

LV and MV polymeric insulated cables for use by distribution and generation utilities —

Part 2: Methods of test

(Implementation of HD 605)

ICS 29.060.20

Committees responsible for this British Standard

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- Association of Consulting Engineers
- British Approvals Service for Cables
- British Cable Makers Confederation
- British Plastics Federation
- ERA Technology Ltd.
- Electricity Association
- Engineering Equipment and Materials Users' Association
- Institution of Incorporated Executive Engineers
- London Underground Ltd.
- UK Steel Association

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Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Section 1. General	
1.1 Scope	1
1.2 Normative references	1
1.3 Classification of tests	2
1.4 Sampling	2
1.5 Test conditions	2
Section 2. Non-electrical tests	
2.1 Dimensional measurements	3
2.2 Mechanical tests on non-metallic components	7
2.3 Mechanical tests on metallic components	10
2.4 Non-electrical tests on samples of complete cable	10
2.5 Physical and chemical tests	18
Section 3. Electrical tests	
3.1 Electrical resistance	25
3.2 Voltage tests	25
3.3 Insulation resistance tests	28
3.4 <i>Not applicable</i>	30
3.5 <i>Not applicable</i>	30
3.6 Spark tests	30
3.7 <i>Not applicable</i>	30
3.8 Heating cycle test	30
3.9 Measurements of electrical resistivity of the semi-conducting screens	32
3.10 Partial discharge test	36
3.11 Tan δ measurement	38
3.12 <i>Not applicable</i>	38
3.13 Adherence of screens at short circuit temperature	38
3.14 Resistivity test for water blocking tape	39
Section 4. Fire performance tests	
4.1 Flame propagation tests	41
4.2 Smoke emission tests	43
4.3 Corrosive gas emission tests	46
Section 5. Long term tests	
5.1 Thermal endurance tests	53
5.2 Pulling lubricant immersion test	59
5.3 Long term water immersion test	59
5.4 Long term voltage test	60
Bibliography	65
Figure 2.1.10.5 — Irregularities of semi-conducting layers and insulation	6
Figure 2.2.2.2 — Test piece for tear resistance test method 2	7
Figure 2.4.3 — Sheath penetration test rig	13
Figure 2.4.5 — Abrasion test	14
Figure 2.4.6 — Cut through tool for testing cable sheaths	15
Figure 2.4.9 — Equipment for water penetration tests	16
Figure 2.5.5 — Dishes and templates	20

	Page
Figure 2.5.9 — Apparatus for measuring swell height of water blocking tape	22
Figure 2.5.14 — Electrochemical test of pad material or semi-conducting tape	24
Figure 3.3.1 — Height of shaped conductors and cores	29
Figure 3.9.3a) — Test piece and arrangement of electrodes for measurement of resistivity of conductor screen of circular core	34
Figure 3.9.3b) — Test piece and arrangement of electrodes for measurement of resistivity of insulation screen of circular core	35
Figure 3.9.3c) — Arrangement of test piece, electrodes and insulating strips for measurement of resistivity of conductor and insulation screens of shaped core	36
Figure 4.2.2 — Arrangement for smoke test method 2	45
Figure 4.3.1.1 — Diagrammatic arrangement of the pyrolysis line gas collection and recording of acid gas emissions for test method 1	48
Figure 4.3.1.2 — Test behaviour for method 1	49
Figure 5.1.1 — Accelerated ageing of a cable with a 40 year service life at a mean operating temperature of 40 °C	54
Figure 5.1.2 — Accelerated ageing of a cable with a 40 year service life at a mean operating temperature of 55 °C	55
Figure 5.1.3 — Accelerated ageing of a cable with a 40 year service life at a mean operating temperature of 60 °C	56
Figure 5.1.4 — Accelerated ageing of a cable with a 40 year service life at a mean operating temperature of 75 °C	57
Table 2.4.5 — Vertical force on cable during abrasion test	12
Table 3.1.2 — Temperature correction multiplication factors	26
Table 5.1.1 — Variation of accelerated ageing time with activation energy	58
Table 5.3.1.1 — Minimum insulation resistance	59
Table 5.3.1.2 — Test voltage	60

Foreword

BS 7870 was prepared by Technical Committee GEL/20. It implements the nationally applicable parts of Harmonization Documents HD 603, 604, 605, 620, 622, 626 and 627, published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board.

Amendment No. 1 introduces the method for the harmonized long duration test that was published by CENELEC in 2002 as HD 605 A3. It also draws attention to the risks of water contamination by *Legionella pneumophila* bacteria during conditioning and ageing procedures.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to text carry the number of the amendment. For example, text altered by Amendment No. 1 is indicated by **A1** **A1**.

BS 7870 applies to cables for fixed installations having a rated voltage U_0/U up to and including 19/33 kV, and is published as a series of separate parts and sections, as listed in the table in the foreword of Part 1.

BS 7870-2 implements the relevant parts of HD 605 and is to be read in conjunction with BS 7870-1:1996

This new edition of BS 7870-2 implements the parts of amendment no. 1 to CENELEC HD 605 that are applicable to the United Kingdom. It supersedes BS 7870-2:1996, which is withdrawn.

The numbering system used in this part aligns with the numbering system used in HD 605 to facilitate cross-reference except for Section 1. As other Harmonization Documents are implemented, this part will be revised so that all the relevant additional methods of test are included.

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

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

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 65 and a back cover.

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Section 1. General

1.1 Scope

BS 7870-2 collates and specifies the additional test methods to be used for testing polymeric insulated and sheathed electric cables, of rated voltage up to and including 19/33 kV, intended for use by distribution and generation utilities.

Test methods in this part of BS 7870 are additional to those already harmonized, e.g. those given in BS 4066 and BS EN 60811, and are used for testing cable types specified in Parts 3 to 8.

Full test conditions (e.g. temperatures, durations) and/or test requirements are not specified in this part. Such data needed to carry out the tests are given in the particular sections.

Tests applicable to each type of cable are given in the particular sections, which state also the sequence, the frequency of test, and the possibility of repeating tests.

NOTE The words “particular section” refer throughout to the section of BS 7870 in which a particular cable type is specified.

1.2 Normative references

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

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

BS 903-A26:1995, *Physical testing of rubber — Part A26: Method for determination of hardness*.

BS 903-A59:1990, *Physical testing of rubber — Part A59: Methods using plastimers*.

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

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

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

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

BS 6360:1991, *Specification for conductors in insulated cables and cords*.

BS 6469-99.2:1992, *Insulating and sheathing materials of electric cables — Part 99: Test methods used in the United Kingdom but not specified in Parts 1 to 5 — Section 2: Electrical tests*.

BS 7622-1, *Measurement of smoke density of electric cables burning under defined conditions — Part 1: Test apparatus*.

BS 7622-2, *Measurement of smoke density of electric cables burning under defined conditions — Part 2: Test procedure and requirements*.

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

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

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

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

BS EN 60811-2-1:1998, *Insulating and sheathing materials of electric and optical cables — Common test methods — Part 2-1: Methods specific to elastomeric compounds — Ozone resistance, hot set and mineral oil immersion tests*.

IEC 60502, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV)*.

IEC 60502-2, *Cables for rated voltages from 6 kV ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ kV)*.

1.3 Classification of tests

The classification of tests is given in BS 7870-1.

1.4 Sampling

If a marking is indented in the insulation or sheath surface, the samples used for the tests shall be taken so as to include such markings.

For multicore cables, except for the test specified in **2.1.1**, not more than three cores (of different colours, if available) shall be tested unless otherwise specified.

NOTE The size and number of samples are given either in this part of BS 7870 or in the particular cable specifications.

1.5 Test conditions

1.5.1 Ambient temperature

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

1.5.2 Tolerance on temperature values

Unless otherwise specified in the particular specification, the tolerance on temperature values quoted in the test methods shall be as follows:

Specified temperature, t °C	Tolerance °C
$-40 \leq t \leq 0$	± 2
$0 < t \leq 50$	according to relevant clause
$50 < t \leq 150$	± 2
$t > 150$	± 3

1.5.3 Frequency and waveform of power-frequency test voltages

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

1.5.4 Pre-conditioning

Where preconditioning is specified, the tests shall be carried out not less than 16 h after the extrusion or cross-linking, if any, of the insulating or sheathing compounds.

Section 2. Non-electrical tests

2.1 Dimensional measurements

2.1.1 Measurement of insulation thickness

2.1.1.1 Procedure

The thickness of insulation shall be measured in accordance with BS EN 60811-1-1:1995, 8.1.

Conformity shall be checked on each core of cables having up to five cores, and on the number of cores stated in the individual specification for cables with more than five cores.

2.1.1.2 Evaluation of results

The average of the values (expressed in millimetres), obtained as specified in the individual specification for the insulation from each core, shall be calculated to two decimal places and rounded off as given below. This shall be taken as the average value of the thickness of insulation.

If in the calculation the second decimal figure is five or more, the first decimal figure shall be raised to the next number thus, for example, 1.74 shall be rounded off to 1.7 and 1.75 to 1.8.

The lowest of all values obtained shall be taken as the minimum thickness of insulation at any place.

2.1.2 Measurement of non-metallic sheath thickness

2.1.2.1 Procedure

The thickness of sheath shall be measured in accordance with BS EN 60811-1-1:1995, 8.2

2.1.2.2 Evaluation of results

The average of the values (expressed in millimetres), obtained as specified in the individual specification for the sheath, shall be calculated to two decimal places and rounded off as given below. This shall be taken as the average value of the thickness of the sheath.

If in the calculation the second decimal figure is five or more, the first decimal figure shall be raised to the next number, thus, for example, 1.74 shall be rounded off to 1.7 and 1.75 to 1.8.

The lowest of all values obtained shall be taken as the minimum thickness of sheath at any place.

2.1.3 Measurement of cable dimensions

2.1.3.1 Measurement of overall dimensions

Unless otherwise specified the samples taken in accordance with 2.1.1 or 2.1.2 shall be used.

The measurement of the overall diameter of any circular cable and of the overall dimensions of flat cables with a major dimension not exceeding 15 mm shall be carried out in accordance with BS EN 60811-1-1:1995, 8.3.

For the measurement of flat cables with a major dimension exceeding 15 mm, a micrometer, a profile projector or similar equipment shall be used.

The mean of the values obtained shall be taken as the mean overall dimensions.

2.1.4 Measurement of wires, strips and tapes

2.1.4.1 Conductor wires

Measurement of the diameter of conductor wires (class 5 conductors) shall be carried out as follows.

a) Sampling

Take at random either 10 % of the total number of wires, rounded upwards, or 10 wires, whichever is the lowest, from one core of each length of cable selected for the test.

b) Method

Determine the diameter of each wire with a micrometer by taking a measurement in three positions, approximately 300 mm away from each other. The readings shall be made to two decimal places. Take the average of the three measurements to be the wire diameter.

2.1.4.2 *Not applicable*

2.1.4.3 *Wires, strips and tapes for armour*

Measurements shall be carried out as follows.

a) *Round wires*

Take at random 10 % of the total number of wires from a sample of completed cable. Determine the diameter of each wire by using a micrometer with flat noses and taking two measurements at right angles to each other. Take the average value as the wire diameter.

b) *Flat wires or strips*

Take at random 10 % of the total number of flat wires or strips from a sample of completed cable. Determine the thickness and width of each flat wire by using a micrometer or vernier calliper with flat noses. Take the average values as the wire thickness and width respectively.

c) *Metallic tapes thickness*

Take and straighten a sample of each armour tape, remove the non metallic coating if any, and determine the tape thickness at six different places by using a micrometer or vernier calliper with flat noses. Take the smallest value to be compared with the specified thickness with a tolerance given in the particular specification.

2.1.5 Measurement of thickness of metallic sheath

Measurements shall be made by one of the following methods.

a) *Strip method*

The measurement shall be made on a test piece of sheath about 50 mm in length removed from the finished cable length. The test piece shall be taken a sufficient distance from the cable end to allow a proper measurement to be made.

The piece shall be slit longitudinally and carefully flattened. After cleaning the test piece, a sufficient number of measurements shall be taken along the circumference of the sheath and not less than 10 mm away from the edge of the flattened piece to ensure that the minimum thickness is measured. The measurement shall be made with a micrometer with plane faces of 4 mm to 8 mm diameter and an accuracy of ± 0.01 mm.

The average of the values (expressed in millimetres), obtained as specified in the individual specification for the sheath, shall be calculated to two decimal places and rounded off as given below. This shall be taken as the average value of the thickness of the sheath.

If in the calculation the second decimal figure is five or more, the first decimal figure shall be raised to the next number, thus, for example, 1.74 shall be rounded off to 1.7 and 1.75 to 1.8.

The lowest of all values obtained shall be taken as the minimum thickness of sheath at any place.

b) *Ring method*

The measurements shall be made on a ring of the sheath carefully cut from the sample. The thickness shall be determined at a sufficient number of points around the circumference of the ring to ensure that the minimum thickness is measured.

The measurements shall be made with a micrometer having either one flat nose and one ball nose, or one flat nose and a flat rectangular nose 0.8 mm wide and 2.4 mm long. The ball nose or the flat rectangular nose shall be applied to the inside of the ring. The accuracy of the micrometer shall be ± 0.01 mm.

2.1.6 *Not applicable*

2.1.7 *Not applicable*

2.1.8 Measurement of the gap between non-metallic tapes of taped bedding

Measure the gap between the adjacent edges of each bedding tape at right angles to the tape, and also the tape width, on a sample of cable 300 mm long, taken not less than 150 mm from the end of a factory length.

Take the measurements by any suitable means in which the error of determination does not exceed 0.5 mm. Measure the gaps at four positions approximately 50 mm apart along the length of the sample.

2.1.9 Measurement of rubber layer thickness

2.1.9.1 *Single rubber layer*

The diameters over the copper concentric neutral/earth conductor and the laid up cores shall be determined by a diameter tape at the same position. The nominal thickness of the rubber layer shall be taken as half the difference between these two diameters, less the diameter of one copper wire comprising the neutral/earth layer.

2.1.9.2 *Double rubber layer*

The diameters over the anti-corrosion layer and over the core of single-phase cables, or over the laid-up cores of three-phase cables, shall be determined by a diameter tape at the same position. The average thickness of the anti-corrosion layer shall be taken as half the difference between these two diameters. For three-phase cables with circular conductors and without fillers the value indicated by the diameter tape measurement over the cores shall be increased by 10 % to give the true diameter over the laid-up cores.

2.1.10 Irregularities of semi-conducting layers and insulation

2.1.10.1 *Not applicable*

2.1.10.2 *Not applicable*

2.1.10.3 *Not applicable*

2.1.10.4 *Not applicable*

2.1.10.5 *Method 5 — Method for inspection for protrusions, contaminants and discoloured particles in the insulation*

This test method is to determine the presence of discontinuities at the semi-conducting screen/insulation interfaces and the presence of contaminants (opaque impurities) and discoloured particles in the insulation. Testing shall be carried out as follows.

a) *Sample preparation*

Test pieces shall be prepared from 300 mm lengths of core. Samples 25 mm long shall be cut from each end of the core to give samples A₁ and A₂.

The remaining portion shall be cut into two pieces of equal length to give samples B and C.

The insulation screen shall be removed from sample B and this shall be cut into further pieces to give samples B₁ and B₂.

b) *Test method to determine discontinuities*

Immerse test pieces A₁ and B₁ in glycerol or polyethylene glycol or similar liquid contained in a glass beaker and maintained at 130 °C to 150 °C, or alternatively heat up the samples in an air oven to a similar temperature. Allow the test pieces to attain the approximate liquid or air temperature such that the insulation becomes transparent.

The interfaces shall be examined in a good light with normal or corrected vision without magnification.

Examine by viewing along the conductor axis the conductor screen/insulation and insulation screen/insulation interfaces and the insulation of the sample A₁, and by viewing radially the conductor screen/insulation interface and the insulation of the second sample B₁.

The conductor and insulation screens shall be bonded to the insulation with no traces of dissociation between them [see Figure 2.1.10.5a)]. There shall be no detectable traces of any inclusions between the screen and the insulation [see Figure 2.1.10.5b)]. The insulation material shall not have broken through the screen [see Figure 2.1.10.5c)] nor shall there be any penetration of the insulation by the screen material [see Figure 2.1.10.5d)].

Repeat for the remaining samples A₂ and B₂.

c) *Test method to determine contaminants and discoloured particles*

Samples for examination shall be produced by cutting wafers from sample C.

At least 5 cm³ of insulation shall be examined using a microscopic based measuring system at a minimum magnification of ×20.

Requirements are as follows:

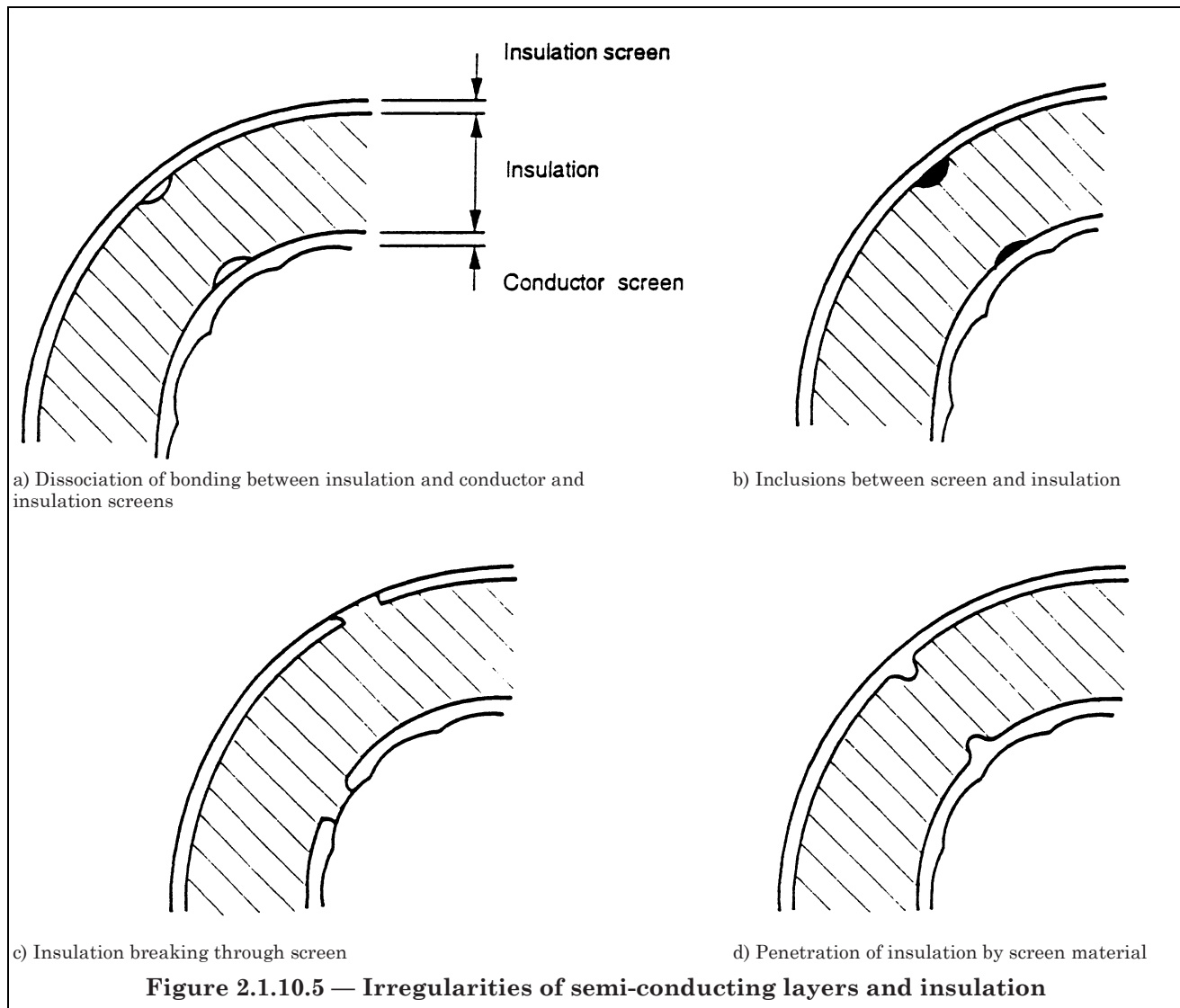
Contaminants

0.05 mm < largest dimension ≤ 0.15 mm 1 per cm³ maximum

0.15 mm < largest dimension rejected

Discoloured particles

1.25 mm < largest dimension rejected



2.2 Mechanical tests on non-metallic components

2.2.1 Not applicable

2.2.2 Determination of tear resistance of the protective sheath

2.2.2.1 Method 1 Not applicable

2.2.2.2 Method 2

Testing shall be carried out as follows.

a) General

This test method is to determine the tear resistance of sheathing materials.

The tear resistance shall be measured along the direction of the cable axis and also where possible, at right angles following the direction of the cable circumference.

b) Preparation of test pieces

Prepare six test pieces having dimensions as shown in Figure 2.2.2.2, with a thickness not greater than 4.0 mm and not less than 1.0 mm. Cut these, preferably along the direction of the cable axis, by means of a sharp knife or die from portions of the sheath from which all irregularities or corrugations, if present, have been removed by grinding or cutting. Make a central longitudinal cut, perpendicular to the width of the test piece, with a sharp razor to a point 3.8 mm from the wider end.

c) Conditioning of test pieces

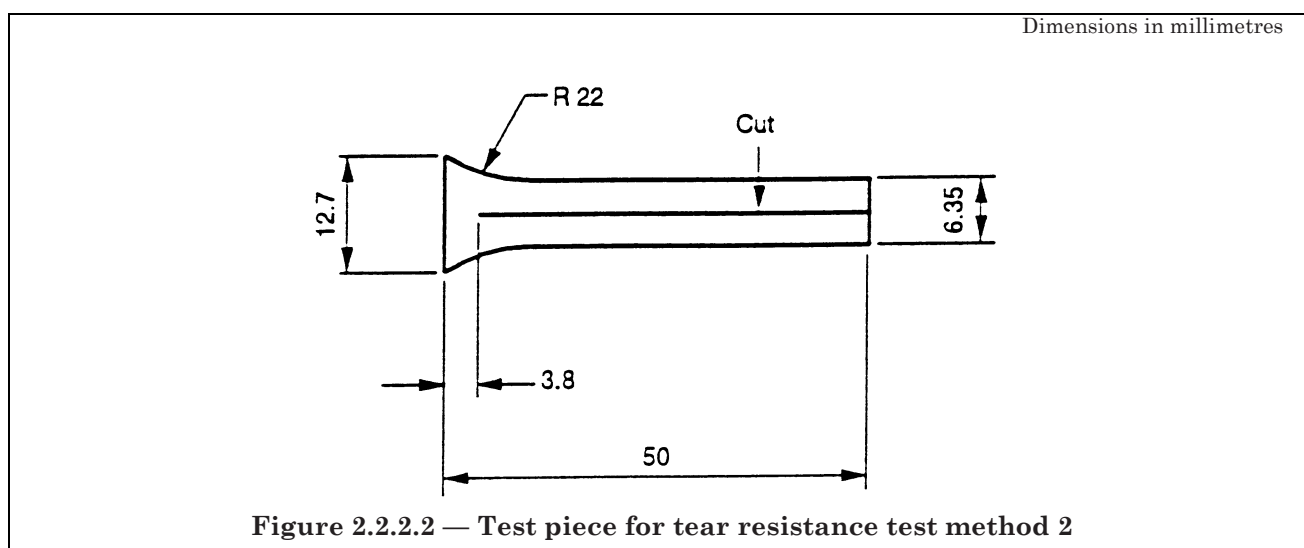
Before the start of the test, keep the test pieces for at least 3 h at the ambient temperature at which the test is to be carried out, which shall be $(20 \pm 5) ^\circ\text{C}$, and commence testing within 5 min of removal from the conditioning chamber.

d) Procedure

Test each test piece in the following way. Place the halves of the split end in the jaws of a tensile testing machine and separate the jaws at a rate between 350 mm/min and 500 mm/min.

e) Evaluation of results

Determine the tear resistance by dividing the maximum load (in newtons) required to tear the section, by the thickness of the test piece (in millimetres). Classify the results in order of increasing value and take the average of the two middle values as the tear resistance.



2.2.3 Not applicable

2.2.4 Not applicable

2.2.5 Determination of hardness for elastomeric insulation and sheath

The hardness of elastomeric insulation and sheath shall be determined in accordance with BS 903-A26.

2.2.6 Not applicable

2.2.7 Plasticity and elongation at break of single (S) and double (D) rubber layers for concentric neutral cables

2.2.7.1 Preparation of rubber from cable

A piece of the completed cable taken from any size of 3×185 mm or larger, not less than 600 mm long, shall have the sheath removed by making two longitudinal cuts through the sheath to either the copper wire neutral or the outer rubber layer. The sheath shall be removed in two halves. The operation shall leave the outer rubber layer (D) virtually untouched. With the unsheathed (D) cable held securely two circumferential marks shall be made around the cable at measured distances at one end with the aid of a non-metallic blade. The distance between the marks shall be such that on removal over this length a total mass of rubber from the two layers shall be at least 200 g.

The outer rubber layer shall be removed between the two circumferential marks by paring it off the neutral wires with the aid of a non-metallic blade. The rubber so removed shall be retained. The neutral wires shall be removed from the cable by pulling them individually outwards from one end of the cable sample. For type (S) the wires shall be removed over a longer distance so as to guarantee 200 g from the inner layer alone.

The inner layer shall be removed over the required distance by paring or by making appropriately spaced longitudinal cuts down to the laid up cores and removing the rubber strips. Any fragments of the binder tape over the laid up cores shall be removed. Care shall be taken to avoid contamination with aluminium or copper dust or slivers.

An homogenized sample shall be prepared by adding the samples from the inner and outer layers for type (D) or the single layer in type (S) and passing through a cool mill 10 times. The rolls shall be maintained at a temperature of $(23 \pm 5)^\circ\text{C}$ and the friction ratio set at between 1.15:1 and 1.25:1. The rubber shall be rolled up after passing through the nip and the rolled up sample presented end-wise to the nip for the next pass. The mill nip shall be set so that the sheet thickness at each pass lies between 3 mm and 4 mm and at no time shall the rubber be allowed to band.

After the tenth pass the homogenized sheet shall remain substantially flat and thereafter be conveniently supported on a flat surface (e.g. clean glass plate) until required for the cutting of the test piece.

2.2.7.2 Rapid plasticity test

The rapid plasticity number shall be determined in accordance with BS 903-A59 at $(100 \pm 1)^\circ\text{C}$ using a platen of diameter (14 ± 0.02) mm.

Six plasticity determinations shall be carried out. The plasticity measurements shall be read directly from the plastimeter and the highest and lowest values of the six measurements shall be ignored. The average of the four remaining values shall be taken as the plasticity of the material.

2.2.7.3 Elongation at break before ageing

Six dumb-bell test pieces shall be cut from the sample of rubber prepared in 2.2.7.1. Three shall be used for determining the elongation at break before ageing and three after ageing.

All pieces shall be kept for at least 3 h at a temperature of $(23 \pm 2)^\circ\text{C}$.

The test shall be carried out in accordance with BS 60811-1-1, 9.1.7.

2.2.7.4 Elongation at break after ageing

For aluminium waveform cable, the three dumb-bell test pieces shall be laid carefully on a flat aluminium sheet (or other suitable flat surface lined with aluminium foil). For copper waveform cable, the three dumb-bell test pieces shall be laid on a flat copper sheet (or other suitable flat sheet lined with copper foil). The sheet and dumb-bells shall be placed in an approved oven having air circulation. The temperature of the oven shall be $(120 \pm 2)^\circ\text{C}$ and the duration shall be 168 h. After this time the sheet and dumb-bells shall be removed from the oven, cooled down and kept at ambient temperature for at least 16 h.

On completion of the ageing treatment, the dumb-bells shall be carefully removed from the flat sheet and the elongation at break determined in accordance with BS EN 60811-1-1, 9.1.7.

2.2.8 Strippability test

2.2.8.1 *Not applicable*

2.2.8.2 *Not applicable*

2.2.8.3 *Not applicable*

2.2.8.4 *Not applicable*

2.2.8.5 *Not applicable*

2.2.8.6 Method 6

When a cold strippable screen is required carry out the following.

Take a core sample of approximate length 400 mm from the cable to be tested.

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

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

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

Repeat the test from the other end of the sample.

2.2.9 *Not applicable*

2.2.10 *Not applicable*

2.2.11 Insulation screen cutting test

The insulation screen at each end of the cable shall be cut horizontally for a distance of 100 mm, at its thinnest position determined by visual examination, using a guarded knife with the blade set at a depth of 0.5 mm. The screen shall then be removed and the insulation examined. If there is no cut in the insulation the whole cable length shall be regarded as satisfactory.

2.2.12 Water immersion test on sheath

2.2.12.1 General

This test is to demonstrate the effect of water on the mechanical properties of sheath by determining the tensile strength and elongation at break of the sheathing material in the condition as manufactured and after immersion in water.

The tensile tests on the conditioned and unconditioned test pieces shall be made in immediate succession.

2.2.12.2 Sampling and preparation of test pieces

Test pieces shall be prepared in accordance with BS EN 60811-1-1:1995, **9.2.3**.

2.2.12.3 Procedure

The dumb-bell samples shall be immersed in approximately 1 l of deionized water for the time and temperature given in the particular section. Following immersion the test pieces shall be allowed to cool to a temperature of $(20 \pm 5)^\circ\text{C}$ before removing them from the water. The test pieces shall then be dried with absorbent paper and within 60 min of drying both the tensile strength and elongation at break shall be measured in accordance with BS EN 60811-1-1:1995, **9.2**.

2.2.12.4 Evaluation of results

Calculate the tensile strength and elongation at break in accordance with BS EN 60811-1-1:1995, **9.2.8**.

2.3 Mechanical tests on metallic components

2.3.1 Tensile tests on metallic components

2.3.1.1 Method 1 — Aluminium components

Take at random 10 % of the total number of wires or strips from one sample of completed cable. Measure the tensile strength of each wire or strip in accordance with BS EN 10002-1. Take the average of all the measurements to be the tensile strength.

The cross-sectional area may be determined by weighing a test piece of approximately 350 mm from the aluminium strip material. The test piece length shall be measured with a tolerance of ± 0.5 mm, the mass shall be measured with a tolerance of ± 0.02 g. The density of aluminium shall be taken as 2 700 kg/m.

2.3.2 Wrapping test for galvanized steel wire

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

2.4 Non-electrical tests on samples of complete cable

2.4.1 Bend tests for complete cable

2.4.1.1 Standard bend test for complete cable

A sample of cable of sufficient length shall be bent around a test cylinder for one complete turn unless otherwise specified. It shall then be unwound and the process repeated, except that the sample shall be bent in the reverse direction. This cycle of operations shall be carried out three times.

Instead of turning the sample, it shall be permissible to reverse the direction of rotation around the test cylinder, the sample being positioned either above or below the cylinder depending on the direction of rotation. Bending shall be carried out at a reasonably uniform speed, each half cycle taking between 0.5 s and 1.0 s per millimetre diameter of cable.

If the test is to be carried out at other than ambient temperature then it shall be performed immediately after conditioning.

The test temperature and mandrel diameter shall be as given in the particular specification.

2.4.1.2 Not applicable

2.4.1.3 Not applicable

2.4.1.4 Not applicable

2.4.1.5 Not applicable

2.4.1.6 Not applicable

2.4.1.7 Method B

Bend the cable sample around a test cylinder at ambient temperature for at least one complete turn. Unwind and repeat the process but this time bend the sample in the reverse direction.

Perform this cycle of operations a total of three times and examine the sample with normal or corrected vision without magnification.

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

for single-core unarmoured cables: $20(D + d)$

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

for three-core unarmoured cables: $15(D + d)$

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

where

D is the approximate overall diameter given in the appropriate table in millimetres (mm);

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

NOTE If the conductor is not circular, $d = 1.13\sqrt{S}$, where S is the nominal cross-sectional area in square millimetres (mm²).

After completion of the bending test, visually examine the sample and subject it to the partial discharge test described in the appropriate cable specification.

2.4.1.8 Cold bend test

A sample of the cable with a length at least five times the test drum diameter shall be subject to the partial discharge test in accordance with **3.10.3**. The sample shall then be cooled to 0 °C for at least 4 h.

The sample shall then, without delay, be bent around a test cylinder, for at least one complete turn. It shall then be unwound and the process repeated after rotating the sample through 180° about its axis.

The sample shall be bent at a reasonably uniform speed, each half cycle of the test taking approximately 1.0 s per millimetre of overall cable diameter.

The diameter of the test cylinder shall be not greater than $20(D + d)$ mm where D is the overall diameter of the cable and d is the conductor diameter as detailed in the cable specification.

The sample shall then again be subjected to the partial discharge test in accordance with **3.10.3**.

The cable shall then be visually examined.

2.4.2 Not applicable

2.4.3 Sheath penetration test

The test shall be carried out on a sample of sheath taken from a complete cable.

The sample shall be mounted in a tester as shown in Figure 2.4.3.

The sample shall be moved at approximately 2 mm/s and when it is moving the loaded point shall be gently lowered on to the sheath surface. The sample shall be moved for 100 mm with the point in contact with the sheath.

At the end of the movement the point shall be lifted and a conductive coating applied to the inside of the groove. A voltage test of 5 kV d.c. for 1 min shall be applied between the conductive coating and armour within 2 min of removing the load.

After removal of the loaded point the sample shall be left for 1 h to recover and then the depth of penetration shall be measured and recorded.

2.4.4 Sheath shrinkage test

2.4.4.1 Not applicable

2.4.4.2 Method 2

A cable sample 10 m long shall be glanded at each end. The cable sample shall be laid straight and the position of the sheath entry into the gland shall be marked.

The cable shall be load cycled between ambient temperature and a conductor temperature of 90 °C. On each cycle the conductor temperature shall be raised from ambient to 90 °C in approximately 3 h and the temperature shall be held stable for at least 1 h at both hot and cold temperatures. The sample shall be subjected to 40 cycles.

The movement between the mark on the outer sheath and the gland shall be measured.

2.4.5 Abrasion test

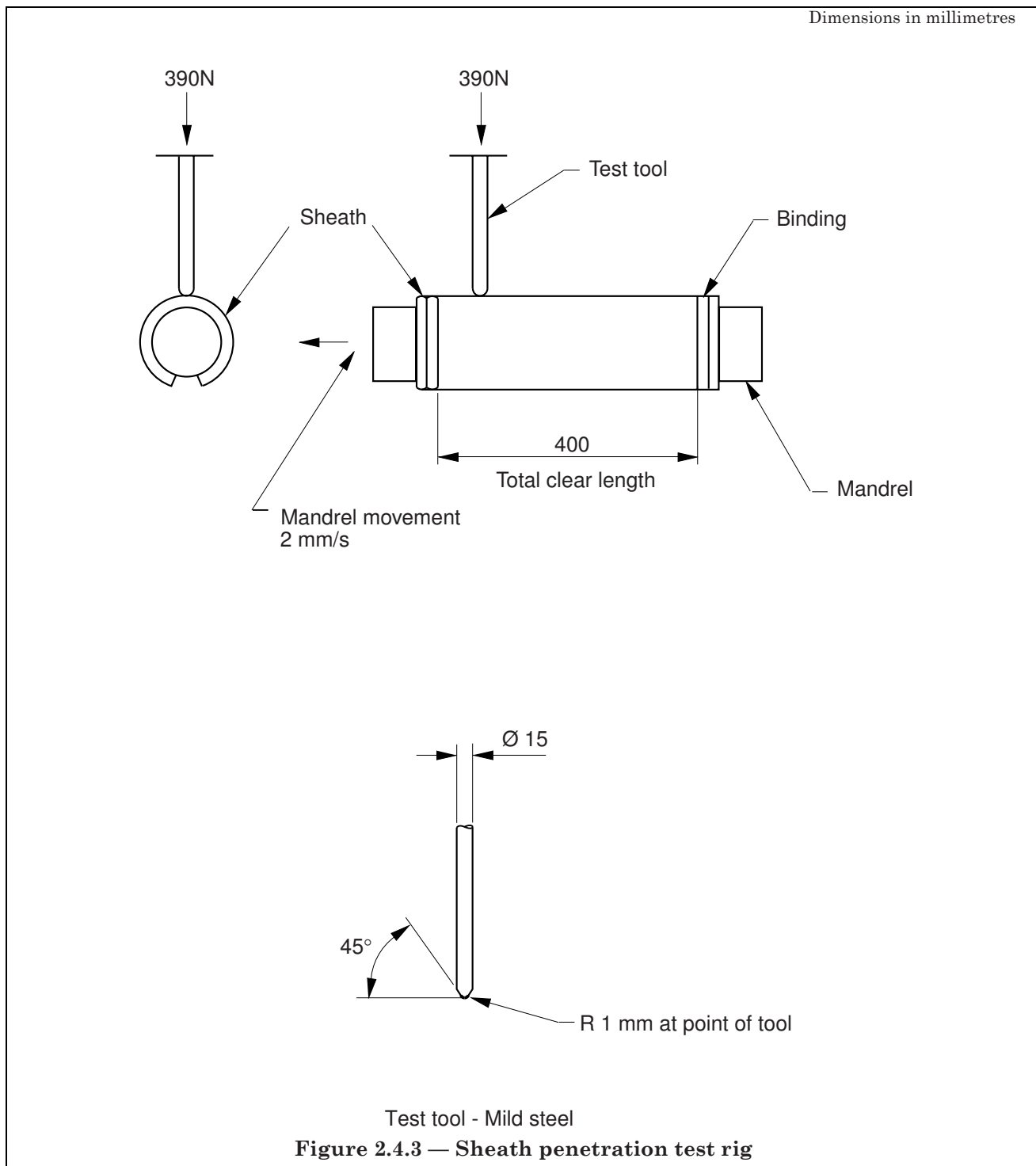
Lay the sample of cable out straight and horizontal on a firm base. In the middle part of the sample and perpendicular to it, place a length of low carbon steel (mild steel) angle horizontally, at right angles to the cable, with its angle edge resting on the cable and with its arm symmetrical about the vertical plane through the longitudinal axis of the cable. Ensure that the outer radius of curvature of the angle edge is not less than 1 mm and not greater than 2 mm (see Figure 2.4.5).

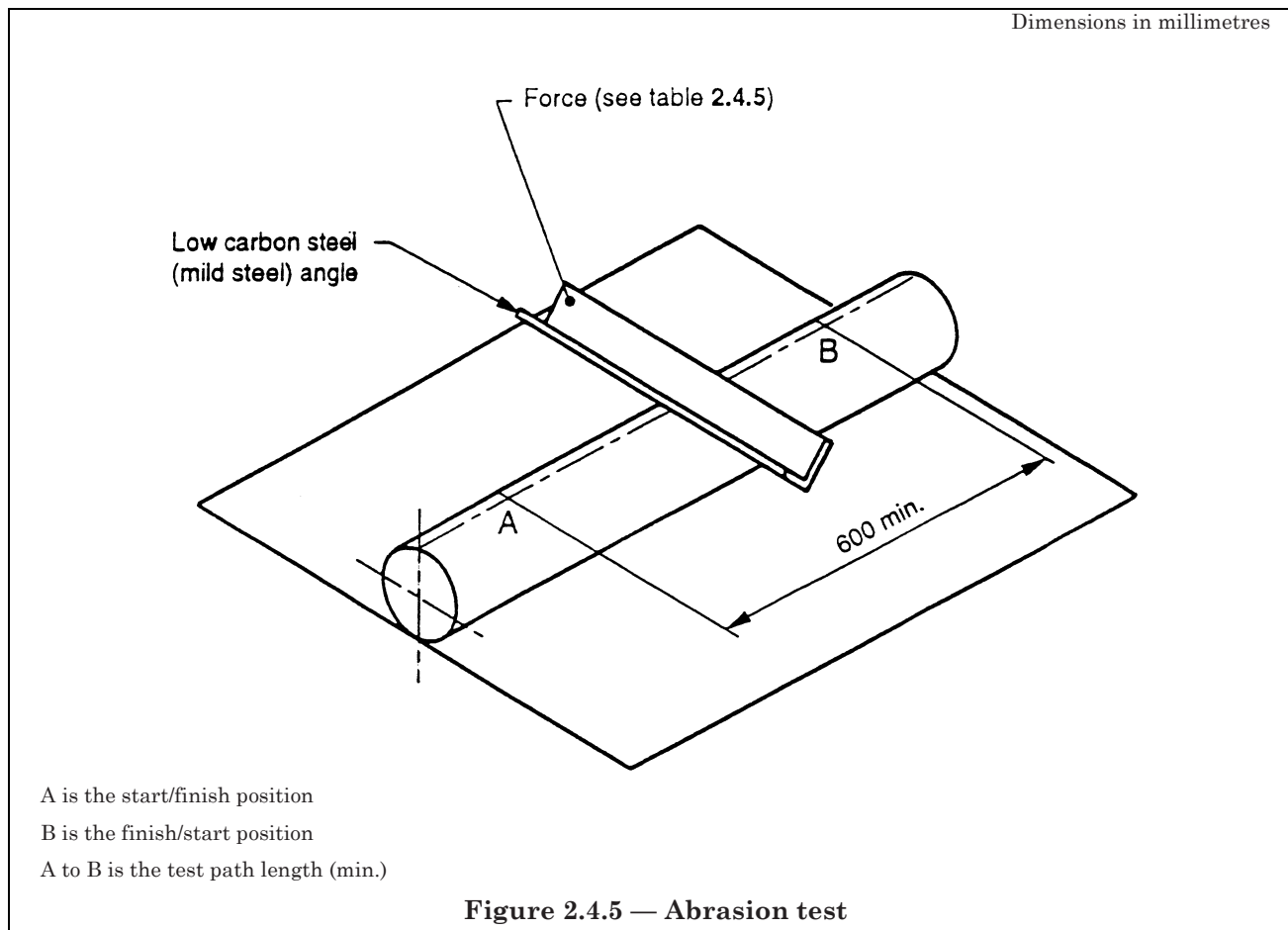
Vertically load the steel angle, above the point of contact, to give a force in accordance with Table 2.4.5.

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

Table 2.4.5 — Vertical force on cable during abrasion test

Overall measured diameter of cable		Force N
Greater than or equal to mm	Less than mm	
10	20	15
20	30	35
30	40	65
40	50	105
50	60	155
60	70	210
70	80	270





2.4.6 Sheath cut-through test

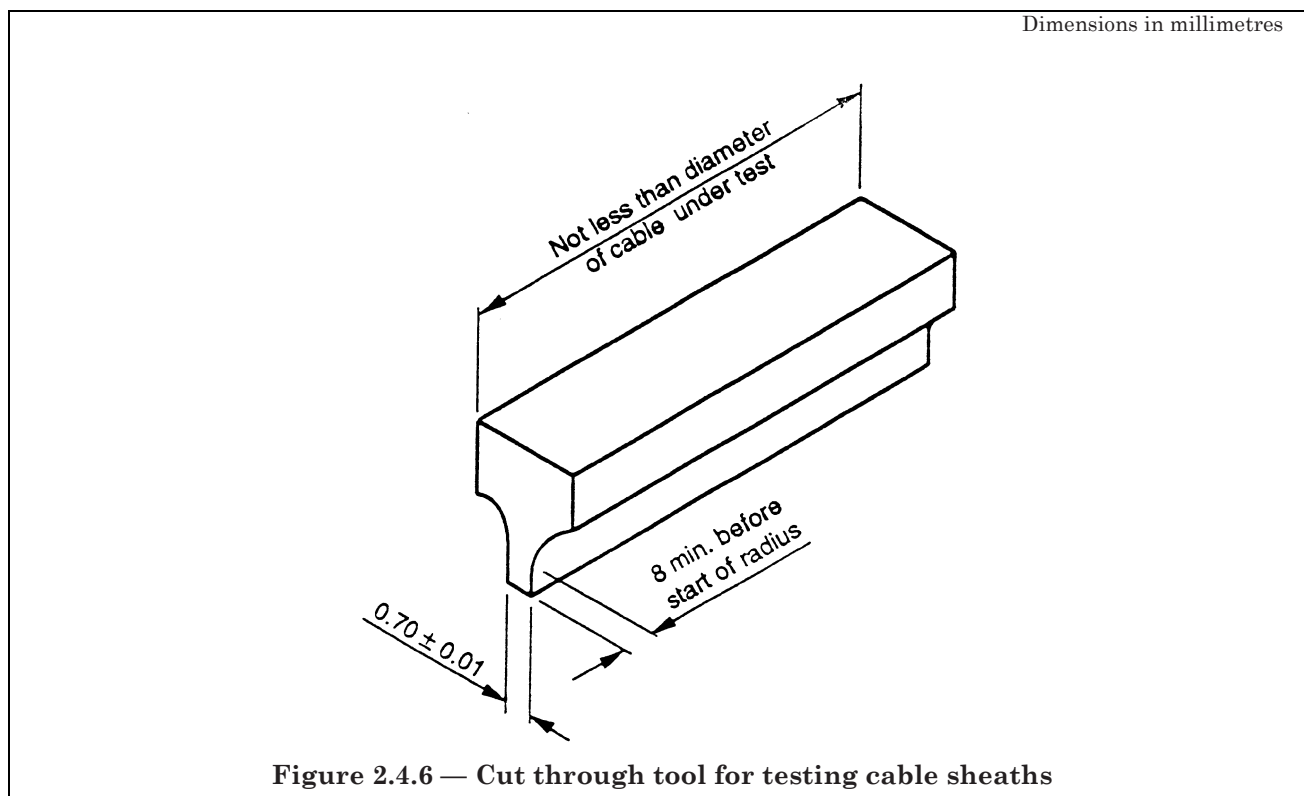
This test shall be carried out on a sample of complete cable approximately 300 mm long.

The dynamic cut-through test shall be performed using a tensile tester operating in a compression mode, or any equivalent apparatus, operating at a speed of 1 mm/min.

The tester shall be equipped to record the force necessary to drive the cutting edge as specified in Figure 2.4.6 through the sheath. The tester shall be equipped with a voltage detection circuit designed to stop the tester when the cutting edge makes contact with the armour of sensitivity such that the maximum load is found. Alternatively if a proof tape is applied over the armour the cut through force shall be determined from a load-deflection plot.

The test shall be conducted with the cable and cutting edge at a temperature of $(20 \pm 5) ^\circ\text{C}$ and $(70 \pm 5) ^\circ\text{C}$. The higher temperature shall be obtained by fitting a chamber to the tester to raise the temperature to this level.

Four tests shall be performed on each cable sample and the cut-through force recorded. The sample shall be moved forward at least 50 mm and rotated through 90° between each test and care shall be taken to avoid any embossed areas.



2.4.7 Crush test

The test shall be carried out on samples of complete cable approximately 300 mm long.

The resistance to dynamic crush shall be measured as in 2.4.6 except that two parallel flat steel blocks shall be used in place of the cutting edge and mandrel. These blocks shall be 50 mm wide (along the longitudinal axis of the cable sample under test). The tester shall be equipped with a low voltage detection circuit designed to stop the tester in the event of contact between:

- i) the block and the armour; or
- ii) any conductor and the armour; or
- iii) any conductor and any other conductor.

The test shall be conducted with the cable at a temperature of $(20 \pm 5) ^\circ\text{C}$ and $(70 \pm 5) ^\circ\text{C}$. The higher temperature shall be obtained by fitting a chamber to the tester.

Four tests shall be performed on separate cable samples and the crush force at which the tester stops recorded in the same manner as determined in 2.4.6. An identical series of tests shall be performed on samples aged as given in the particular specification.

2.4.8 Not applicable

2.4.9 Water penetration test

The test shall be carried out on a representative sample of completed cable which has been subjected to the bend test specified in 2.4.1.1.

A 1 m length of cable shall then be cut out centrally from the length which has been subjected to bending and a ring of the oversheath and outer layer of the anti-corrosion material removed from the centre of the length so as to expose all the neutral/earth conductor wires over a distance of 10 mm.

The 1 m length of cable with ends left open shall then be placed in apparatus such as that illustrated in Figure 2.4.9, which provides a means of applying a head of water, of height h , defined in the particular specification.

The water, which shall contain fluorescein, shall be at ambient temperature and the exposed neutral/earth conductor shall be left immersed under these conditions for 24 h.

After removing the length of cable from the apparatus, it shall be carefully dried with clean rag or paper and the cable components examined under ultraviolet light for the presence of water.

The oversheath shall be removed by making two cuts 180° apart parallel to the axis of the cable. The inside of the oversheath and the outer surface of the anti-corrosion layer shall be inspected for the presence of water, and the length of water penetration, if any, noted.

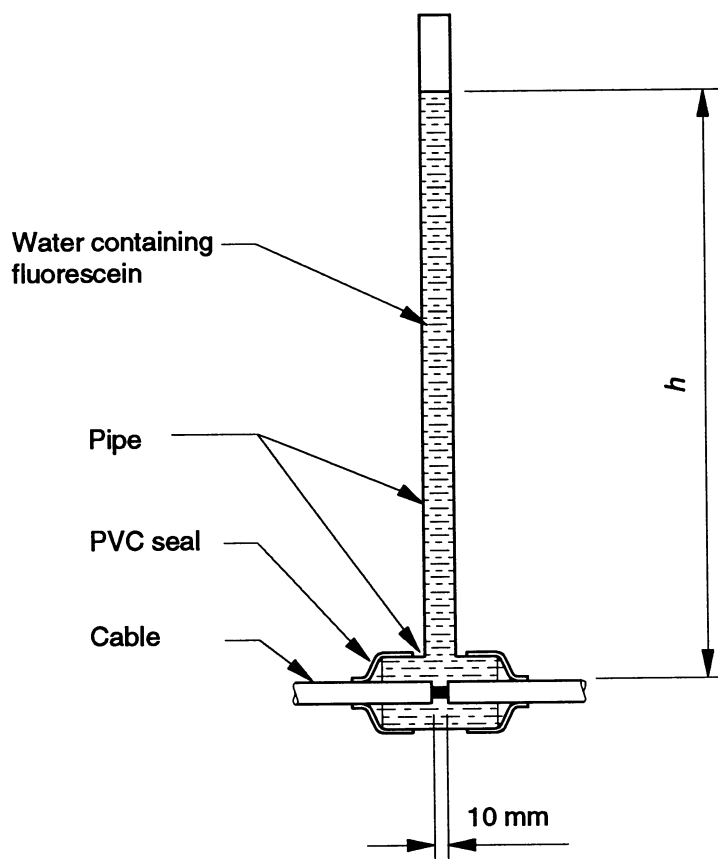


Figure 2.4.9 — Equipment for water penetration tests

The outer layer of anti-corrosion material shall be carefully removed by peeling or slicing so as to expose the wires, starting from the ends and working inwards. Again, the distance of water penetration along the wires, if any, shall be noted.

The wires forming the neutral/earth conductor shall then be carefully removed and both the wires and the exposed surface of the anti-corrosion material beneath the wires shall be inspected for the presence of water and the distance recorded over which the water has migrated.

The remaining anti-corrosion material shall then be removed and the cores of the cable inspected for the presence of water. Care shall be taken in dissecting the cable to avoid the inadvertent spread of water.

2.4.10 Test for restriction of corrosion of neutral/earth conductor

The oversheath and anti-corrosion layer of a sample of cable which has been subjected to the bend test in accordance with 2.4.1.1, shall be punctured down to the concentric neutral/earth conductor in four places in the mid-portion of the specimen by, for example, a cork drill, to produce holes of 10 mm diameter.

The four holes shall be spaced approximately 100 mm apart along the sample, and spaced around the circumference at 90° from each other. Without disturbing the material in the interstices between the wires, the exposed surfaces of the aluminium wires shall be carefully cleaned of all adhering material forming the anti-corrosion layer.