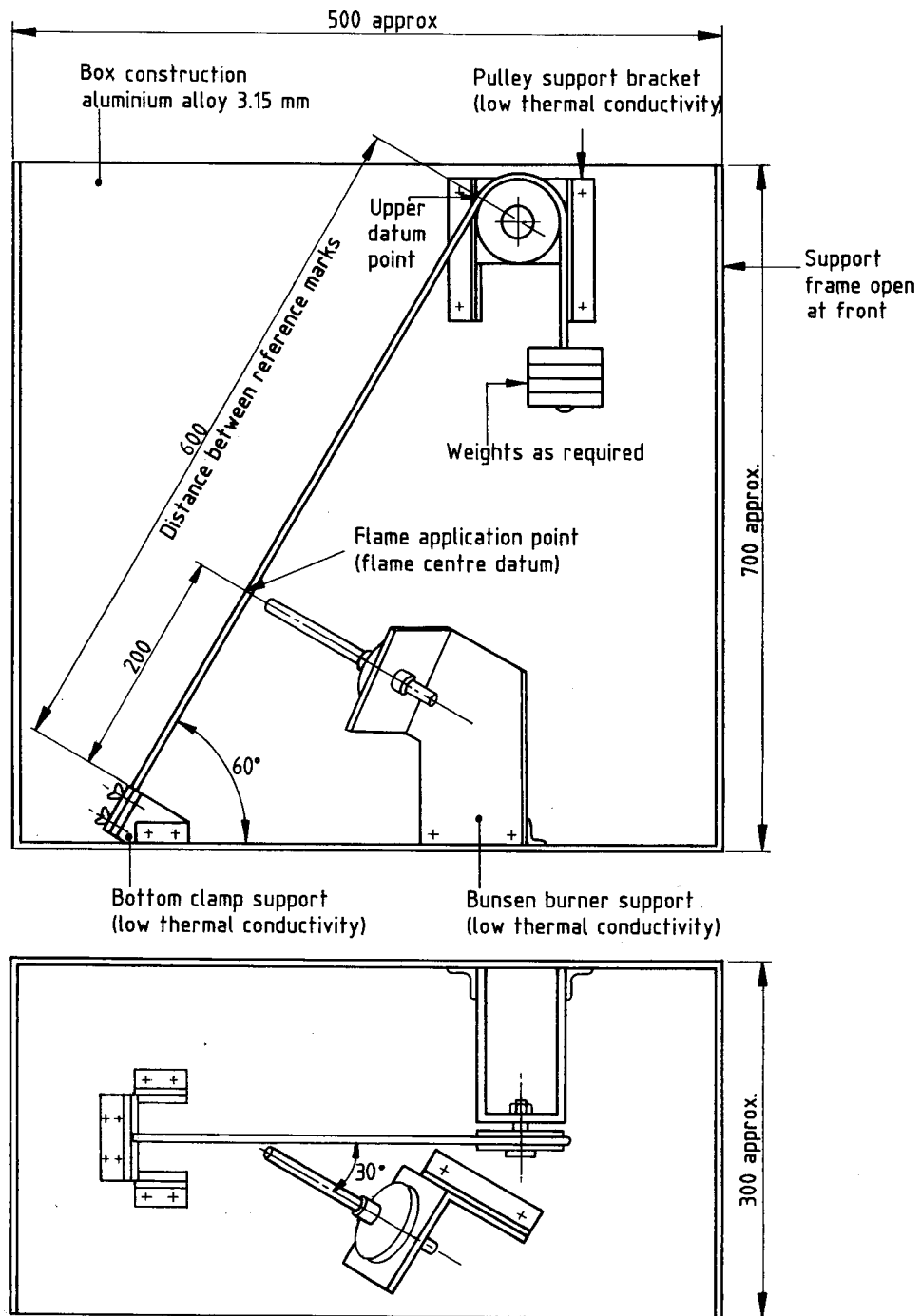


Figure 8 — General arrangement of apparatus for flammability test (method 1)

Dimensions in mm

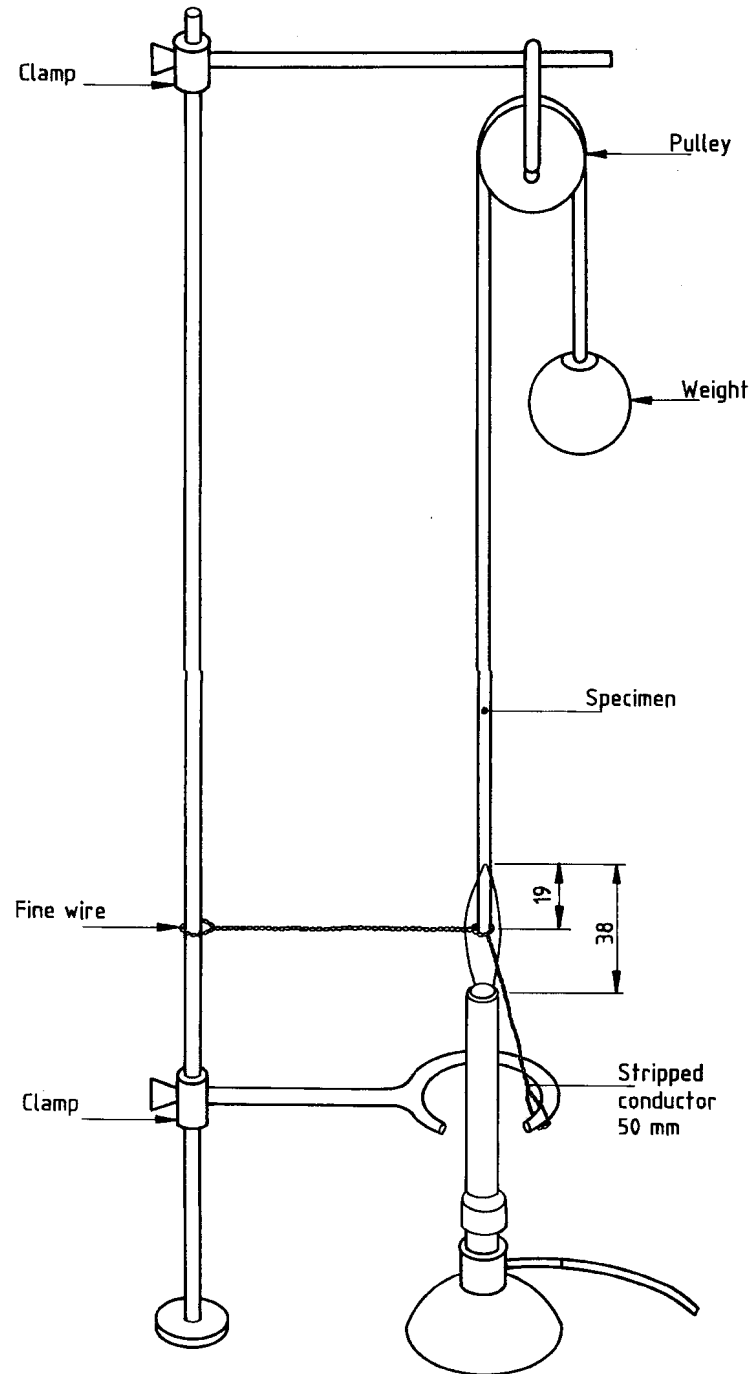
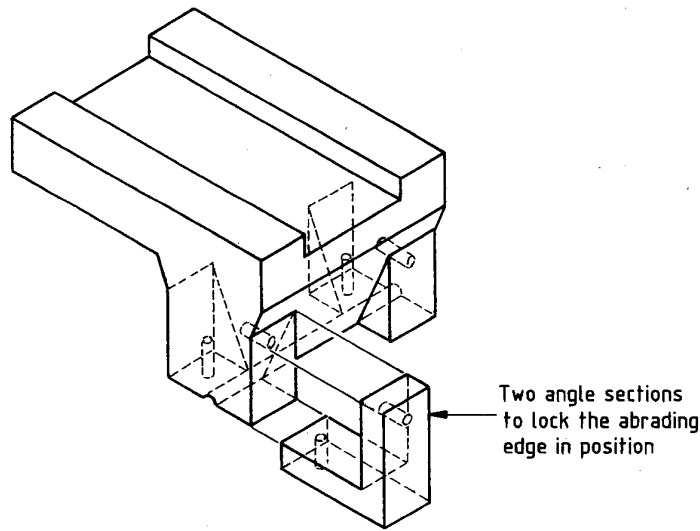
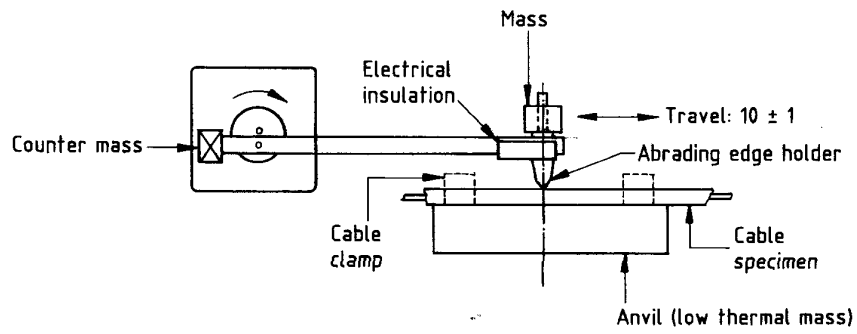
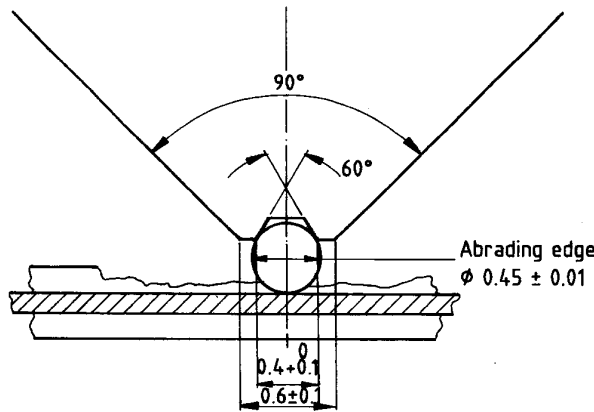


Figure 9 — General arrangement of apparatus for flammability test (method 2)



a) Arrangement for abrading edge holder



b) Profile end section of abrading edge holder

NOTE An example of a cutting edge is a sewing needle, chrome plated, sharps size 11, or a tungsten carbide rod finished with a 350 grit wheel.

Figure 10 — General arrangement for scrape abrasion test

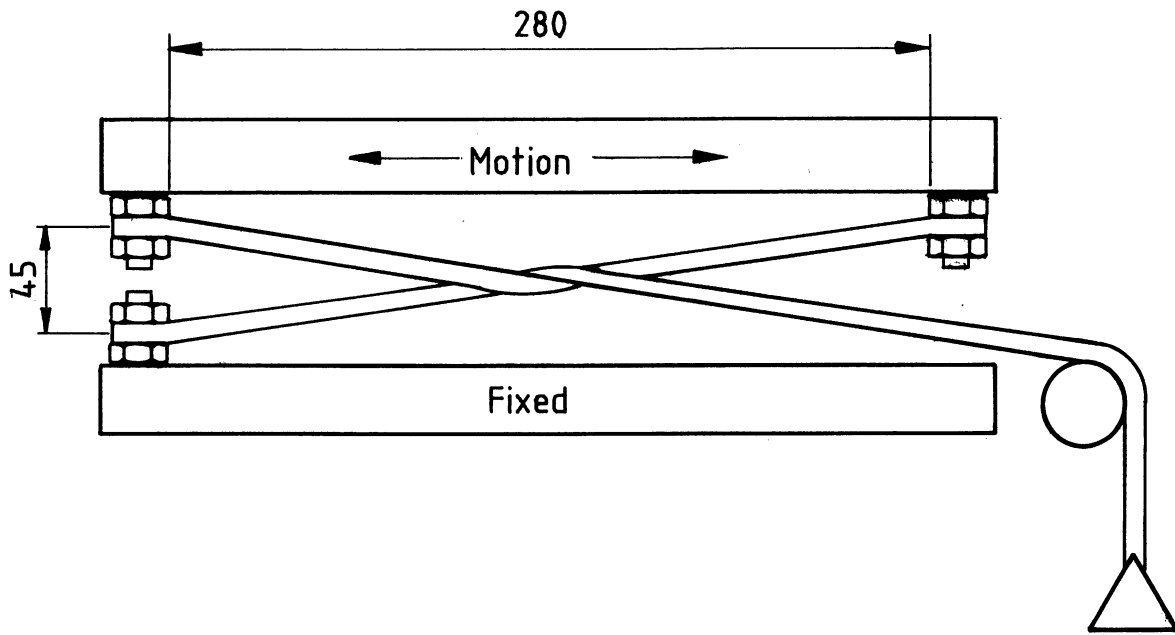
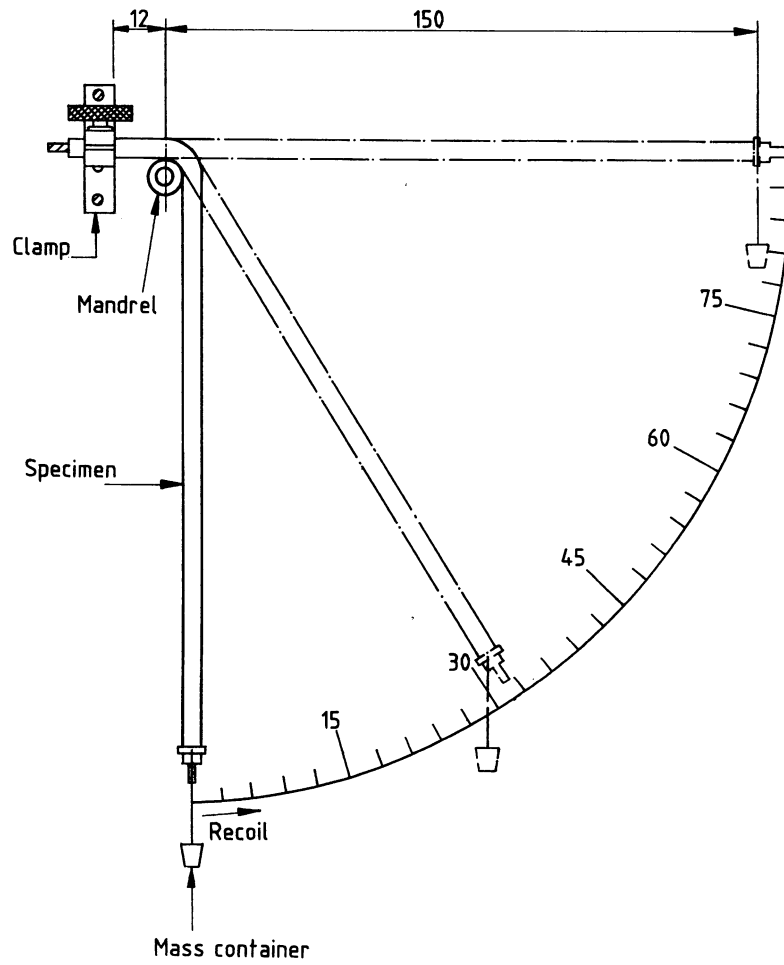


Figure 11 — Abrasion test rig



NOTE Mass added gradually by means of poured lead shot.

Figure 12 — Pliability test rig (method 1)

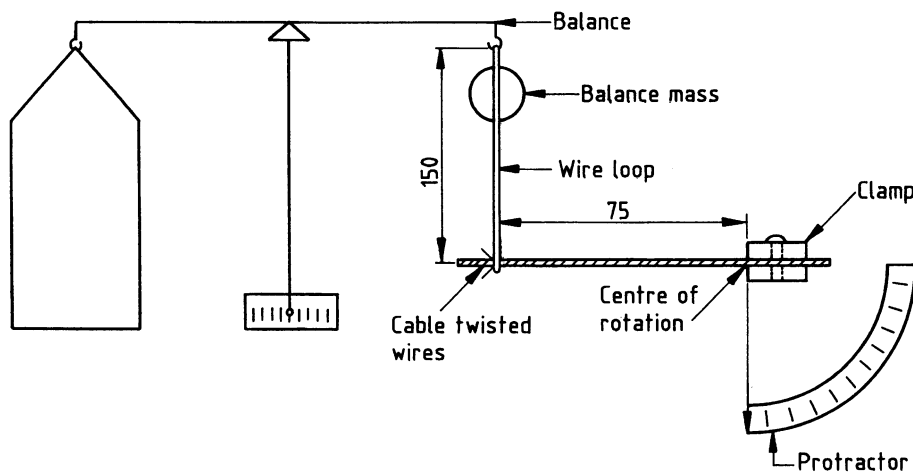


Figure 13 — Pliability test rig (method 2)

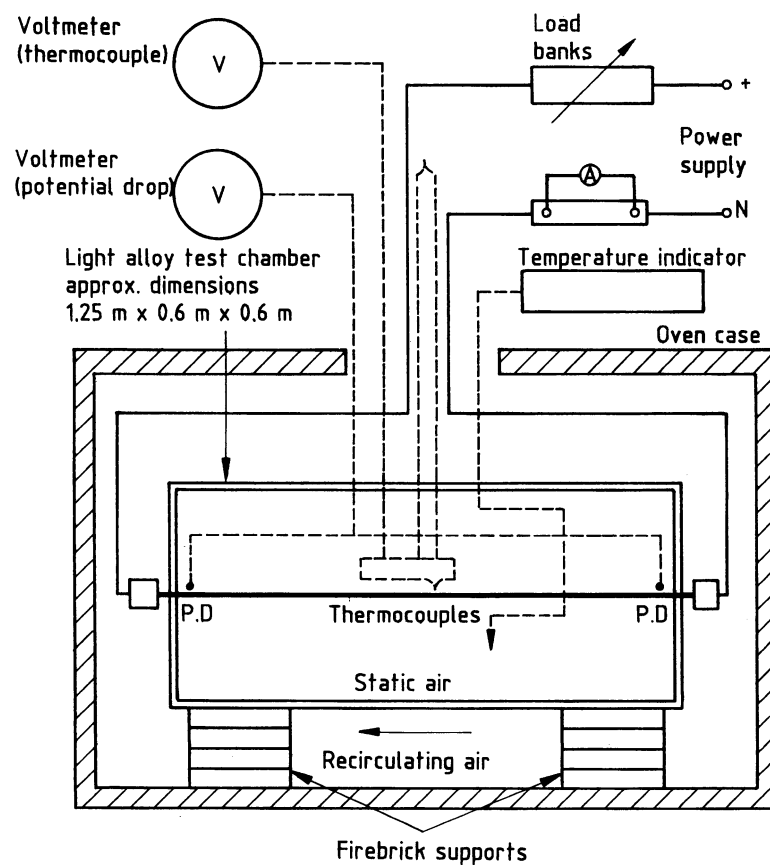


Figure 14 — Oven and associated equipment for current rating tests

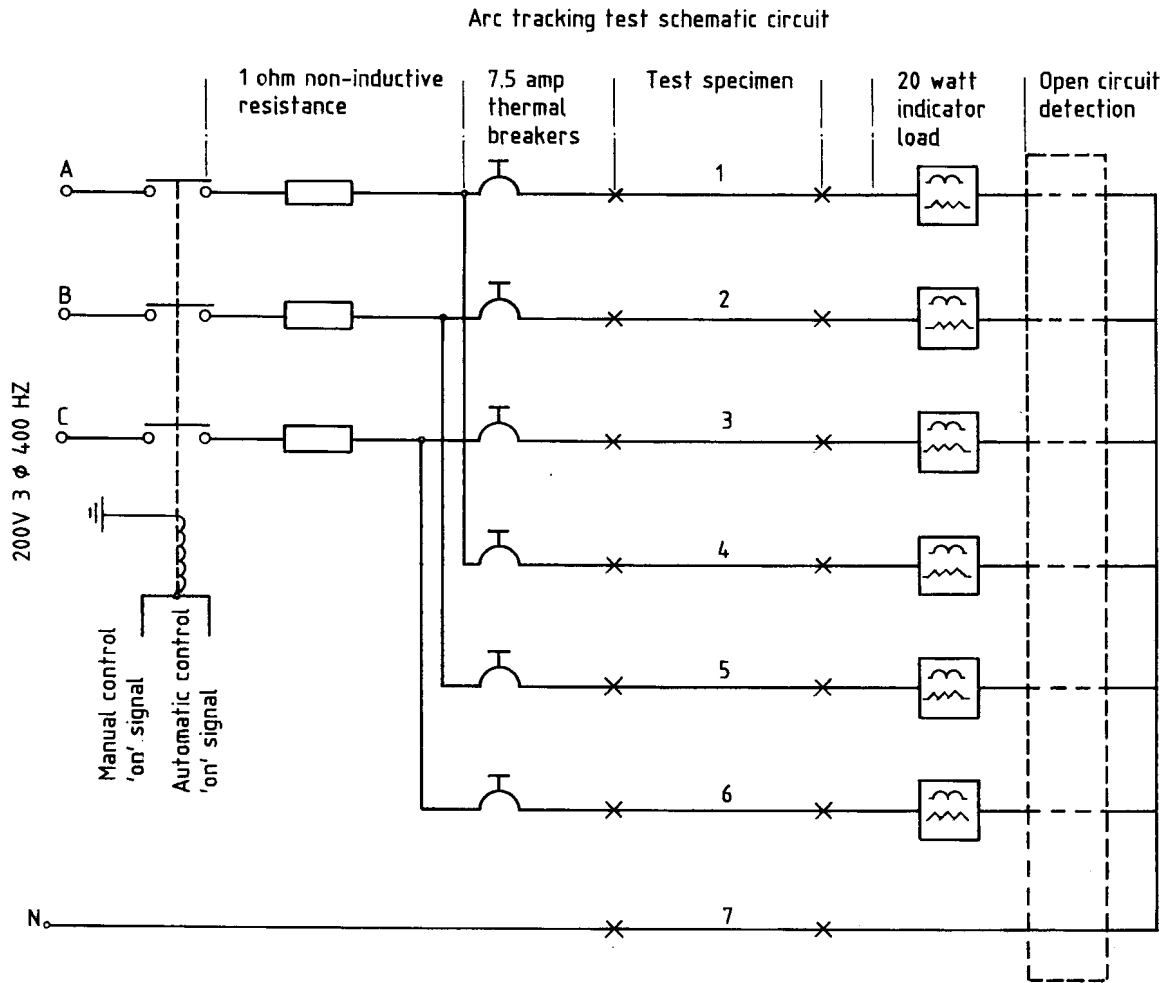


Figure 15 — Resistance to wet arc tracking : electrical connections

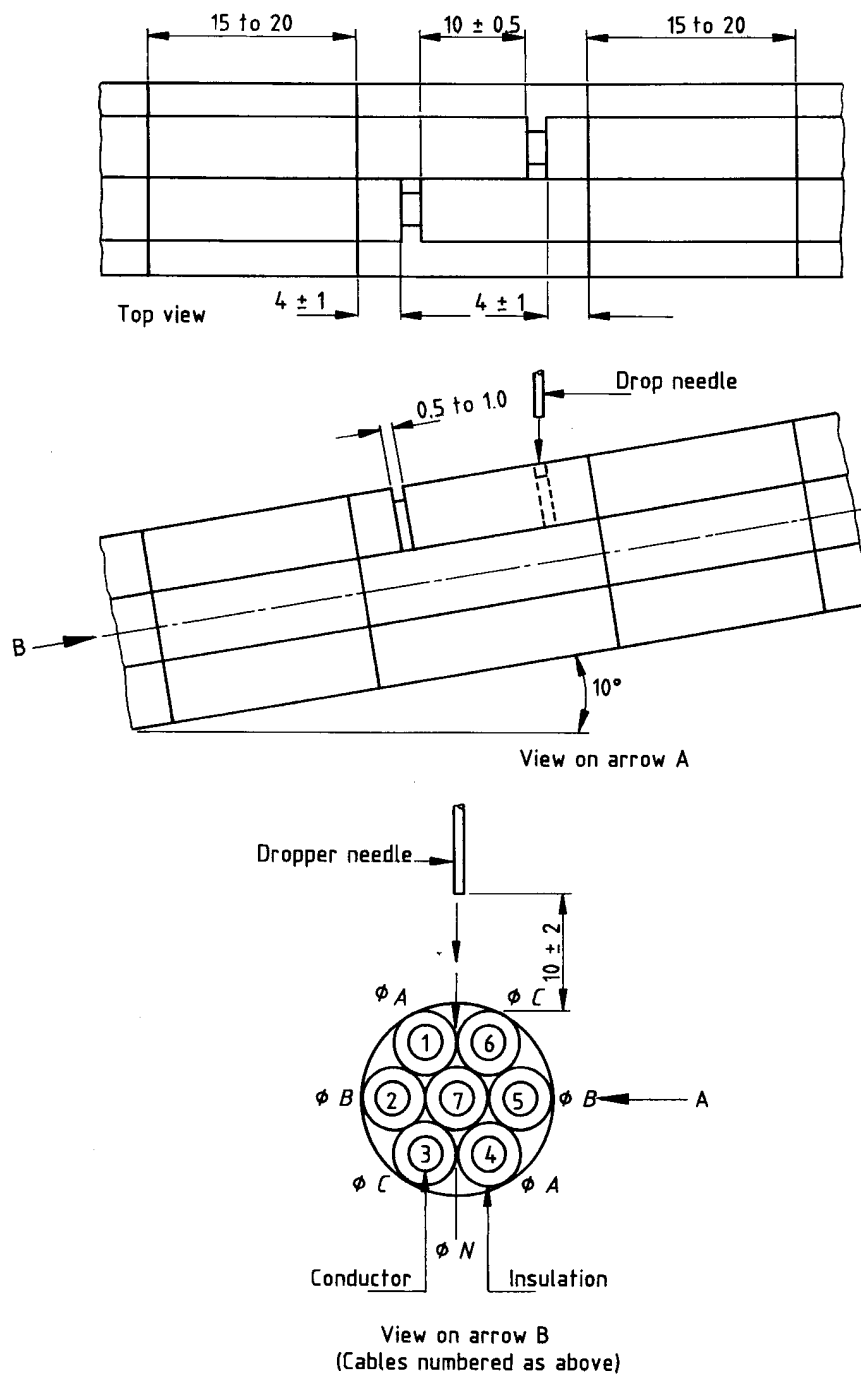


Figure 16 — Resistance to wet arc tracking : test configuration

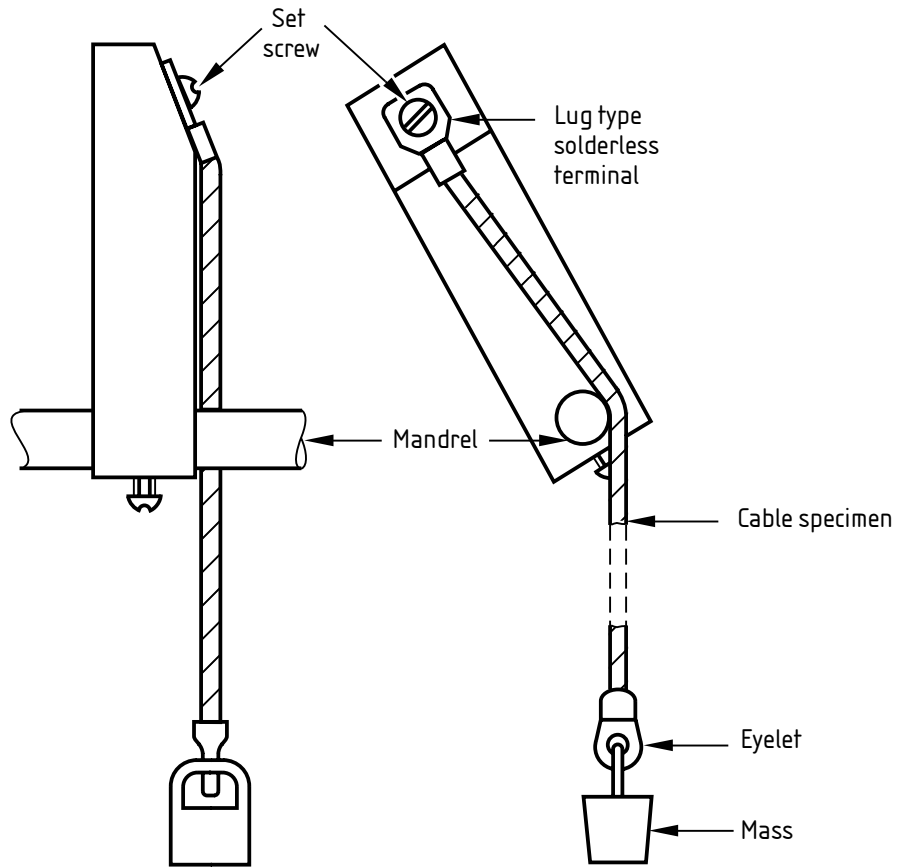


Figure 17— Method of attachment of cable test specimen to mandrel

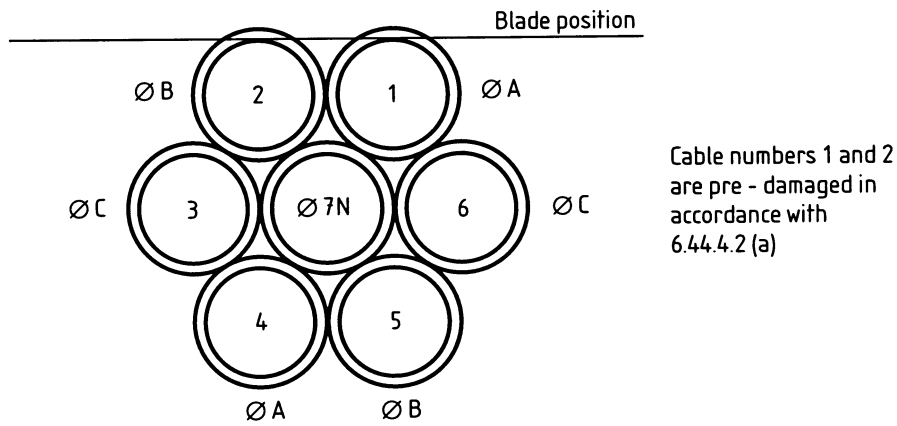


Figure 18 — Dry arc cable bundle lay up

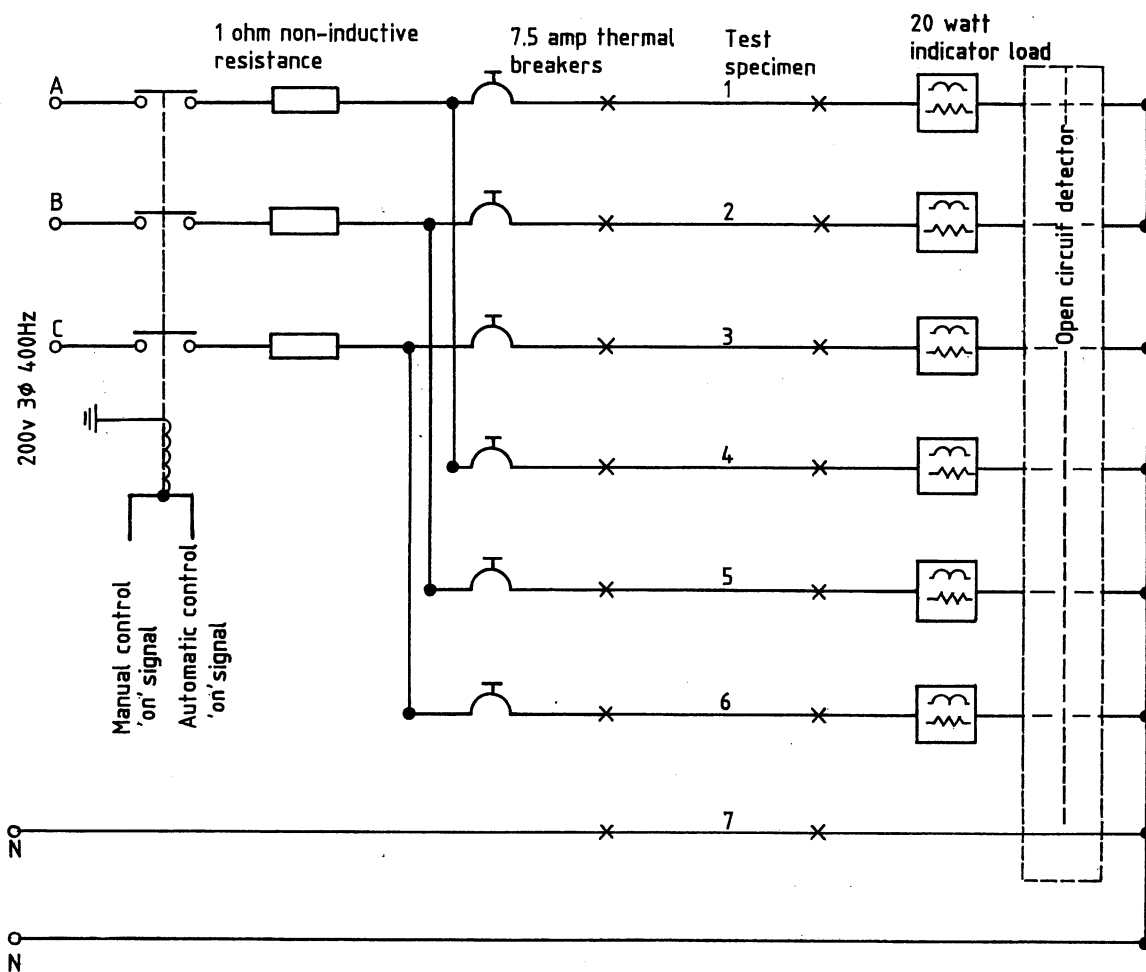


Figure 19 — Dry arc test schematic circuit

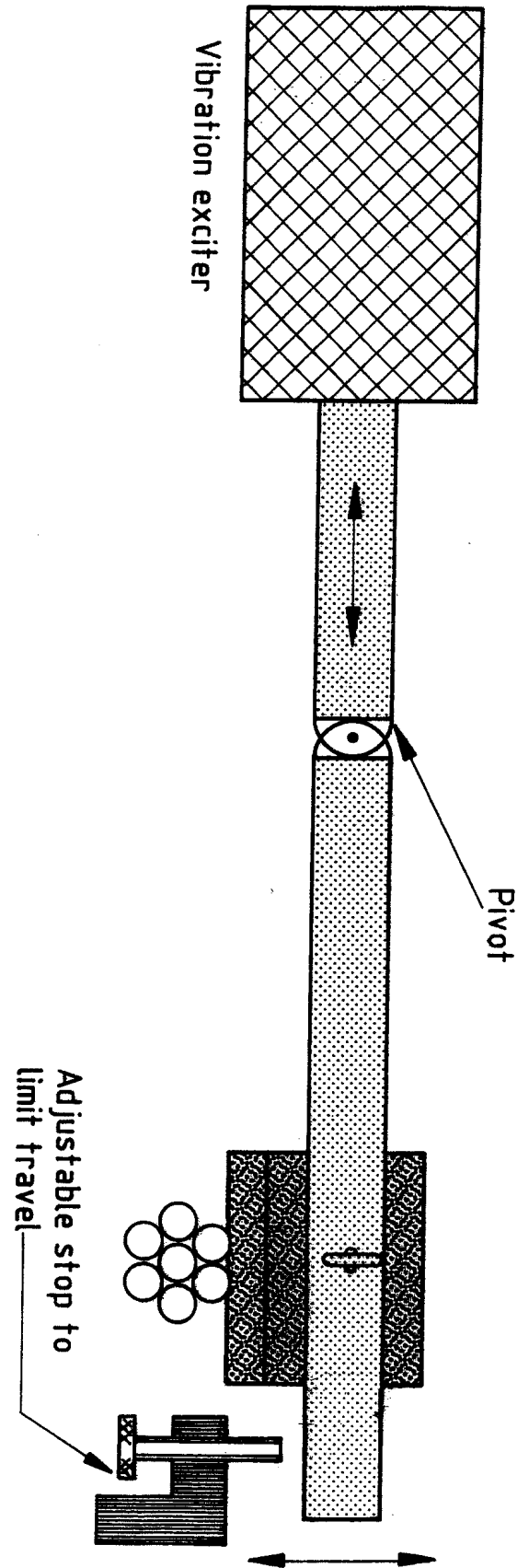


Figure 20 — Schematic representation of dry arc test apparatus

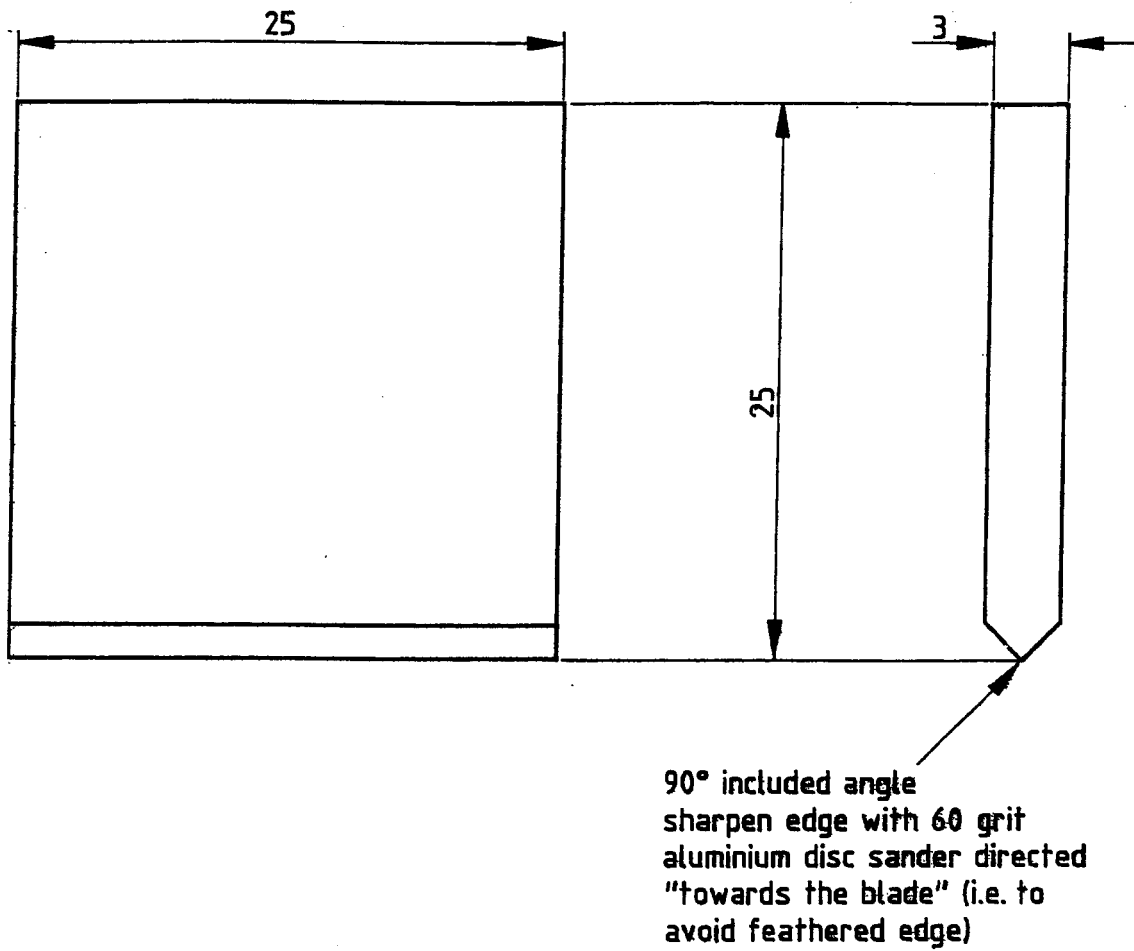


Figure 21 — Blade details

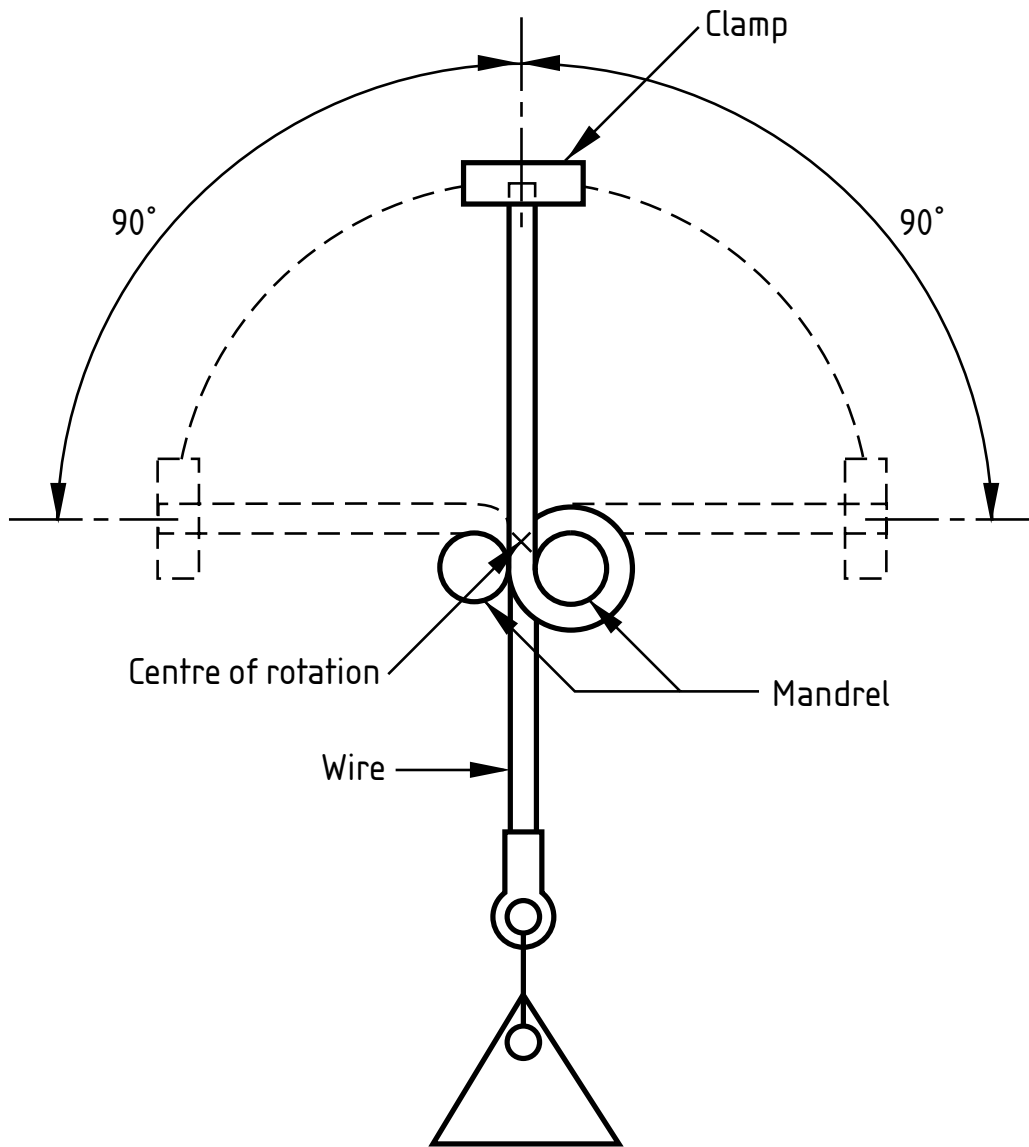


Figure 22 — Flexure endurance test schematic

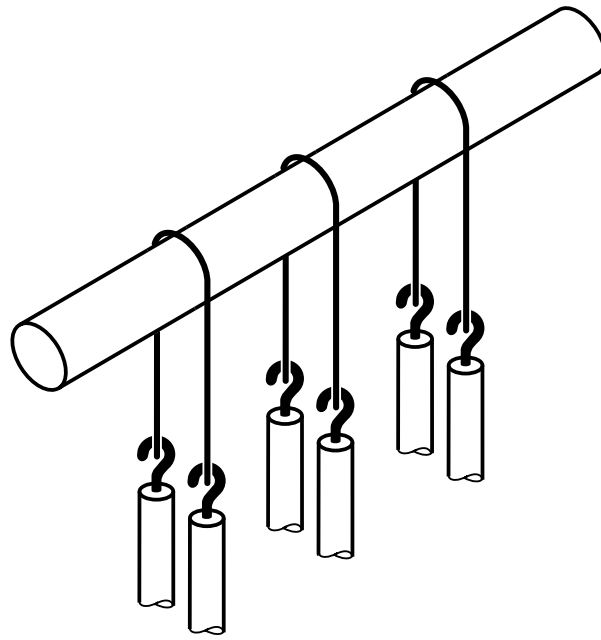


Figure 23 — Accelerated ageing test rig (schematic)

Annex A (normative) Formulae for calculating braiding details

A.1 Formulae for glass braid

A.1.1 Filling factor

The filling factor K_f is given by the following formula:

$$\frac{mnd_w}{2\pi D} \left(1 + \frac{\pi^2 D^2}{L^2} \right)^{1/2} \quad (\text{A.1})$$

where

D is the mean diameter of braid (i.e. diameter under braid + $2d_r$);

d_w is the effective width of one end;

d_r is the effective radial depth of one end;

L is the lay length;

m is the total number of spindles;

n is the total number of ends per spindle.

NOTE of d_w and d_r for the sizes of yarn in common use are stated in the individual cable specification.

A.1.2 Lay factor

The lay factor K_L is given by the following formula.

$$1 + \frac{\pi^2 D^2}{L^2} \quad (\text{A.2})$$

where D and L are as defined in A.1.1.

A.2 Formulae for metal braid

A.2.1 Filling factor

The filling factor K_f is given by the following formula.

$$\frac{mnd_w}{2\pi D} \left(1 + \frac{\pi^2 D^2}{L^2} \right)^{1/2} \quad (\text{A.3})$$

where

D is the mean diameter of braid;

d_w is the diameter of braiding wire;

L is the lay of braiding wire;

m is the total number of spindles;

n is the total number of ends per spindle.

A.2.2 Lay factor

The lay factor K_L is given by the following formula.

$$1 + \frac{\pi^2 D^2}{L^2} \quad (\text{A.4})$$

where D and L are as defined in **A.2.1**.

A.2.3 Coverage

The percentage coverage of F is given by the formula

$$100 (2K_f - K_f^2)$$

Annex B (normative)

Identification marks

NOTE The marks shown in Table B.1 are purely for identification purposes. New applications for marks should be made to the British Standards Institution, 389 Chiswick High Road, London W4 4AL. Use of the BSI Technical Committee reference ACE/6 will assist BSI in dealing with the correspondence connected with this list. The marks used by manufacturers who are taken over by other companies, or who are absorbed into other companies, may be transferred to the new owners upon application to the BSI committee secretary.

Table B.1 — Manufacturer's identification marks

Manufacturer	Code
AEI Cables Ltd.	AA
WL Gore and Associates (UK) Ltd.	AB
Alcatel Cables	AC
British Insulated Callenders Cables Ltd.	BB
Pirelli General Cable Works Ltd.	CC
Reliance Cords and Cables Ltd.	DD
Rist's Ltd.	EE
Delta Enfield Cables Ltd.	FF
Huber and Suhner AG	GG
The Concordia Electric Wire and Cable Co Ltd.	HH
Habia Cable Ltd	HC
Davu Wires and Cables Ltd.	KK
Duratube and Wire Ltd.	LL
Ripaults Ltd.	NN
Permanoid Ltd.	QQ
Standard Telephones and Cables Ltd.	RR
Raychem Ltd.	SS
Sterling Cable Co Ltd.	TT
Raydex CDT	UU
Vactite Wire Co Ltd.	VV
BICC Communications Ltd.	WW
Brand Rex Ltd.	XX
Crompton Parkinson	YY
Telephone Cables Ltd.	ZZ

Examples of identification marks, indicating county of origin, conforming to BS EN ISO 3166-1 are as follows:

United Kingdom	GB
Switzerland	CH
United States of America	US

Annex C (normative)

Relative thermal life and temperature rating

NOTE This text is reproduced from ASTM D 3032-80 with permission.

C.1 Introduction

This annex describes a procedure for determining life versus temperature curves and temperature indices for electrically insulated cables.

C.2 Summary of method

C.2.1 Three or four sets of specimens of a given sample of cable are exposed for selected periods of time at several fixed temperatures. After each exposure period the specimen is wrapped on a mandrel to simulate a flexing stress and then immersed in a water bath where it is given a voltage withstand test. A given specimen is subjected to a continued series of exposures at its designated test temperature until failure occurs.

C.2.2 The life data at different temperatures are analyzed on the basis of the Arrhenius equation which relates exposure time to failure to the reciprocal of the absolute temperature of exposure.

C.3 Significance

C.3.1 The chemical changes that degrade the physical and electrical properties of insulation on conductors are accelerated when the cable is exposed to elevated operating temperatures. This test method can be used to determine the relative effects of different temperatures on the life of a given insulating system or to compare different insulating systems at a given temperature. The times to failure in this test cannot be quantitatively related to the life of insulating materials in actual service, but do provide an indication of such life under the specific parameters of the test. The results of these shorter time tests at higher temperatures can be extrapolated to longer times at lower temperatures providing that the extrapolation is limited and is based on adequate data with sufficient linearity.

C.3.2 Embrittlement of the insulation and the loss of its electrical strength are the usual causes of failure due to thermal ageing on cable in practical applications; hence the failure points for these accelerated conditions are determined by tests of embrittlement and electrical strength.

C.3.3 In comparing different systems, it is important that the dimensions and constructions of each should be those to be used in the intended application.

C.3.4 It is important to know that changing the condition of test will change the results. Decreasing the mandrel size, increasing mass during mandrel bend, bending at too high a rate, or increasing proof voltage will decrease life. Too few temperature exposure cycles will result in erroneously long life values.

C.4 Apparatus

C.4.1 *Circulating air oven*, for relative thermal life. The oven shall produce between 100 and 200 changes of air per hour.

The temperature fluctuation at 200 °C due to the control system shall not exceed 5 °C. The temperature differential across the oven chamber at any one time shall not exceed 7 °C.

The oven shall have a vertical internal dimension of at least 500 mm.

C.4.2 *Rack*, for holding specimens in the oven. A simple one can consist of 6 mm steel rods located horizontally approximately 25 mm below the top of the chamber. These can be mounted as part of the chamber or as a removable rack carrying the specimens.

C.4.3 *Mass with hooks*, for holding cable specimens straight in the oven during ageing. An appropriate mass size is about one-half of the mandrel test mass given in **C.4.4**. It is suggested that this mass shall have also a hook on the bottom so that the additional mass required for the mandrel wrap can be added without removing the stabilizing mass.

C.4.4 *Mandrel*, supported horizontally, and fitted at one end with a crank for mandrel test wrapping of the specimens. The rod shall be supported at least 0.6 m above a horizontal work surface. The mandrel shall be provided with some convenient means for attaching one end of the cable for wrapping. A suggested method of attachment is the crank arm shown in Figure 17. The diameter of the round mandrel and the masses with hooks for attaching to the lower end of the specimens during the mandrel wrap shall be as specified in Table C.1.

Table C.1 — Mandrel diameters

Cable size	Mandrel diameter mm	Mass kg
20	13	0.7
14	25	2.7

It is strongly recommended that evaluations be limited to these two conductor sizes. If, however, it is necessary to use other masses and sizes of mandrel they shall be in accordance with those specified in Table C.2.

C.4.5 Apparatus as used in test 16(a) shall be provided for performing the voltage withstand test as described in **C.7.4.4**.

C.5 Sampling

C.5.1 Samples shall consist of lengths of cable, preferably with a stranded conductor, having constructions that are considered to be typical and representative of the materials to be tested.

Table C.2 — Additional mandrel diameters and masses

Cable size	Mandrel diameter mm	Mass kg
28	10	0.10
26	10	0.16
24	10	0.25
22	13	0.40
18	20	1.0

C.5.2 Each specimen shall be a cable with a size 20 stranded conductor; if not, all specimens of a given construction shall have the same conductor size. The concentricity should be at least 85 % since, on a mandrel test, strains and the resulting stresses can be excessive and cause premature cracking for an eccentric construction where the thicker section is remote from the mandrel.

C.6 Test specimens

C.6.1 The conductor shall be of the construction and materials expected to be used in practice.

C.6.2 Each specimen shall be a 300 mm to 400 mm length of cable whose insulation is free of visible imperfections. Strip approximately 6 mm of insulation at each end and apply a lug from which the weights can be suspended. The lug shall be of a type that not only contacts the conductor but also clamps the insulation to prevent pull-back with temperature exposure. Ten specimens constitute a set for life testing at each temperature. Prepare at least four sets of specimens. Sufficient cable should be on hand for the preparation of eight sets of specimens in case the life at some exposure temperature does not fall within the originally estimated limits.

C.6.3 It is recommended that a control cable construction whose performance is known from laboratory and/or field experience or both should be run at the same time. This requires a duplicate number of specimens as described in **C.6.2**. Two or more constructions whose performances are not known can be compared and equivalent numbers of specimens will be required for each.

C.7 Procedure

C.7.1 *Qualification of laboratory oven*

C.7.1.1 For determination of the temperature index, adjust the oven for 150 ± 10 % air changes per hour.

C.7.1.2 Perform an experiment to confirm that the ovens to be used for testing have a suitable thermal capacity. Load the ovens with dummy test specimens that represent the normally expected loading. Attach thermocouples to a minimum of six of the dummy specimens to provide a representative sampling of the work chamber. Preferably temperatures are displayed on a multipoint recorder. Oven adequacy is determined by the temperatures obtained when the oven has stabilized. The average specimen temperature has to be within $\pm 2\text{ }^{\circ}\text{C}$ and the maximum instantaneous deviation within $5\text{ }^{\circ}\text{C}$ of the applicable operating temperature, regardless of the specimen location. Ovens that do not conform to the requirement may be used provided that one records the actual temperature representative of the specimen exposures. Temperatures shall be recorded, either continuously or at frequent intervals for each sensor location (adjacent to actual specimens). Where temperatures are varying, a time weighted average shall be used with care; if the temperature range averaged is as great as $10\text{ }^{\circ}\text{C}$, the results are questionable.

C.7.2 Selection of temperatures for test

C.7.2.1 Select the lowest ageing test temperature by adding $20\text{ }^{\circ}\text{C}$ to the temperature index expected at the selected end of life (10 000 h, 20 000 h or 40 000 h). An additional two and preferably three should be selected in $10\text{ }^{\circ}\text{C}$ to $20\text{ }^{\circ}\text{C}$ successive steps. If the log average life at the highest test temperatures is found to be less than 100 h, too high a test temperature has been selected and these data should be discarded. Tests should be repeated at a lower temperature. Extrapolation to a temperature index should not exceed $25\text{ }^{\circ}\text{C}$ below the lowest ageing test temperature. If extrapolation beyond $25\text{ }^{\circ}\text{C}$ is required, an additional series of tests shall be made at a still lower temperature. If, in addition, the average life found at the lowest test temperature is less than 5 000 h, tests will be made at lower temperatures until at least 5 000 h average life data are achieved.

C.7.2.2 The average life of the specimens may be affected by the number of cycles; therefore to maintain a consistency in the procedure that will assure a reliable degree of reproducibility, make an effort to reach an average of not less than eight cycles and not more than fifteen cycles. A first estimate of cycle time is specified in Table C.3. This table provides a selection of the days per cycle and the recommended ageing temperatures for cables having thermal index temperatures ranging from $105\text{ }^{\circ}\text{C}$ to $240\text{ }^{\circ}\text{C}$. This range could be extended easily if necessary. During the course of the test, increase or decrease the length of the remaining cycles if necessary.

C.7.2.3 Make an estimation of the highest test temperature by running cycles of approximately one day in length, at $80\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$ above the nominal rating temperature of the cable, or at a point just below the melting point of the primary insulation, if it is within this range.

C.7.2.4 Begin the test sequence with the highest temperatures, since exposure times will be relatively short. On the basis of these results, review the proposed lower exposure temperatures and revise if necessary.

C.7.3 Hanging of specimens

Vertically hang specimens from the mounting rack in the oven using the masses specified in **C.4.4** to keep them straight.

C.7.4 Inspection testing

C.7.4.1 Remove the group of specimens from the oven. Allow them to cool to room temperature. Remove the specimens from the rod.

C.7.4.2 Attach one end of the specimen to the mandrel. Hang the prescribed added mass to its lower end. Rotate the mandrel so that the specimen is wrapped on it, first in one direction and then in the opposite direction. Do this twice. During the wrapping, allow the cable to twist freely and seek its own position on the mandrel with the only limitation being that the cable has to stay in contact with the mandrel and not wind upon itself. The speed of winding shall be uniform at a rate of one turn in 3 s to 5 s. It is preferable to have the winding motorized, but it may be done by hand. Then remove the masses and detach the specimens from the mandrel.

C.7.4.3 Connect the two ends of a specimen together and immerse the specimen in the solution described in 7.17.1 with the ends above the surface, 25 mm of the insulation being exposed. Soak for 1 h.

Table C.3 — Recommended exposure times in days per cycle^a

Exposure or ageing temperature °C	Estimated temperature value °C						
	105	130	155	180	200	220	240
310							1
300							2
290 ± 3						1	4
280						2	7
270					1	4	14
260					2	7	28
250				1	4	14	49
240				2	7	28	
230 ± 3				4	14	49	
220			1	7	28		
210			2	14	49		
200		1	4	28			
190		2	7	49			
180 ± 2	1	4	14				
170	2	7	28				
160	4	14	49				
150	7	28					
140 ± 2	14	49					
130	28						
120	49						

^a A cycle consists of one ageing period followed by one proof-voltage test.

C.7.4.4 Apply a 40 Hz to 60 Hz, 1.5 kV r.m.s., withstand test using a rate of rise of 0.5 kV/s. Maintain this voltage for 1 min. If the specimen fails the voltage-withstand test, discontinue the thermal ageing on that specimen and record the total ageing time at that temperature. Failure is defined as drawing in excess of 10 mA per specimen while subjected to the voltage of the withstand test.

C.7.4.5 Wash the specimens that pass the voltage-withstand test in tap water to remove the salt, dry, and replace them in the oven as specified in **C.7.3**.

C.7.4.6 Repeat **C.7.4.1** to **C.7.4.5** inclusive until all ten specimens in the group have failed.

C.8 Calculation of results

C.8.1 Calculate the exposure time to failure for each specimen by taking the total test temperature exposure time minus one-half of the exposure time of the last cycle. As an example, suppose a specimen failed the withstand test following the ninth 100 h exposure. Thus the actual insulation failure occurred at some time between 800 h and 900 h. The value to use for calculation is 850 h. The time to be entered on the Arrhenius plot for a given test temperature is the average life of the 10 specimens of the group life tested at that temperature.

$$\text{Average life} = \log^{-1} \frac{(\log t_1 + \log t_2 + \log t_3 \dots + \log t_{10})}{10} \quad (\text{C.1})$$

where

t_1, t_2, \dots, t_{10} are the successive times to failure of the 10 specimens of that group.

C.8.2 A complete regression analysis of the life-temperature data can be made by following the statistical procedures. For an abbreviated method of calculating the regression life line (without confidence limits), the procedure outlined in **C.12** may be used.

C.9 Interpretation of results

C.9.1 The data for thermal life of one insulating system are best presented as an Arrhenius plot where the logarithmic average life (see **C.8.1**) is plotted against the reciprocal of the absolute exposure temperature. This usually approximates a straight line but not necessarily so (see Figure C.1).

C.9.2 To compare two insulating systems, a comparison of the Arrhenius plots of the two provides the most useful information.

C.9.3 The temperature index (absolute) is deduced from the Arrhenius plot, at the desired time, preferably 20 000 h, and is expressed as follows:

$$TI/164 \quad (C.2)$$

(meaning that as an example, the 20 000 h life point on the Arrhenius plot came at 164 °C). If any time other than 20 000 h is used for the index, the number of thousands of hours so used shall prefix the index. This will be expressed, for example:

$$TI\ 5\ kh/183 \quad (C.3)$$

C.9.4 When a comparison is made with a reference material (that is, the reference material is run in the same oven at the same time as the test material), plot on the thermal endurance graph both materials on the same sheet, to find the point on the graph for the known material which corresponds to its recognized temperature index and then to use this same time for obtaining the temperature index of the second material. When the temperature index is determined in this way, it is called relative temperature index and is expressed, for example:

$$RTI/141$$

C.9.5 Where the Arrhenius plot is not a straight line but can be fitted by two straight lines of different gradients meeting at a transition temperature, there should be at least three observation points on the line segment at the lower temperature end. If not, an additional life test should be run in this lower temperature region.

C.9.6 If a linear plot with at least three points over a range of at least 50 °C cannot be obtained, no attempt shall be made to extrapolate the data and only the curve through the actual data points should be reported.

C.10 Test report

The test report shall include the following.

- a) A complete description of each insulation system with the identity and dimensions of each layer and the dimensions, stranding, and materials and plating of the conductor, and the concentricity of the insulation and coverings.
- b) Tabulation of the average and standard deviation for the log average life at each exposure temperature. It should be stated here whether all specimens were tested to failure or whether truncated data were used.
- c) Graphical presentation of the logarithm of the average life versus the reciprocal of the absolute temperature of exposure for each construction tested.
- d) A statement detailing the capability of the oven with a judgement made as to whether the results can be considered as absolute or whether they should be limited to the relative thermal capability of the two or more constructions evaluated.
- e) The temperature index (or indices) determined. When the oven permits only the relative thermal capability, the relative temperature index (*RTI*) shall be reported.

C.11 Precision and accuracy.

Because experience has shown that different laboratory ovens rarely give duplicate results on thermal ageing tests, it is strongly recommended that this method be limited to evaluation of the relative performance of two or more insulation systems tested at the same time. The procedure can be used in a laboratory to evaluate a series of materials and arrange them in order of their relative thermal endurance with a reasonable certainty that another laboratory could arrive at the same relative performance.

C.12 Calculation of the regression line

C.12.1 It has been established that many film insulations deteriorate in a manner so that the following equation applies:

$$L = Ae^{b/K} \tag{C.4}$$

where

L is the insulation life;

K is the absolute temperature (in kelvins);

A, b are constants for each insulation;

e is the base of natural logarithms.

Equation C.4 may be expressed as a linear function by taking logarithms:

$$\log L = \log A + b/K \tag{C.5}$$

Let

$$Y = \log L$$

$$a = \log A$$

$$X = 1/K$$

$$\text{Then } Y = a + bX \tag{C.6}$$

Thus, data from testing at higher temperatures may be plotted on $\log L$ versus $1/K$ graph paper and a line extrapolated to lower temperatures. However, since the nature of logarithmic plots does not allow accurate extrapolation by the method of drawing the best apparent straight line through the data points, a more rigorous method has to be used for greater accuracy and uniformity. By the use of the method of least squares, the constants a and b may be derived in terms of the experimental data obtained. These equations are as follows:

$$a = [(\Sigma(YX) - c(\Sigma Y))/((-cn) + \Sigma X)] \quad (\text{C.7})$$

$$b = (\Sigma Y - an) / \Sigma X \quad (\text{C.8})$$

$$c = \Sigma X^2 / \Sigma X \quad (\text{C.9})$$

where

$X = 1/K$ is the reciprocal of the test temperature, K ($^{\circ}\text{C} + 273$);

n is the number of end points used in the calculation;

$Y = \log L$ is the logarithm of the average life at each test point;

Σ is the summation of n values.

Knowing the constants a and b , the slope of the regression line is readily found by use of equation 3:

$$Y = a + bX$$

$$K = 1/X = b/(Y - a)$$

$$\text{Temperature at 20 000 h (in } ^{\circ}\text{C)} = [b/(4.301 0 - a)] - 273 \quad (\text{C.10})$$

$$\text{Temperature at 2 000 h (in } ^{\circ}\text{C)} = [b/(3.301 0 - a)] - 273 \quad (\text{C.11})$$

C.12.2 To simplify the handling of the test data used in the equation of **C.12.1**, the following steps should be taken (see Tables C.4 and C.5).

- a) List the individual end points in columns as illustrated in the sample calculation.
- b) Under ‘ °C’, list each temperature at which an individual test was completed (for reference only).
- c) In the second and third columns, list the reciprocals ($X = 1/K$) and the reciprocals squared ($X^2 = 1/K^2$) of the temperatures converted to kelvins.
- d) In the fourth column, list the end point, L , of each individual set (not less than ten twists) in hours, and in the fifth column, list the natural log of the value in column four ($Y = \log L$).
- e) In column six, list the products of $\log L$, Y , (column five) and reciprocal of the test temperature in kelvins, X (column two).
- f) Add columns two, three, five and six, and enter the summation (indicated by Σ) at the bottom of the respective column.
- g) Indicate the number of data points included, n , on the worksheet.
- h) Using the actual experimental values obtained in the style of table C4 sample, solve for c (equation C.10), a (equation C.7), and b (equation C.8) in that order. (The constants will always be negative.)
- i) Using constants a and b , solve for temperature in °C at 20 000 h (equation C.10) and at 2 000 h (equation C.11).
- j) Plot the above two temperature points on $\log L$ versus $1/K$ graph paper and draw the regression line through them.
- k) Plot the individual end points, L , at their respective temperatures on the same graph.

Table C.4 — Sample calculations

Temperature °C	$X = 1/K$	$X^2 = 1/K^2$	L	$Y = \log L$	$XY = \log L/K$
150	$2.364\ 07 \times 10^{-3}$	$5.588\ 83 \times 10^{-6}$	4 800	3.681 24	$8.702\ 71 \times 10^{-3}$
150	$2.364\ 07 \times 10^{-3}$	$5.588\ 83 \times 10^{-6}$	4 500	3.653 21	$8.636\ 44 \times 10^{-3}$
165	$2.283\ 11 \times 10^{-3}$	$5.212\ 59 \times 10^{-6}$	1 600	3.204 12	$7.315\ 36 \times 10^{-3}$
165	$2.283\ 11 \times 10^{-3}$	$5.212\ 59 \times 10^{-6}$	1 300	3.113 94	$7.109\ 47 \times 10^{-3}$
185	$2.183\ 41 \times 10^{-3}$	$4.767\ 28 \times 10^{-6}$	350	2.544 07	$5.554\ 75 \times 10^{-3}$
185	$2.183\ 41 \times 10^{-3}$	$4.767\ 28 \times 10^{-6}$	425	2.628 39	$5.738\ 85 \times 10^{-3}$
200	$2.114\ 16 \times 10^{-3}$	$4.469\ 67 \times 10^{-6}$	150	2.176 09	$4.600\ 60 \times 10^{-3}$
200	$2.114\ 16 \times 10^{-3}$	$4.469\ 67 \times 10^{-6}$	175	2.243 04	$4.742\ 15 \times 10^{-3}$
—	$17.889\ 50 \times 10^{-3}$	$40.076\ 74 \times 10^{-6}$	—	23.244 10	$52.400\ 33 \times 10^{-3}$

$n = 8$

$$c = \frac{\Sigma(X^2)}{\Sigma X} = \frac{40.076\ 74 \times 10^{-6}}{17.889\ 50 \times 10^{-3}} = 2.240\ 24 \times 10^{-3}$$

$$a = \frac{\Sigma(XY) - c(\Sigma Y)}{(-cn) + \Sigma X} = \frac{52.400\ 33 \times 10^{-3} - ((2.240\ 24 \times 10^{-3})23.244\ 10)}{(-2.240\ 24 \times 10^{-3}(8)) + 17.889\ 50 \times 10^{-3}} = 10.116\ 29$$

Temperature at 20 000 h (in °C)

$$= \frac{b}{Y - a} - 273 = \frac{5\,823}{4.301\,0 + 10.116\,29} - 273 = 131$$

Temperature at 2 000 h (in °C)

$$= \frac{b}{Y - a} - 273 = \frac{5\,823}{3.301\,0 + 10.116\,29} - 273 = 161$$

Table C.5 — Commonly used test temperatures in °C and the corresponding kelvins with its reciprocal and reciprocal squared values (see Table C.3)

°C	K	$X = 1/K$	$X^2 = 1/K^2$
105	378	$2.645\,50 \times 10^{-3}$	$6.998\,67 \times 10^{-6}$
125	398	$2.512\,56 \times 10^{-3}$	$6.312\,96 \times 10^{-6}$
130	403	$2.481\,39 \times 10^{-3}$	$6.157\,30 \times 10^{-6}$
140	413	$2.421\,31 \times 10^{-3}$	$5.862\,74 \times 10^{-6}$
150	423	$2.364\,07 \times 10^{-3}$	$5.588\,83 \times 10^{-6}$
165	438	$2.283\,11 \times 10^{-3}$	$5.212\,59 \times 10^{-6}$
175	448	$2.232\,14 \times 10^{-3}$	$4.982\,45 \times 10^{-6}$
180	453	$2.207\,51 \times 10^{-3}$	$4.873\,10 \times 10^{-6}$
185	458	$2.183\,41 \times 10^{-3}$	$4.767\,28 \times 10^{-6}$
190	463	$2.159\,83 \times 10^{-3}$	$4.664\,87 \times 10^{-6}$
200	473	$2.114\,16 \times 10^{-3}$	$4.469\,67 \times 10^{-6}$
220	493	$2.028\,40 \times 10^{-3}$	$4.114\,41 \times 10^{-6}$
225	498	$2.008\,03 \times 10^{-3}$	$4.032\,18 \times 10^{-6}$
240	513	$1.949\,32 \times 10^{-3}$	$3.799\,85 \times 10^{-6}$
250	523	$1.192\,05 \times 10^{-3}$	$3.655\,94 \times 10^{-6}$
260	533	$1.876\,17 \times 10^{-3}$	$3.520\,01 \times 10^{-6}$
280	553	$1.808\,32 \times 10^{-3}$	$3.270\,02 \times 10^{-6}$
300	573	$1.745\,20 \times 10^{-3}$	$3.045\,72 \times 10^{-6}$
320	593	$1.686\,34 \times 10^{-3}$	$2.843\,74 \times 10^{-6}$

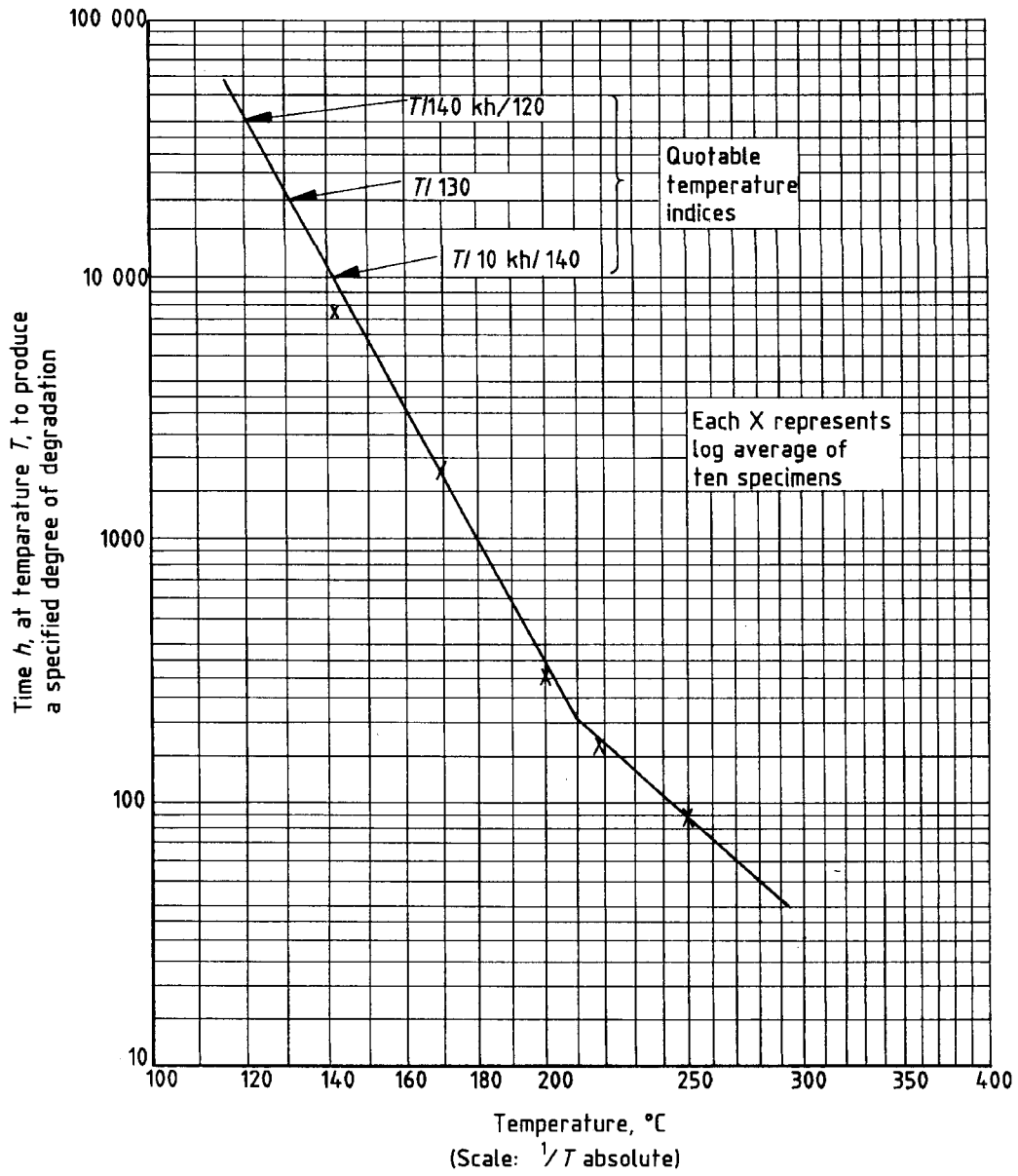


Figure C.1 — Model Arrhenius plot

Annex D (normative)**Formulae for the calculation of resistance of conductors for use in aircraft electrical cables**

The resistance values of aircraft cable conductors specified in BS G 231 have been calculated using the following formula:

$$R_{20} = \frac{4A}{\pi n d^2} = K_1, K_2, K_3, K_4 \quad (\text{D.1})$$

where

R_{20} = maximum resistance at 20 °C in Ω/km

A = volume resistivity at 20 °C = 17.241 $\Omega \text{ sq. mm/km}$ for copper

n = number of wires in conductor

d = diameter of individual wires in conductor

K_1 = factor for wire diameter variation = 1.0 if d is actual minimum diameter

K_2 = a) factor for stranding
b) additional factor required for rope stranding

K_3 = factor for multicore conductor resistance = 1.0 for single cores
= 1.04 for multicore
= 1.06 for multipair

K_4 = factor for plating of wires = 1.0 for silver plated or unplated
= varies with size of wire if plating thickness is constant for nickel or tin coating. (See Figure D.1)

Due to weight constraints the strands for aircraft cable conductors are manufactured to closer tolerances than general and experience has shown that resistance and weight values can best be calculated by using a \pm tolerance on the following individual wire diameters:

± 0.002 mm on wires up to and including 0.125 mm diameter;
and
 ± 0.004 mm on wires greater than 0.125 mm diameter.

Hence the use of K_1 is eliminated.

$$\text{Thus } R_{20} = \frac{21.95}{nd^2} = K_2, K_4 \text{ } \Omega/\text{km} \quad (\text{D.2})$$

For stranded conductors $K_2 = 1.04$.

For rope stranded conductors $K_2 = 1.04 \times 1.02 = 1.06$

K_4 values in Table D.1 have been obtained from Figure D.1. The values calculated are for uninsulated conductors. To allow for additional stretch during processing an additional factor of 1.04 is introduced to give the conductor resistance of the finished cable

Table D.1 — Plating factor

Wire size	Factor K_4 for nickel or tin plating
0.08	$1/0.922 = 1.085$
0.10	$1/0.936 = 1.068$
0.12	$1/0.948 = 1.056$
0.15	$1/0.957 = 1.045$
0.20	$1/0.968 = 1.033$
0.25	$1/0.974 = 1.027$
0.30	$1/0.978 = 1.022 \text{ } 5$
0.315	$1/0.979 = 1.021 \text{ } 5$
0.335	$1/0.980 = 1.020 \text{ } 4$
0.4	$1/0.983 = 1.017$
0.45	$1/0.984 = 1.016$
0.6	$1/0.989 = 1.011$
0.9	$1/0.996 = 1.004$

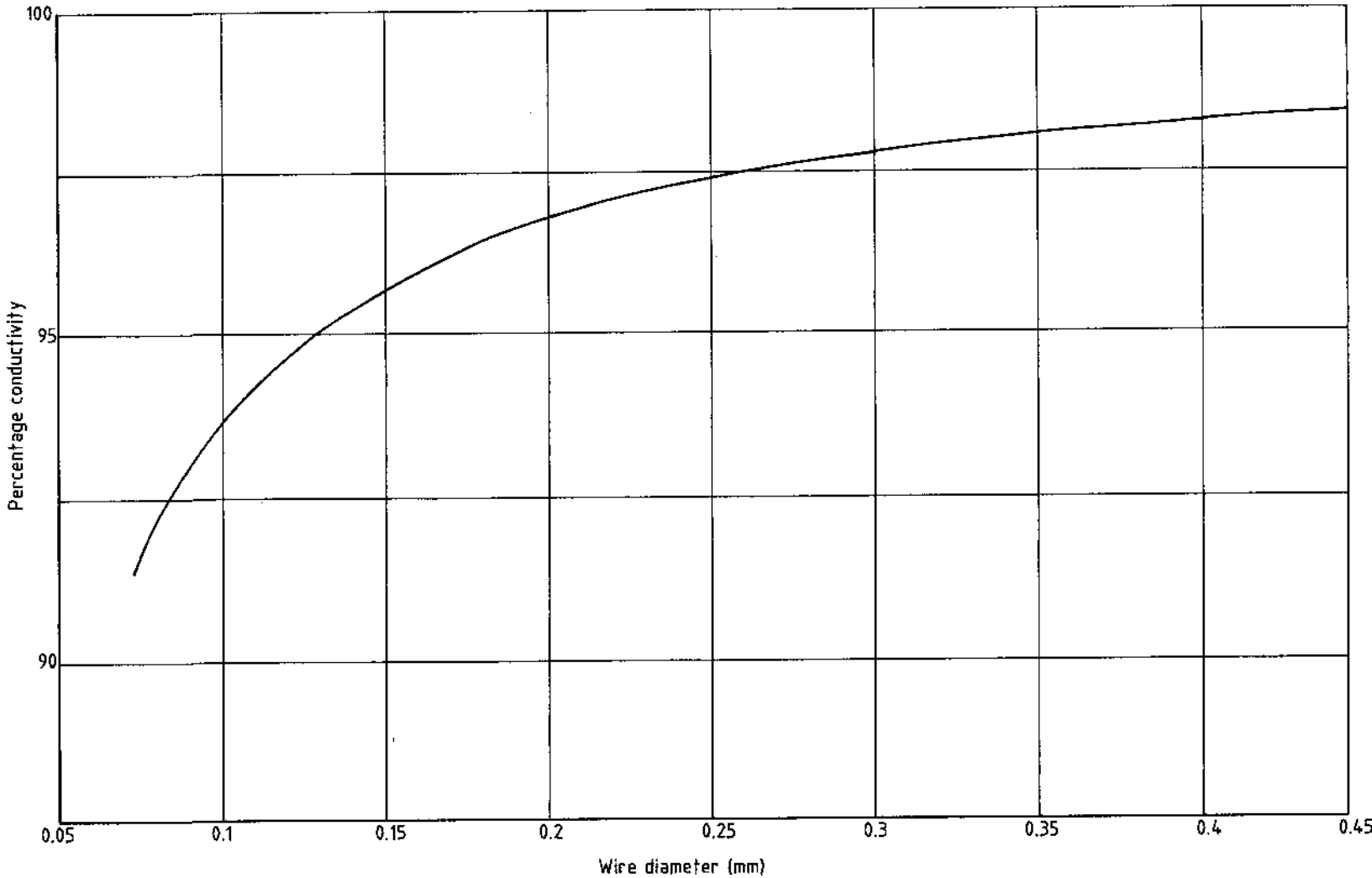


Table D.2 — Copper wire conductivity for nickel plating thickness of 2 microns

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