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British Standard Methods of test for Insulation and sheaths of electric cables

Méthodes d'essai des enveloppes isolantes et des gaines des câbles électriques

Verfahren zur Prüfung der Isolierung und Umhüllungen elektrischer Kabel

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Foreword

This new edition of BS 6469 has been prepared under the direction of the Cables and Insulation Standards Policy Committee. It supersedes BS 6469 : 1984, which is withdrawn.

This edition includes alterations introduced by Amendments No. 1 and 2 to BS 6469 : 1984 together with some further technical changes to bring the standard up-to-date but it does not reflect a full review or revision of the standard, which will be undertaken in due course.

Differences in the text between this edition and BS 6469 : 1984 are indicated by a line in the margin.

This standard is in technical agreement with the series of CENELEC* Harmonization Documents HD 505 insofar as the test methods are applicable to harmonized types of cables and cords.

These test methods are in general agreement with those described in the International Electrotechnical Commission (IEC) 811 series of publications.

The first edition of this standard updated and brought together into one standard the methods of test described in BS 5468†, BS 5469†, BS 6234, BS 6746 and BS 6899. The standard does not, however, specify requirements for compliance which are contained in those standards or in relevant cable standards.

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

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

*European Committee for Electrotechnical Standardization.

†Withdrawn with the publication of BS 6899 : 1984.

British Standard Methods of test for

Insulation and sheaths of electric cables

Section one. General

1.1 Scope

This standard describes methods of test used for testing extruded polymeric insulation and sheaths of electric cables.

These test methods are applicable when specified, by reference to this standard, in the specification for the type of cable.

Where full test conditions, such as temperature and duration, are not specified in this standard, it is intended that they should be specified by the standard dealing with the relevant type of cable.

Conditioning values and testing parameters are specified for the most common types of insulating and sheathing compounds.

Where applicable, criteria for passing or failing a test are given, but test requirements are specified in the relevant cable standard for each particular type of cable.

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

1.2 Definitions

For the purposes of this British Standard, the definitions given in BS 4727 : Part 2 : Group 08 apply, together with the following:

median value. When several test results have been obtained and ordered in an increasing or decreasing succession, the median value is the middle value if the number of available values is odd, and is the mean of the two middle values if the number is even.

1.3 Sampling, pre-conditioning and test temperature

WARNING NOTE. The methods of test contained in this British Standard do not necessarily detail all precautions necessary to meet the requirements of the Health and Safety at Work Act 1974. Attention should be paid to any appropriate safety precautions and the tests should be carried out only by trained personnel.

1.3.1 Sampling. For multicore cables and cords, not more than three cores (of different colours, if any) shall be tested unless otherwise specified in the relevant cable standard.

1.3.2 Pre-conditioning. All tests shall be carried out not less than 16 h after the extrusion or vulcanization (or cross-linking), if any, of the insulating or sheathing compounds.

1.3.3 Test temperature. Unless otherwise specified, tests shall be made at an ambient temperature of $20 \pm 5^\circ\text{C}$.

Section two. Methods of test for general application

2.1 Measurement of thicknesses and diameters

2.1.1 Measurement of insulation thickness

2.1.1.1 General. Measurement of insulation thickness may be required as an individual test or as a step in the procedure for carrying out other tests, such as the determination of mechanical properties.

2.1.1.2 Measuring equipment. The measuring equipment used shall be either:

- (a) a measuring microscope allowing a reading of 0.01 mm and an estimated reading to three decimal places when measuring insulation with a thickness less than 0.5 mm; or
- (b) a suitable measuring projector with a magnification of at least $\times 10$.

In case of dispute the microscope shall be used.

2.1.1.3 Selection of samples and preparation of test pieces. Select samples as specified in the relevant cable standard.

Remove any covering from the insulation and withdraw the conductor together with separator (if any) taking care to avoid damage to the insulation. Do not remove semi-conducting inner and/or outer layers, if bonded to the insulation.

Prepare each test piece of insulation in the form of a thin slice by cutting with a suitable device (e.g. a sharp knife or razor blade) along a plane perpendicular to the axis of the conductor. Do not separate the cores of non-sheathed flat cords.

If the insulation carries an indented marking take the test piece in such a way as to include this marking.

2.1.1.4 Measuring procedure. Place the test piece under the measuring equipment with the plane of the cut perpendicular to the optical axis.

If the inner profile of the test piece is of circular form, make six measurements as shown in figure 1. For sector-shaped cores make six measurements as shown in figure 2.

If the insulation is taken from a stranded conductor, make six measurements as shown in figures 3 and 4.

If the outer profile shows unevenness, make the measurements as shown in figure 5.

In the case of non-sheathed parallel twin flexible cords, make three measurements on each core of each piece of insulation, two on lines approximately parallel to the minor axis and one on the major axis. Also measure the thickness

of insulation in the direction of the other core and take the value of insulation thickness of each core as half the distance between the conductors as shown in figure 6. Take all measurements where the insulation is thin, at the deepest part of the grooves caused by the conductor.

If there are unremovable screening layers under and/or over the insulation, exclude these from the measurements.

If unremovable screening layers are present under and/or over opaque insulation, use a measuring microscope.

In all cases, make the first measurement at the place where the insulation is thinnest.

Take the readings in millimetres to two decimal places if the thickness is 0.5 mm or greater, and to three decimal places if the thickness is less than 0.5 mm.

2.1.1.5 Evaluation of results. Evaluate the results of the measurements as specified in the test requirements of the relevant cable standard.

In the case of tests carried out to determine cross-sectional area or surface area, calculate the 'mean value of the thickness' of each test piece (see 2.2.1.4) from all the measurement results obtained on that piece.

2.1.2 Measurement of thickness of non-metallic sheaths

2.1.2.1 General. Measurement of sheath thickness may be required as an individual test or as a step in the procedure for carrying out other tests, such as the determination of mechanical properties. The test method applies to the measurement of all sheaths for which thickness limits are specified, e.g. bedding, as well as external sheaths.

In each case, the method of selecting samples shall be in accordance with the relevant cable standard.

2.1.2.2 Measuring equipment. The measuring equipment used shall be either:

- (a) a measuring microscope allowing a reading of 0.01 mm; or
- (b) a suitable measuring projector with a magnification of at least $\times 10$.

In case of dispute the microscope shall be used.

2.1.2.3 Selection of samples and preparation of test pieces. Select samples as specified in the relevant cable standard.

Remove all materials, if any, inside and outside the sheath and prepare each test piece in the form of a thin slice by cutting with a suitable device (e.g. a sharp knife or razor blade) along a plane perpendicular to the axis of the cable. If the sheath carries an indented marking take the test piece in such a way as to include this marking.

2.1.2.4 Measuring procedure. Place the test piece under the measuring equipment with the plane of the cut perpendicular to the optical axis.

If the inner profile of the test piece is of circular form, make the measurements as shown in figure 1.

If the inner, substantially circular, surface is not regular or smooth, make six measurements radially at positions where the sheath is thinnest as shown in figure 7.

If the inner profile is not circular, make an appropriate number of measurements (not exceeding six) radially where the sheath is thinnest, i.e. at the bottom of the grooves caused by the cores as shown in figure 8.

In order to eliminate the influence of any irregularities in the outer surface which may be due to the presence of a

proofed tape or a ribbed sheath finish, make the measurements as shown in figure 9.

In the case of flat sheathed cords, make measurements on lines approximately parallel to the minor axis and on the major axis at the position of each core as shown in figure 10.

In all cases, for figures 1 to 10 make the first measurement at the place where the sheath is thinnest.

In the case of flat twin sheathed cables and flat twin sheathed cables with protective conductor, make three measurements at the position of each core, two on lines approximately parallel to the minor axis and one on the major axis (as shown in figures 11 and 12).

In the case of flat 3-core sheathed cables and flat 3-core sheathed cables with protective conductor, make measurements as shown in figures 13 and 14.

In the case of sheathed flat cables composed of n single cores, make measurements on the first and n th core. Measure the thickness of sheath approximately at right angles to the major axis and also the thickness approximately along the axis as shown in figure 15.

In the case of sheathed flat cables composed of n units and n multicore units, make measurements at points where the cores are nearest the periphery of the cable approximately at right angles to the major axis, and also the thickness approximately along the axis as shown in figures 16 and 17 respectively.

In the case of flat single sheathed cables with protective conductor, make a total of four measurements as follows:

- (a) two at the position of the core approximately parallel to the minor axis of the cable;
- (b) one at the position of the protective conductor approximately parallel to the major axis of the cable;
- (c) one at the thinnest point of the sheath, wherever it occurs.

Figure 43 shows these positions with an example in which the thinnest point is at the core position.

For other cases make measurements as shown in figure 18.

In all cases, for figures 11 to 18 measure the thinnest place on the sheath if this should not coincide with any of the previously described measurements.

Take the readings in millimetres to two decimal places.

2.1.2.5 Evaluation of results. Evaluate the results of the measurements as specified in the test requirements of the relevant cable standard.

In the case of tests carried out to determine cross-sectional area or surface area, calculate the 'mean value of the thickness' of each test piece (see 2.2.2.4) from all the measurement results obtained on that test piece.

2.1.3 Measurement of diameters and overall dimensions

2.1.3.1 General. The measurement of the diameter over the insulation of cores or the diameter over the sheath may be required as an individual test or as a step in the procedure for carrying out other tests. The methods described in 2.1.3.3 are for general use except where the procedure for a particular test specifies a different or alternative method.

2.1.3.2 Measuring equipment. For flat cords and cable and for other cords and cables (diameter not exceeding 15 mm) a micrometer, a profile projector or similar apparatus shall be used.

For cables with overall diameter exceeding 15 mm a measuring tape shall be used.

NOTE. For measurements made in the course of routine tests, it is permissible to use a dial micrometer or a vernier calliper, care being taken to limit the pressure.

2.1.3.3 Measuring procedures. For flat cords and cables, measure the overall dimensions along the major and minor axes.

For other cords and cables with an overall diameter not exceeding 15 mm, make the measurements in two directions perpendicular to each other.

Unless otherwise specified in the relevant cable standard, take the readings in millimetres to two decimal places for diameters or overall dimensions up to and including 15 mm, and to one decimal place for diameters or overall dimensions exceeding 15 mm.

2.1.3.4 Evaluation of results. Evaluate the results of the measurements as specified in the test requirements of the relevant cable standard.

2.2 Determination of tensile strength and elongation at break

2.2.1 Method of test for insulation

2.2.1.1 General. This test is to determine the tensile strength and elongation at break of the insulating material (exclusive of any semi-conducting layers) of the cable in the condition as manufactured (i.e. without any ageing treatment) and, when required by the relevant cable standard, after one or more accelerated ageing treatment(s).

The tensile tests on the aged and unaged test pieces shall be made in immediate succession.

The procedure is as follows.

- (a) Take samples as described in 2.2.1.2.
- (b) Prepare test pieces as described in 2.2.1.3.
- (c) Determine the cross-sectional area of each test piece as described in 2.2.1.4.
- (d) Condition the test pieces as described in 2.2.1.6.
- (e) Carry out the test as described in 2.2.1.7.
- (f) Evaluate the results as described in 2.2.1.8.

2.2.1.2 Selection of samples. Take a sample of sufficient size to provide a minimum of five test pieces each for:

- (a) the tensile tests without ageing, and
- (b) the tensile tests after each of the required ageing treatments, of each core to be tested or of the insulation from each core to be tested.

Do not use a sample that shows signs of mechanical damage.

Do not separate the cores of flat non-sheathed cords.

2.2.1.3 Preparation of test pieces

2.2.1.3.1 General. Whenever possible, prepare dumb-bell test pieces from the samples of insulation, as described in 2.1.1.3.2. If the core is of such small size that it is not possible to prepare dumb-bell test pieces, prepare tubular test pieces as described in 2.1.1.3.3.

2.2.1.3.2 Dumb-bell test pieces. Prepare the test pieces from samples of insulation removed from the conductor, cutting it open in the direction of the axis of the core.

Remove any semi-conducting layers inside and/or outside the insulation mechanically, i.e. without using a solvent.

Cut each sample of insulation into pieces, each about 100 mm long, or longer if necessary (see 2.2.1.2), and mark

the pieces to identify the sample from which they are cut and their positions relative to each other in the original sample.

Grind or cut the pieces of insulation in order to obtain two parallel surfaces between the marker lines mentioned in the last paragraph of this subclause, care being taken to avoid undue heating. For polyethylene insulation employ cutting only, not grinding. After grinding or cutting, the thickness of the pieces shall be not less than 0.8 mm and not more than 2.0 mm.

Punch out a dumb-bell test piece in accordance with figure 19 from each prepared piece of insulation or, if possible, punch two dumb-bell test pieces side by side.

When the diameter of the core is too small to allow the dumb-bell in accordance with figure 19 to be used, then punch out a small dumb-bell test piece in accordance with figure 20 from each prepared piece of insulation.

If necessary, mark the central 20 mm for the larger dumb-bells, or 10 mm for the smaller dumb-bells, by two lines on each test piece, as shown in figures 19 and 20, immediately before the tensile test.

2.2.1.3.3 Tubular test pieces. Cut the samples of core into pieces each about 100 mm long, or longer if necessary for certain types of tensile testing grips, and remove the conductor and any other coverings, taking care not to damage the insulation. Mark the tubes to identify the sample from which they were prepared and their relative positions in the sample.

If necessary, mark the central 20 mm by two lines immediately before the tensile test.

2.2.1.4 Determination of cross-sectional area

2.2.1.4.1 General. Determine the cross-sectional area of each test piece as described in 2.2.1.4.2 or 2.2.1.4.3.

For test pieces that are to be aged, determine the cross-sectional area before the ageing treatment.

2.2.1.4.2 Dumb-bell test pieces. Calculate the cross-sectional area of each dumb-bell test piece from the width and the smallest of three thickness measurements of the piece between the marker lines.

If there is doubt about the uniformity of the width, measure this at the same three positions as the thickness at both surfaces of the test piece, taking the mean of the two measurements as the width at each position.

Use the smallest of the three cross sections thus calculated for evaluation of the tensile strength as described in 2.2.1.7.

Make the measurements using a micrometer or similar instrument giving a contact pressure not exceeding 0.07 N/mm^2 . Express the results in millimetres to two decimal places. In case of dispute, if measuring insulation which is a natural or synthetic rubber, the contact pressure shall not exceed 0.02 N/mm^2 ; this does not apply to sheathing material.

2.2.1.4.3 Tubular test pieces

2.2.1.4.3.1 General. Calculate the cross-sectional area of each tubular test piece by one of the methods described in 2.2.1.4.3.2 and 2.2.1.4.3.3. In case of dispute method 2.2.1.4.3.3 shall be used.

2.2.1.4.3.2 Calculate the cross-sectional area from the dimensions, using the equation

$$A = \pi (D - \delta)\delta$$

where

A is the cross-sectional area (in mm^2);

δ is the mean value of the thickness of the test piece (in mm) determined as described in 2.1.1 or 2.1.2 and rounded to two decimal places;

D is the mean value of the outer diameter of the test piece (in mm) determined as described in 2.1.3, and rounded off to two decimal places.

2.2.1.4.3.3 Calculate the cross-sectional area from the density, the mass and the length, using the equation:

$$A = \frac{1000 m}{\rho l}$$

where

m is the mass of the test piece (in g) to three decimal places;

l is the length (in mm) to one decimal place;

ρ is the density, measured as described in 2.4 on an additional sample of the same insulation or sheath (without ageing) (in g/cm^3) to three decimal places.

2.2.1.5 Ageing treatment. Each required ageing treatment shall be carried out on five test pieces (see 2.2.1.2) as described in 2.3 under the conditions specified in the relevant cable standard.

2.2.1.6 Conditioning of test pieces. Before the tensile test, all test pieces, whether unaged, or aged as described in 2.3, shall be kept for at least 3 h at a temperature of $23 \pm 2^\circ\text{C}$, for PVC, or $23 \pm 5^\circ\text{C}$ for other types of material.

2.2.1.7 Tensile testing procedure

2.2.1.7.1 Test temperature. Carry out the test at ambient temperature and complete each test within 5 min of the removal of the test piece from the conditioning chamber. In case of doubt, for PVC insulation, repeat the test at $23 \pm 2^\circ\text{C}$.

2.2.1.7.2 Distance between the grips and rate of separation

NOTE. The grips of the tensile testing machines may be either of a self-tightening type or not.

The total length between the grips shall be:

about 34 mm, for small dumb-bells as shown in figure 20;

about 50 mm, for dumb-bells as shown in figure 19;

about 50 mm, for tubes, if tested with self-tightening grips;

about 85 mm, for tubes, if tested with non self-tightening grips.

The rate of separation of the grips, for all materials except polyethylene of a density higher than 0.925 g/cm^3 at 23°C , shall be $250 \pm 50 \text{ mm/min}$.

For polyethylene of density higher than 0.925 g/cm^3 , the rate of separation shall be $25 \pm 5 \text{ mm/min}$ unless the manufacturer prefers to test at the higher rate of separation.

2.2.1.7.3 Measurements. Measure the breaking load and the distance between the two marker lines at rupture simultaneously on each test piece.

Ignore the measured values on any test piece which breaks in or near the grips. In case of doubt, mark the test pieces at a distance of about 5 mm from the last point of contact

of each set of grips, and ignore the measured values of any test piece which breaks outside these marks. If less than four valid results have been obtained, in order to calculate the tensile strength and elongation-at-break repeat the test.

2.2.1.8 Evaluation of results. Calculate the tensile strength by dividing the breaking load by the cross-sectional area of the unstretched test piece.

Calculate the elongation at break as the increase in the distance between the marker lines at rupture from the distance between the marker lines on the unstretched test piece, expressed as a percentage of the latter.

Record the median values of the results for each property.

2.2.2 Method of test for sheaths

2.2.2.1 General. This test is to determine the tensile strength and elongation at break of the sheathing material of the cable in the condition as manufactured and, when required by the relevant cable standard, after one or more accelerated ageing treatment(s).

The tensile tests on the aged and unaged test pieces shall be made in immediate succession.

The procedure is as follows.

(a) Take samples as described in 2.2.2.2.

(b) Prepare test pieces as described in 2.2.2.3.

(c) Determine the cross-sectional area of each test piece as described in 2.2.2.4.

(d) Condition the test pieces as described in 2.2.2.6.

(e) Carry out the tensile test as described in 2.2.2.7.

(f) Evaluate the results as described in 2.2.2.8.

2.2.2.2 Selection of samples. Take a sample of the cable or cord to be tested, or of the sheath removed from the cable, of sufficient size to provide a minimum of five test pieces for the tensile tests without ageing, and for the required number of test pieces for each of the tensile tests after ageing specified for the sheathing material in the relevant cable standard. Do not use a sample that shows signs of mechanical damage.

2.2.2.3 Preparation of test pieces

2.2.2.3.1 General. Whenever possible, prepare dumb-bell test pieces from the samples, as described in 2.2.2.3.2.

If the cable is of such small size that it is not possible to prepare dumb-bell test pieces, prepare tubular test pieces as described in 2.2.2.3.3.

2.2.2.3.2 Dumb-bell test pieces. Prepare test pieces from samples of sheath removed from the cable, cutting it open in the direction of the cable axis, in the same way as described for insulation in 2.2.1.3.2 with the following modifications.

The minimum thickness of the pieces shall be not less than 0.6 mm.

If the sheath has ridges on the inside caused by the cores, cut the sheath in the direction of the ridges for removal from the cable and eliminate the effect of the ridges in the grinding or cutting.

For polyethylene sheaths, the thickness of the dumb-bells need not be reduced to 2.0 mm when the full sheath thickness is greater, provided that the test pieces are smooth on both surfaces.

2.2.2.3.3 Tubular test pieces. Prepare test pieces from the samples of sheath in the same way as described for insulation in 2.2.1.3.3 with the following modification.

Remove all the components of the cable inside the sheath, including cores, fillers and inner coverings.

2.2.2.4 Determination of cross-sectional area. Calculate the cross-sectional area of each test piece as described in 2.2.1.4.2 or 2.2.1.4.3, noting that for tubular test pieces, if the sheath has ridges, the method in 2.2.1.4.3.3 shall be used.

2.2.2.5 Ageing treatment. Carry out each required ageing treatment on five test pieces (2.2.2.2) as described in 2.3 under the conditions specified in the relevant cable standard.

2.2.2.6 Conditioning of test pieces. Condition the test pieces as described in 2.2.1.6.

2.2.2.7 Tensile testing procedure. Carry out the tensile testing procedure as described in 2.2.1.7.

2.2.2.8 Evaluation of results. Evaluate the results as described in 2.2.1.8.

2.3 Thermal ageing methods

2.3.1 Ageing in an air oven

2.3.1.1 General. This test is to determine the effect on the tensile strength and elongation at break of accelerated ageing in an air oven, when specified in the relevant cable standard. When the test is to be carried out on prepared test pieces, and the temperature and duration are the same as those given for the loss of mass test described in 4.1, the two tests may be combined and the same test pieces used for both tests.

When the cable standard requires the test to be carried out on prepared test pieces, the procedure shall be as described in 2.3.1.3 and when the cable standard requires the test to be carried out on pieces of complete cable the procedure shall be as described in 2.3.1.4.

Compounds of different compositions shall not be tested in the same oven at the same time*.

2.3.1.2 Equipment. An oven with natural air flow or air flow under pressure shall be used. The air enters the oven in such a way that it flows over the surface of the test pieces and leaves near the top of the oven. The oven shall have not less than 8 and not more than 20 complete air changes per hour at the specified ageing temperature.

NOTE. Two methods of measuring the rate of airflow through an oven are given in 2.3.4.

When testing materials other than rubber, a rotating fan shall not be used inside the oven.

A rotating fan inside the air oven is normally permissible when testing rubber compounds, but in case of dispute, ageing shall be carried out in an oven which is designed to operate without a fan rotating inside it.

2.3.1.3 Procedure for prepared test pieces. Select samples as described in 2.2.1.2 or 2.2.2.2, prepare test pieces as described in 2.2.1.3 or 2.2.2.3 and determine the cross-sectional area as described in 2.2.1.4 or 2.2.2.4.

Carry out the ageing in an atmosphere having the composition and pressure of the ambient air.

Suspend the test pieces vertically and substantially in the middle of the oven so that each piece is at least 20 mm from any other piece.

If any of the test pieces are to be used for the loss of mass test, the test pieces shall not occupy more than 0.5 % of the volume of the oven.

Keep the test pieces in the oven at the temperature and for the time specified for the material in the relevant cable standard.

As soon as the ageing period is completed, remove the test pieces from the oven and leave them at ambient temperature, avoiding direct sunlight, for at least 16 h.

Carrying out the tensile test and evaluate the results, as described in 2.2.1.7 and 2.2.1.8.

2.3.1.4 Procedure for pieces of complete cable. Take three pieces of completed cable as described in 2.2.2.2.

Suspend the pieces of cable vertically and substantially in the middle of the oven so that each piece is at least 20 mm from any other piece.

The pieces of cable shall not occupy more than 2 % of the volume of the oven.

Keep the pieces of cable in the oven at the temperature and for the time specified in the relevant cable standard.

As soon as the ageing period is completed, remove the pieces of cable from the oven and leave them at ambient temperature, avoiding direct sunlight, for at least 16 h.

Then dismantle the three pieces of cable and prepare test pieces from the insulation of each core (up to a maximum of three cores) and from the sheath of each piece of cable, as described in 2.2, so that there are six test pieces from each core and six from the sheath.

If the test pieces need to be cut or ground to reduce their thickness to not more than 2 mm, this operation shall be effected, as far as possible, on the side which was not facing a material of different type in the complete cable. If it is necessary to cut or grind ridges on the side which was facing the different type of material, the material removed on that side shall be the minimum compatible with the adequate smoothing.

Determine the cross-sectional area of each test piece, condition the test pieces, carry out the tensile test and evaluate the results, as described in 2.2.1.4, 2.2.1.6, 2.2.1.7 and 2.2.1.8.

2.3.2 Ageing in an air bomb

2.3.2.1 General. This test is to determine the effect on the tensile strength and elongation at break of accelerated ageing in an air bomb, when specified in the relevant cable standard.

Compounds of substantially different compositions shall not be tested at the same time.

2.3.2.2 Equipment. An air bomb, which can be filled with air that is substantially free from oil and moisture to a pressure of 0.55 ± 0.02 MPa, and in which the temperature can be maintained at the value specified in the relevant cable standard shall be used.

2.3.2.3 Procedure. Select samples as described in 2.2.1.2 or 2.2.2.2 and prepare test pieces as specified in 2.2.1.3 or 2.2.2.3.

Determine the cross-sectional area of each test piece as described in 2.2.1.4.

Place the test pieces in the air bomb without touching one another.

The test pieces shall not occupy more than 10 % of the effective volume of the bomb.

*Alternatively, the problems of cross contamination are avoided by use of a cell type oven as described in BS 903 : Part A19.

Fill the bomb with air to the pressure given in 2.3.2.2, and raise the temperature to the value specified in the relevant cable standard.

Keep the test pieces in the bomb at the temperature and for the time specified for the material in the relevant cable standard.

As soon as the ageing period is completed, release the pressure gradually, so as to reach atmospheric pressure in not less than 5 min in order to avoid formation of porosity in the test pieces. Remove the test pieces from the bomb and leave them at ambient temperature, avoiding direct sunlight, for at least 16 h.

Condition the test pieces, carry out the tensile test and evaluate the results, as described in 2.2.1.6, 2.2.1.7 and 2.2.1.8.

2.3.3 Ageing in an oxygen bomb

WARNING. Use of the oxygen bomb entails a certain degree of danger unless handled with special care. It is essential that all necessary steps be taken to eliminate the risk of explosion resulting from abrupt oxidation.

2.3.3.1 General. This test is to determine the effect on the tensile strength and elongation at break of accelerated ageing in an oxygen bomb, when specified in the relevant cable standard.

Compounds of substantially different compositions shall not be tested at the same time.

2.3.3.2 Equipment. An oxygen bomb, which can be filled with commercial oxygen of not less than 97 % purity to a pressure of 2.1 ± 0.07 MPa, and in which the temperature can be maintained at the value specified in the relevant cable standard shall be used.

2.3.3.3 Procedure. Select samples as described in 2.2.1.2 or 2.2.2.2 and prepare test pieces as described in 2.2.1.3 or 2.2.2.3.

Determine the cross-sectional area of each test piece as described in 2.2.1.4.

Place the test pieces in the bomb without touching one another.

The test pieces shall not occupy more than 10 % of the effective volume of the bomb.

Fill the bomb with oxygen to the pressure given in 2.3.3.2, and raise the temperature to the value specified in the relevant cable standard.

Keep the test pieces in the bomb at the temperature and for the time specified for the material in the relevant cable standard.

As soon as the ageing period is completed, release the pressure gradually, so as to reach atmospheric pressure in not less than 5 min in order to avoid formation of porosity in the test pieces. Remove the test pieces from the bomb and leave them at ambient temperature, avoiding direct sunlight, for at least 16 h.

Condition the test pieces, carry out the tensile test and evaluate the results as described in 2.2.1.6, 2.2.1.7 and 2.2.1.8.

2.3.4 Methods of measuring airflow in ovens

2.3.4.1 General. The methods in 2.3.4.2 and 2.3.4.3 are suitable for determining the rate of airflow through an air oven as described in 2.3.1.2.

2.3.4.2 Method 1: indirect or power consumption method

2.3.4.2.1 Description of method. In this method, the additional power required to maintain the oven at a given temperature with its ports open, over that required to maintain the oven at the same temperature with its ports closed, is used as a measure of the quantity of air passing through the oven when the ports are open. The average power in watts (P_1) required to maintain the oven temperature at the specified ageing temperature when the ports are open is determined over a period of 30 min or longer. The ventilation ports (and, if necessary, the thermometer aperture) are then closed and the average power in watts (P_2) required to maintain the same temperature over a similar period is determined.

It is essential that the difference between the oven temperature and the ambient temperature should be the same for the two tests to within 0.2°C . The ambient temperature should be measured at a point about 2 m from the oven, approximately level with its base, and at least 0.6 m from any solid objects.

Equations (1) and (2) in 2.3.4.2.4 assume that when the ports are closed no air passes through the oven. Therefore, ensure that there are no leakages, seal the door joint with adhesive tape and see that all apertures including the inlet port are effectively closed.

2.3.4.2.2 Measurement with a wattmeter. If the power consumption is measured with a wattmeter, measure the total length of time, in seconds, for which the oven heaters are 'on' with a stop-watch and take the reading of the wattmeter once during each 'on' period. Take the average of the wattage readings multiplied by the total time registered by the stop-watch and divided by the duration of the test, in seconds, as the power in watts required to maintain constant temperature.

2.3.4.2.3 Measurement with a watt-hour or kilowatt-hour meter. If a watt-hour meter or a kilowatt-hour meter is to be used, divide the reading of the total energy consumption registered by the meter by the duration of the test, measured as a fraction of an hour. If a household kilowatt-hour meter is used, the dial units are too large to enable a sufficient accuracy to be obtained over a reasonably short test; therefore, use the rotating disc with which the meter is provided as the power consumption indicator. Put the meter into operation until the index mark on the disc is opposite the centre of the window, and then disconnect it until the start of the test.

To reduce the possible error, continue the test long enough to permit about 100 revolutions of the disc and preferably end the test when the mark on the disc is visible. If, however, the mark is out of sight at the end of the test, add an estimated fraction of a revolution. Start and stop the test at corresponding points on the 'on-off' heating cycle (e.g. at the moment when the heaters are switched on by the thermostat).

*1013.25 mbar = 101.325 kPa.

2.3.4.2.4 Calculation. The amount of air passing through the oven when the ports are open is given by the equations:

$$m = \frac{P_1 - P_2}{C_p (t_2 - t_1)} \quad (1)$$

$$V = \frac{3600 m}{\rho} \quad (2)$$

where

C_p is the specific heat of air at constant pressure (1.003 J/g);

t_1 is the ambient temperature (in °C);

t_2 is the oven temperature (in °C);

$P_1 - P_2$ is the difference in power consumption determined according to 2.3.4.2.1 (in W);

m is the mass of air passing per second (in g);

V is the volume of air passing per hour (in L);

ρ is the density of air in the laboratory at the time of test (in g/L).

NOTE. The density of air at a pressure of 1013.25 mbar* and 20 °C is 1.205 g/L.

Hence:

$$V = \frac{3600 (P_1 - P_2)}{1.003 \rho (t_2 - t_1)}$$

or

$$V = \frac{3590 (P_1 - P_2)}{\rho (t_2 - t_1)}$$

2.3.4.3 Method 2: direct and continuous method

2.3.4.3.1 Description of method. An air source at high pressure is passed through an air pressure regulator and the airflow through the oven is then directly monitored by a flowmeter.

The flowmeter described in 2.3.4.3.2.3 can be considered as fully reliable, easy to manufacture and to calibrate, and is suitable for the range of airflow rates involved. Tests have shown that the adoption of a slightly forced ventilation does not, in practice, alter the uniformity of the temperature at the various points in the oven.

2.3.4.3.2 Measuring equipment

2.3.4.3.2.1 High pressure air source, i.e. from a pipe system of air cylinders.

2.3.4.3.2.2 Air pressure regulator. A device to reduce the air pressure from the many atmospheres of the supply mains to the quite low pressure values needed for feeding the oven.

It is equipped with an adjustable valve which permits a constant pressure downstream.

2.3.4.3.2.3 Flowmeter. An instrument with which the rate or airflow can be measured. It is illustrated in figure 21 and operates on a manometric principle, with:

(a) a calibrated capillary tube, with an internal diameter of about 2 mm and a length of about 70 mm;

(b) a manometric tube with a double graduation of pressure difference ranging between 0 and ± 300 mm of water, using distilled water as the manometric liquid;

Figure 22 shows a typical calibration curve which permits the control of airflow up to 500 L/h or 600 L/h.

2.3.4.3.2.4 Air oven. An ordinary air oven to be operated when carefully sealed, including sealing round the inlet tube, which should preferably enter the oven through the bottom. The outflow hole, which should be at the top of the oven, is the only port to be open.

2.4 Methods for determining density

2.4.1 General. It is sometimes necessary to determine the density of a test piece as a step in another test method, for instance in determining the cross-sectional area in 2.2.1.4.3.3. Two methods are described in 2.4.2 and 2.4.3, but any alternative method is acceptable provided this gives at least the same accuracy as the suspension method given in 2.4.2, e.g. the methods given in BS 903 : Part A1 and BS 3715. In case of dispute the density bottle method described in 2.4.3 is the reference method to be used.

2.4.2 Suspension method (general method)

2.4.2.1 Principle. Small pieces of the material to be tested are immersed in a liquid that does not react with the material. Water is added until the pieces are in free suspension and the density of the liquid is determined by a hydrometer.

2.4.2.2 Apparatus and materials

2.4.2.2.1 Mixing cylinder.

2.4.2.2.2 Thermostat.

2.4.2.2.3 Hydrometer, calibrated at 23 °C, accurate to three decimal places.

2.4.2.2.4 Thermometer, with 0.1 °C divisions.

2.4.2.2.5 Ethanol (ethyl alcohol), of recognized analytical quality or another suitable liquid for densities below 1 g/mL.

2.4.2.2.6 Zinc chloride solution, for densities equal to or greater than 1 g/mL.

2.4.2.2.7 De-ionized water, complying with the requirements of BS 3978.

2.4.2.3 Procedure. From the insulation or the sheath to be tested, take a sample perpendicularly to the conductor axis and cut it into small pieces of 1 mm to 2 mm edge length.

If the density is expected to be lower than 1 g/mL, prepare a mixture of ethanol and de-ionized water (or other suitable mixture).

If the density is expected to be 1 g/mL or higher, prepare a mixture of zinc chloride and de-ionized water (or other suitable mixture).

Place two or three pieces of the sample in the liquid, which is at a temperature of 23 ± 0.1 °C, avoiding any formation of air bubbles. Add de-ionized water to the liquid until the pieces are freely suspended within the liquid in the mixing cylinder, ensuring that the liquid mixture is homogeneous and is maintained at the specified temperature.

Determine the density of the liquid mixture by means of the hydrometer, in g/mL to three decimal places. Take this as the density of the samples under test.

2.4.3 Density bottle method (reference method)

2.4.3.1 Principle. The mass of some small pieces of the material to be tested, contained in a density bottle, is determined and this is compared with the mass of an

equal volume of liquid of known density, obtained by weighing the bottle completely filled with liquid containing the specimen, and again weighing completely filled without the specimen.

2.4.3.2 Apparatus and materials

2.4.3.2.1 *Balance*, with a precision of 0.1 mg.

2.4.3.2.2 *Density bottle*, of 50 mL capacity.

2.4.3.2.3 *Liquid bath*, provided with a thermostatic control.

2.4.3.2.4 *Liquid*, of known density that does not react with the material (e.g. ethanol of recognized analytical quality)*.

2.4.3.3 *Specimen*. Take a sample from the bare insulation or sheath with a mass not less than 1 g and not greater than 5 g. Make the specimen by cutting the sample of insulation or sheath into a number of small pieces; cut small tubes of insulation or sheath longitudinally into two or more parts to prevent the enclosure of air bubbles.

2.4.3.4 *Conditioning*. For the test, the specimen shall be at an ambient temperature of $23 \pm 2^\circ\text{C}$.

2.4.3.5 *Procedure*. (Attention is drawn to the Warning Note at the beginning of 1.3.) Weigh the bottle empty and dry (m_1). Introduce a suitable quantity of the specimen into the bottle and weigh again (m_2). Cover the test specimen with the immersion liquid (e.g. 96 % ethanol) and remove all air from the specimen by, e.g., applying a vacuum to the bottle standing in a desiccator. Break any vacuum applied and fill the bottle with immersion liquid and bring to a temperature of $23 \pm 0.5^\circ\text{C}$ in a liquid bath, the bottle being filled to the limit of its capacity. Wipe the bottle dry and weigh with its contents (m_3). Empty the bottle and refill with immersion liquid. Remove all air, bring the bottle and its contents to a temperature of $23 \pm 0.5^\circ\text{C}$, ensure that it is filled to the limit of its capacity and re-weigh (m_4).

2.4.3.6 *Calculation*. Calculate the density at 23°C , ρ_{23} , in g/mL, of the insulation or sheath from the following equation:

$$\rho_{23} = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \rho_l$$

where

$m_2 - m_1$ is the mass of the specimen (in g);

$m_4 - m_1$ is the mass of liquid required to fill the bottle (in g);

$m_3 - m_2$ is the mass of liquid required to fill the bottle when containing the specimen (in g);

ρ_l is the density of the immersion liquid at 23°C (in g/mL).

NOTE. ρ for 96 % ethanol is 0.7988 g/mL.

If the insulation or sheath is filled polyethylene, apply a correction to the result as given in 2.4.3.7.

2.4.3.7 *Correction for filled polyethylene*. Antioxidants and organic coloured pigments which are normally used in negligible quantities can be ignored. However, where other additives such as mineral fillers are used in considerable quantities, it is necessary to make an appropriate correction. Determine the nature and quantity of the additive by reputable chemical means and, unless the only additive is carbon black, correct the value using the following equation:

$$\rho = \frac{m \times \rho_c \times \rho_F}{(m_c \times \rho_F) - (m_F \times \rho_c)}$$

where

ρ is the density of the polyethylene, corrected value (in g/mL);

ρ_c is the density, ρ_{23} , of polyethylene compound calculated as given in 2.4.3.6 (in g/mL);

ρ_F is the density of the filler additive, measured value (in g/mL);

m is the mass of polyethylene polymer ($m_c - m_F$) (in g);

m_c is the mass of polyethylene compound, measured value (in g);

m_F is the mass of filler, measured value (in g).

For compounds containing only carbon black as the filler, make the correction by means of the following simplified equation:

$$\rho = \rho_c - 0.0045 \times c_B$$

where

c_B is the percentage of carbon black by mass.

2.5 Shrinkage test

2.5.1 *General*. This test is to determine the shrinkage of insulation during heat treatment, when required by the relevant cable standard.

2.5.2 *Selection of samples*. Take one sample, about 0.3 m in length, of each core to be tested at least 0.5 m away from the end of the cable length.

2.5.3 *Preparation of test pieces*. Remove all coverings, except adherent semi-conducting screens, from the samples without delay.

Within an interval of not more than 5 min from the time of cutting the samples, mark a test length of 200 ± 5 mm on the middle part of each piece of core. Measure the distance between the marks to an accuracy of 0.5 mm. Prepare each test piece by cutting and removing the insulation from both ends of each sample up to positions between 2 mm and 5 mm away from the marks.

2.5.4 *Procedure*. Carry out the test in an air oven as described in 2.3.1.2.

Support the test pieces, by means of either:

- (a) a specially-prepared talc bath; or
- (b) a device on which the bare ends of conductors can rest.

In either case the combined volume of test apparatus and test piece shall not exceed 10 % of the volume of the oven.

Preheat the oven with the test apparatus in place for a minimum of 2 h, at the temperature specified in the appropriate cable standard, before the test piece is introduced.

Support the test pieces horizontally on the surface of the talc bath, or by the bare ends of conductors.

If the talc bath method is used, ensure that there is sufficient depth of talc so that the test piece does not touch the bottom of the bath. Spread the talc evenly, without compacting it, at the start of each test, so as to permit free movement of the insulation.

With the test pieces in place in the air oven, heat them for

*It is assumed that ethanol or similar materials will only be handled by experienced people aware of its flammability.

the temperature and for the time specified in the relevant cable standard.

At the end of the test period remove the apparatus with the test pieces still in place and allow them to cool in air to room temperature.

Re-measure the distance between the two marks on each piece to the nearest 0.5 mm.

In cases of dispute, use the talc bath method as the reference method.

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

2.6 Gravimetric water absorption test

2.6.1 General. This test is to determine the water absorption of insulation, when required by the relevant cable standard.

2.6.2 Selection of samples. Select samples as specified in the relevant cable standard, or, if not so specified, take a length of completed cable sufficient to allow the preparation of two test pieces from each core as described in 2.6.3.

2.6.3 Preparation of test pieces. Remove all coverings from the cores.

If the nominal insulation thickness is not less than 0.7 mm, but less than 1.4 mm, prepare two test pieces from each core by cutting strips about 4 mm wide and between 80 mm and 100 mm long, longitudinally in the insulation.

If the nominal insulation thickness is 1.4 mm or more, prepare two test pieces from each core by grinding or cutting slices of insulation between 1.2 mm and 1.5 mm thick, with surfaces approximately parallel and free from roughness.

2.6.4 Procedure. Thoroughly clean the surfaces of the test pieces, and heat them at $70 \pm 2^\circ\text{C}$ under vacuum (residual pressure about 0.1 kPa) for 72 h. Compounds of substantially different compositions shall not be treated in the same cell or oven at the same time.

After this treatment, cool the strips in a desiccator and weigh them to the nearest 0.1 mg (mass m_1).

Then immerse the test pieces in de-ionized water at the temperature and for the time specified in the standard for the type of cable. Immerse each test piece completely in a separate glass tube equipped with a condenser, or in a beaker covered with a glass lid. If a condenser is used, cover its upper part with aluminium foil to prevent any contamination.

After the time specified in the relevant cable standard or after 14 days, if the time is not specified in the cable standard, transfer the test pieces into de-ionized water at room temperature and allow them to cool. Then remove each test piece from the water, shake it to detach any adherent drops, dry it with filter paper leaving no fibres, and weigh it to the nearest 0.1 mg (mass m_2).

2.6.5 Evaluation of results. Calculate the mass variation from the equation:

$$V = \frac{m_2 - m_1}{A}$$

where

V is the mass variation (in mg/cm^2);

m_1 is the mass of the test piece after treatment under vacuum (in mg);

m_2 is the mass of the test piece after immersion in water (in mg);

A is the total surface area of the test piece (in cm^2).

Record the mean value of the variation in mass of the two test pieces as the result.

2.7 Method for measurement of green and yellow proportion on the insulation of circuit protective conductors

2.7.1 General. It is sometimes necessary to check the requirements for the proportion of green and yellow colours on the insulation of circuit protective conductors as required by the relevant cable standard. The following method is recommended for use in case of dispute but is not appropriate where the colour marking forms a spiral on the insulation.

2.7.2 Selection of samples. Take two samples of the green and yellow core, each approximately 100 mm in length, from places separated by at least 2 m.

2.7.3 Preparation of test pieces. Measure a 15 mm length from each of the samples and cut three sections of insulation from each 15 mm test piece length, one from each end and one from the centre.

2.7.4 Procedure. Project a $\times 10$ minimum magnified image of each cross section onto a ground glass screen and make a visual estimation of the centre of the cross section and of the colour boundaries at the outer surface of the core (see figure 42). Measure to the nearest degree, using a protractor placed on the magnified image, the angle subtended at the centre of the cross section by each portion of green (or yellow if appropriate).

2.7.5 Evaluation of results. Calculate the percentage proportion (G_P) of green (or yellow if appropriate) for each cross section using the following equation:

$$G_P = \frac{A_T}{360} \times 100$$

where

A_T is the total sum of each of the angles of rotation through each of the portions of green (or yellow if appropriate).

Calculate the mean of these and round to the nearest integer.

Compare the result with the requirement specified in the relevant cable standard.

Section three. Methods of test for properties relevant to cross-linked compounds

3.1 Mineral oil immersion test

3.1.1 General. The purpose of this test is to check compliance of oil resisting compounds with the requirements of the relevant cable standard.

3.1.2 Oil to be used. Unless otherwise agreed between the purchaser and the supplier, the characteristics of the mineral oil to be used are as follows:

aniline point (BS 2000 : Part 2)	93 ± 3 °C
kinematic viscosity at 98.9 °C (BS 2000 : Part 72)	20 ± 2 (m ² /s) × 10 ⁻⁶ *
flash point (minimum) (BS 4689)	240 °C

NOTE. These characteristics are as specified for No. 2 oil in BS 903 : Part A16 : 1971.

3.1.3 Procedure

3.1.3.1 Selection of samples. Take three samples as described in 2.2.2.2, prepare two test pieces from each sample as described in 2.2.2.3, and determine the cross-sectional area of each test piece as described in 2.2.2.4.

3.1.3.2 Oil immersion. Freely suspend the test pieces without touching one another in an oil bath, previously heated to, and maintained at, the temperature specified in the relevant cable standard for the specified time.

At the end of this time, remove the test pieces from the oil, blot them lightly to remove excess oil and suspend them in air at ambient temperature for at least 16 h.

3.1.3.3 Conditioning of test pieces. Condition the test pieces as described in 2.2.1.6.

3.1.3.4 Tensile testing procedure. Carry out the tensile test as described in 2.2.1.7.

3.1.4 Evaluation of results. Calculate the tensile strength and the elongation at break as described in 2.2.1.8, using the cross-sectional area measured before immersion in oil.

Record the difference between the median value for each property after immersion, expressed as a percentage of the median value obtained on the untreated test pieces.

3.2 Ozone resistance test

WARNING. Attention is drawn to the highly toxic nature of ozone. A Technical Data Note published by HM Factory Inspectorate gives threshold limit values (TLV) for chemical substances in the work-room environment. Reference to this document shows that the recommended TLV for ozone is 0.1 p.p.m. (parts of ozone per million parts of air by volume), i.e. 0.1 p.p.m. is the maximum average concentration to which workers may safely be exposed during a normal working week. However, it is essential that efforts are made to minimize exposure at all times and 0.1 p.p.m. should be regarded as the absolute maximum with an appreciably lower maximum average.

3.2.1 General. The purpose of this test is to check resistance of insulating materials to ozone.

The test method is described in 3.2.2 and ways of determining ozone concentration are given in 3.2.3. The test method is based in part on the test method given in BS 903 :

Part A43, to which reference should be made for details of suitable equipment and general information on ozone testing.

3.2.2 Test method

3.2.2.1 Test apparatus

NOTE. Suitable apparatus is illustrated in figure 23.

* 1 m²/s = 10⁶ cSt.

3.2.2.1.1 A device for generating a controlled amount of ozone.

3.2.2.1.2 A means for circulating ozonized air, under controlled conditions of humidity and temperature through a chamber containing the specimen to be treated.

3.2.2.1.3 A means for determining ozone concentration.

3.2.2.2 Sampling. Whether the cable is single or multicore, only one core need be tested. Cut sufficient length of core from a position not less than 1.5 m from the end of the length of cable to provide two test pieces, unless the core has an extruded semi-conducting layer on the outside, in which case take sufficient for four test pieces.

3.2.2.3 Preparation of test pieces. Remove any protective coverings present on the core without damaging the insulation, unless these were applied directly to the insulation prior to vulcanization and are adherent to it.

If the core has a semi-conducting screen in the form of tape on the outside, remove this.

If the core has an extruded semi-conducting layer on the outside, remove this from two pieces and leave it in position on the other two.

3.2.2.4 Bending of test pieces. Carry out the bending at room temperature or 20 °C, whichever is higher, using a brass, aluminium or wooden mandrel having the appropriate diameter given in table 1.

Table 1. Diameter of bending mandrel for ozone resistance test

Outside diameter of core <i>D</i>	Mandrel diameter as a multiple of the core diameter
mm	
Not greater than 12.5	4
Greater than 12.5, not greater than 20.0	5
Greater than 20.0, not greater than 30.0	6
Greater than 30.0, not greater than 45.0	8
Greater than 45.0	10

If the core does not have an extruded core screen, bend one sample in the direction and plane of its existing curvature, without twisting, for one complete turn around a mandrel and bind it with twine or tape where the ends cross. Bend a second test piece of the same core similarly in the plane of its existing curvature, but in the opposite direction (see figure 24).

If the core as manufactured has an extruded core screen, bend two samples as above, one with the semi-conducting layer removed and one with the semi-conducting layer left in position, in each direction.

If the test piece is too rigid to permit the ends to be crossed, bend and tie it so that at least a 180 ° bend of the specified mandrel diameter is obtained.

3.2.2.5 Conditioning of test pieces. Wipe the surface of each test piece with a clean cloth to remove dirt or moisture. Keep the bent test pieces on their mandrels in air at room temperature without any further treatment for between 30 min and 45 min before exposing to ozone.

3.2.2.6 Exposure to ozone. Expose, for the specified period the conditioned test pieces, in a chamber fitted with a test cock and maintained at a temperature of 25 ± 1 °C to a circulating current of air having the ozone concentration specified in the cable standard. Maintain the air flow