Electric cables — Internal gas-pressure cables and accessories for alternating voltages up to and including 275 kV (U_m = 300 kV) — Requirements and test methods

(Implementation of HD 634)

ICS 29.060.20

British Standards

Committees responsible for this British Standard

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Contents

Foreword

This British Standard has been prepared by Subcommittee GEL/20/16.

It implements the nationally applicable parts of Harmonization Document HD 634 published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board.

BS 7923 applies to internal gas-pressure cables and accessories for alternating voltages up to and including 275 kV (U_m = 300 kV).

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 25 and a back cover.

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1 Scope

This British Standard specifies tests and requirements for radial-field impregnated-paper-insulated cables and accessories in which, during normal operation, a gas pressure exceeding 1.2 MPa (12 bar) gauge is applied internally, i.e. with the gas in direct contact with the insulation.

It also specifies tests for cables and accessories intended for use in systems with a nominal voltage not exceeding 275 kV between phases.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 228:1994, *Specification for short-pitch transmission precision roller chains and chain wheels.*

BS 4727-2:Group 08, *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms — Part 2: Terms particular to power engineering — Group 08: Electric cables.*

IEC 60060-1, *High-voltage testing techniques — Part 1: General definitions and test requirements.*[1]

IEC 60228:1978, *Conductors of insulated cables.*[2]

IEC 60229:1982, *Tests on cable oversheaths which have a special protective function and are applied by extrusion.*

IEC 60230, *Impulse tests on cables and their accessories.*[3]

IEC 60507:1991, *Artificial pollution tests for high-voltage insulators to be used on a.c. systems.*

IEC/TS 60859, *Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above — Fluid-filled and extruded insulation cables — Fluid-filled and dry type cable-terminations.*

3 Terms and definitions

For the purposes of this British Standard the definitions given in BS 4727-2:Group 08 and the following apply.

3.1
rated voltage U_0
nominal power-frequency voltage between any conductor and armour or earth for which the cable and its accessories are suitable

3.2
rated voltage U
nominal power-frequency voltage between phase conductors for which the cable and its accessories are suitable

3.3
maximum voltage U_m
maximum sustained voltage between phase conductors for which the cable and its accessories are suitable

3.4
peak voltage U_p
peak value of the impulse withstand voltage for which the cable and its accessories are suitable

4 Voltage designation

Cables and accessories shall be designated by the rated voltage between conductor and screen U_0 and by the rated voltage between conductors U, both in kilovolts, e.g. 76/132 kV.

NOTE See IEC 60183.

[1] Published by BSI as BS 923-1.
[2] Published by BSI as BS 6360.
[3] Implemented by CENELEC as HD 48.

5 Characteristics

For the purpose of carrying out and recording the tests described in this British Standard, the following characteristics shall be known or declared for each cable tested:

a) rated voltage U_0, in kilovolts (kV);

b) lightning impulse withstand voltage U_p, in kilovolts (kV);

NOTE 1 The lightning impulse withstand voltage U_p specified above for each particular cable should be selected in accordance with IEC 60071-1.

c) type of conductor, material, nominal cross-sectional area of the conductors in square millimetres (mm^2), and conductor resistance (for conductor resistances, see **7.2**);

d) conductor resistance, if the nominal cross-sectional area is not in accordance with the values given in IEC 60228;

e) number of cores;

f) capacitance between each conductor and screen, in microfarads per kilometre (μF/km);

g) maximum permissible conductor temperature, in degrees Celsius (°C), for continuous operation under the specified ambient and installation conditions;

h) minimum and maximum permissible static fluid pressure, in kilopascals (kPa) or bars[4)];

i) type and material of the metallic sheath and the construction of the sheath reinforcement, if any;

j) thermal resistance between conductor(s) and metallic sheath, in kelvin metres per watt (K·m/W);

NOTE 2 The thermal resistance should be calculated using the formulae given in IEC 60287-2-1.

k) cable design stress, in kilovolts per millimetre (kV/mm);

l) maximum design pressures of accessories, in kilopascals (kPa) (see Clause **9**);

m) type of conductor screen (with or without carbon-black paper);

n) specified minimum thickness of insulation, nominal thickness of the metallic sheath and anti-corrosion covering, in millimetres (mm);

o) nominal outside diameter of the cable and conductor, in millimetres (mm);

p) type and material of the corrosion-resistant covering over the metallic sheath;

q) cable thermal resistance.

The following additional characteristics shall be stated by the manufacturer when requested by the purchaser:

1) details of construction, e.g. shaped or circular conductor, screened or unscreened conductor, types of joint and sealing end, etc.;

2) insulation thickness of the cable, in millimetres (mm), and maximum voltage gradient in the cable insulation at U_0, in kilovolts per millimetre (kV/mm), neglecting any stranding effect;

3) maximum current rating, in amperes (A), under the specified installation and operating conditions;

4) estimated effective (a.c.) resistance, in ohms per kilometre (Ω/km), of the cable at the maximum operating temperature and under the specified installation conditions;

5) estimated inductance, in henrys per kilometre (H/km), per phase of the completed cable under the specified installation conditions.

4) 1 bar = 10^5 N/m^2 = 10^5 Pa.

6 Test categories, frequency and conditions

6.1 Categories of tests

NOTE Test classified as sample or routine might be required as part of any type approval scheme.

6.1.1 *Routine tests*

Tests made on all production cable lengths and accessories to demonstrate their integrity.

6.1.2 *Sample tests*

Test made on samples of completed cable or accessories, or components taken from a completed cable or accessory, adequate to verify whether the finished product meets the design specifications.

6.1.3 *Type tests*

Test required to be made before supplying a type of cable or accessory covered by this standard on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the cable materials, design or type of manufacturing process, which might change the performance characteristics.

6.1.4 *Tests after installation*

Tests intended to demonstrate the integrity of the cable and its accessories after installation and before use.

6.2 Frequency of tests

6.2.1 *Frequency of measurements of dimensions*

This test shall be carried out on each drum length.

6.2.2 *Frequency of bend tests*

Provided that the total length of cable supplied to the purchaser under a single contact exceeds 50 drums of one type of cable, the test shall be carried out on 2 % of drum lengths.

6.3 Test conditions

6.3.1 *Ambient temperature*

Unless otherwise specified in the details for the particular test, tests shall be made at an ambient temperature of (20 ± 15) °C.

6.3.2 *Frequency of waveform of power frequency test voltage*

The frequency of the alternating test voltages shall be in the range 49 Hz to 61 Hz. The waveform shall be substantially sinusoidal.

NOTE The test voltage values quoted are r.m.s. values.

6.3.3 *Waveform of impulse test voltage*

In accordance with IEC 60230, the impulse wave shall have a virtual front time between 1 µs and 5 µs and a nominal time to half the peak value between 40 µs and 60 µs. In other respects the impulse wave shall be in accordance with IEC 60060-1.

7 Routine tests on cables

7.1 General

7.1.1 The tests specified in **7.2**, **7.3**, **7.4**, **7.5** and **7.6** shall be carried out as routine tests (see **6.1.1**) on all completed cables under a single contract.

7.1.2 For the tests specified in **7.3**, **7.4** and **7.4**, the cables shall be suitably terminated and the tests shall be carried out at atmospheric pressure, except for not-fully-impregnated insulation, for which either atmospheric pressure or an internal gas pressure not exceeding 200 kPa (2.0 bar) shall be used.

7.2 Conductor resistance test

7.2.1 ***Procedure***

The d.c. resistance of conductors in the finished cable shall be measured.

The measured value of resistance shall be corrected to a temperature of 20 °C and a length of 1 km. The correction for temperature and length shall be made in accordance with IEC 60228.

The cable shall be maintained at a reasonably constant temperature for at least 12 h before the test. If there is any doubt as to whether the conductor temperature is the same as the ambient temperature, this period shall be extended to 24 h.

7.2.2 ***Requirements***

7.2.2.1 The measured value of resistance for 3-core cables (with a nominal cross-sectional area not exceeding 400 mm^2) and for single core cables (with a nominal cross-sectional area not exceeding 2 000 mm^2), when corrected, shall not exceed the value specified for class 2 conductors in columns 8 and 9 (for copper conductors) or column 10 (for aluminium conductors) of IEC 60228:1978, Table II.

7.2.2.2 For cables with a nominal cross-sectional area greater than those specified in **7.2.2.1** or not included in IEC 60228:1978, Table II, the d.c. resistance shall meet the value stated by the manufacturer.

7.3 Capacitance test

7.3.1 ***Procedure***

The capacitance shall be measured at power frequency by means of an a.c. bridge.

7.3.2 ***Requirement***

The capacitance of each core shall be not greater than 8 % above the declared value [see Clause **5**f)].

7.4 Tan δ measurement test

7.4.1 ***Procedure***

The tan δ measurement of the insulation shall be made at ambient temperature between each conductor and core screen, employing the following power-frequency test voltages.

a) For cables with fully-impregnated insulation, the test voltage shall be increased from $0.25U_0$ to U_0 in steps of $0.25U_0$. The tan δ at $0.5U_0$ shall not exceed 0.005 and the increase in tan δ between $0.25U_0$ and U_0 shall be not more than 0.001 per step of $0.25U_0$, the total increase between $0.25U_0$ and U_0 being not greater than 0.002.

b) For cables having not-fully-impregnated insulation, the test voltage shall be increased from $0.25U_0$ to $0.5U_0$. The tan δ at $0.25U_0$ shall not exceed 0.005 and the increase in tan δ between $0.25U_0$ and $0.5U_0$ shall not exceed 0.001.

If the measurements are made at a temperature below 20 °C, the results shall be corrected to 20 °C, either by subtracting from the measured value 2 % of this value per degree Celsius (°C) of the difference between the test temperature and 20 °C, or by the use of a correction curve appropriate to the insulation if agreement on such a curve has been reached between the purchaser and the manufacturer. No correction shall be made if the test temperature is 20 °C or higher.

7.4.2 *Requirement*

The tan δ and the tan δ difference shall not exceed the appropriate values given in Table 1, or the declared values, whichever are the lower.

Table 1 — Tan δ measurement requirements

Rated voltage, U_0	Maximum tan $\delta \times 10^{-4}$		Maximum tan δ difference[a] 10^{-4}
kV	At $0.25U_0$	At $0.5U_0$	$0.5U_0$ to $0.25U_0$
33	47	150	—
66	47	67	24
132	47	67	24

[a] The tan δ difference is the maximum variation in value between the two test voltages.

7.5 High-voltage test

7.5.1 *Procedure*

The high-voltage test shall be made at ambient temperature, and the test voltage, which shall be either a.c. or d.c., shall be applied for 15 min between each conductor and core screen. The voltage shall be gradually increased to the specified value.

The value of the test voltage shall be as follows.

a) If an a.c. test voltage is used, the value of the test voltage shall be as specified in Table 2.

NOTE The a.c. test may be made in conjunction with the measurement of tan δ (see **7.4**).

b) If a d.c. test voltage is used, the value of the test voltage shall be:

1) for fully-impregnated cables, $5U_0$;

2) for not-fully-impregnated cables, $4U_0$.

Table 2 — High voltage test values

Rated voltage, U_0 kV	Test voltage kV
33	12.5
66	25
132	50

7.5.2 *Requirement*

No breakdown of the insulation shall occur.

7.6 Test on oversheath

When the oversheath is tested in accordance with IEC 60229:1982, Clause **3**, no breakdown shall occur.

8 Sample tests on cables

8.1 Measurement of thickness

8.1.1 *Measurement of insulation thickness*

Measurement of the insulation thickness shall be made on a representative sample of each drum length of cable. The sample shall be not less than 300 mm in length and taken not less than 300 mm from the end of a factory length.

The insulation thickness shall be derived by taking half the difference of diameter tape measurements over the (screened) conductor and over the insulation after the insulation screen has been removed.

8.1.2 ***Measurement of sheath thickness***

Measurement of the sheath thickness shall be made on a representative sample of each drum length of cable.

The sample to be measured shall be taken not less than 300 mm from the end of a factory length and shall consist of a ring carefully cut from the cable.

The thickness of the sheath shall be determined at a sufficient number of points around the circumference of the ring sample to ensure that the minimum thickness is measured (see **8.1.3**).

The measurements shall be made with a micrometer having either one flat nose and one ball nose or one flat nose and one 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.

8.1.3 ***Measurement of the thickness of extruded oversheath***

Measurement of the thickness of the extruded oversheath shall be made on a representative sample of each drum length of cable. The sample shall be taken not less than 300 mm from the end of the factory length.

The measurement shall be made either by micrometer or by an optical method in which the error of determination shall not exceed 0.03 mm. In cases of dispute the optical method shall be used.

The measurements shall be made at six approximately equally spaced points around the periphery of the sample.

NOTE Care should be taken to ensure that the minimum thickness is measured.

The smallest measurement and the average of the measurements shall be recorded.

8.1.4 ***Re-test procedure***

If any sample, when subjected to the tests specified in **8.1.1**, **8.1.2** and **8.1.3**, fails to conform to the manufacturer's specification [see Clause **5**n)], two further samples shall be taken from the same batch and subjected to the same tests as those in which the original sample failed. If both additional test samples pass the tests, all the cables in the batch from which they were taken shall be deemed to conform to the specified requirements. If either fails, the batch of which the samples were representative shall be deemed not to conform.

NOTE Further re-sampling and testing should then be a matter for negotiation.

8.2 Bending test

The bending test shall be made on a sample of cable of sufficient length to provide at least one complete turn round the test cylinder. The test shall be made at ambient temperature, unless otherwise specified by the customer at the time of enquiry.

The diameter of the test cylinder shall be as specified in Table 3, with a tolerance of ±5 %.

Table 3 — Diameter of the test cylinder

Type of cable	Diameter of the test cylinder
Single core cables with lead, lead-alloy or corrugated aluminium sheaths	$25(D + d)$
3-core cables with lead, lead-alloy or corrugated aluminium sheaths	$20(D + d)$
All cables with plain aluminium sheaths	$36(D + d)$[a]

Key

D is the measured diameter over the pressure-retaining sheath or over crest of the corrugations of the corrugated aluminium sheathed cable.

d is the measured diameter of the conductor or, if a non-circular conductor is concerned, it is 1/3.14 times the measured conductor perimeter.

[a] The fact that the diameter of the test cylinder is larger for these cables indicates that they have to be transported on larger diameter drums and installed with larger installation radii than reinforced lead or corrugated aluminium sheathed cables.

The cable shall be laid out straight and level and one end shall be secured to the test cylinder.

A reference line shall be drawn along the top of the cable parallel to its longitudinal axis.

The cylinder shall be rotated steadily so that all the cable is taken up in a closely-wound coil. The cylinder shall then be rotated in either the opposite direction or the same direction so that the cable is unwound.

The cable shall then be rotated 180° about its longitudinal axis and the winding and unwinding process repeated with the same directions of test cylinder rotation as before.

Finally, either one of the two following procedures shall be carried out:

a) the cable shall be rotated about its longitudinal axis by 180° to regain its initial position, i.e. reference line uppermost; or

b) the direction of rotation of the test cylinder shall be reversed so that the cable is retained in the same position and alternates between the bottom and the top of the test cylinder.

The complete cycle of wind/unwind/cable rotation/wind/unwind/cable rotation shall be carried out three times on the cable sample.

8.3 Quality of insulation paper

When requested, the amount of water-soluble impurities present in the insulation paper before impregnation shall be determined as follows.

Approximately 10 g of paper shall be dried in an air oven at a temperature of 103 °C to 105 °C for 1 h and weighed. It shall then be cut into approximately 13 mm squares and extracted in a porcelain dish or glass beaker on a boiling water bath with 0.2 l of distilled water for 15 min. The extract shall be decanted through a filter paper and the process shall be repeated until four filtrations have been made, the same filter paper being used in each case. The total extract shall be evaporated to dryness on a water bath and finally dried to constant mass at a temperature of 103 °C to 105 °C. A blank determination shall then be carried out and any mass obtained in this shall be subtracted from the mass obtained in the test.

The value obtained shall be calculated as a percentage of the dry paper mass.

9 Routine tests on accessories

9.1 General

The tests specified in **9.2**, **9.3** and **9.4** shall be carried out on each accessory to be supplied to the purchaser.

9.2 Joint sleeves and porcelain assemblies

9.2.1 *Hydraulic test*

9.2.1.1 *Procedure*

Each cable joint and sealing-end carcass shall be tested hydraulically for 15 min at twice the maximum operating gas pressure.

9.2.1.2 *Requirement*

There shall be no failure of or leaking from the casing, i.e. it shall not break open.

9.2.2 *Pneumatic test*

9.2.2.1 *Procedure*

The gas pressure in each complete circuit and its associated accessories shall be raised to the maximum operating pressure as declared in accordance with Clause **5**a) and maintained at this pressure for 7 days, when the pressure shall be reduced to the normal operating pressure declared in accordance with Clause **5**a). After stabilization at this pressure, the circuit shall be sealed off and left undisturbed for a further 7 days.

9.2.2.2 *Requirement*

During the whole of this test there shall be no evidence of gas leakage.

9.3 Gas regulators

9.3.1 *Procedure*

Each regulator shall be tested at the full input pressure for which it was designed. Pressure gauges shall be fitted on the high-pressure and low-pressure sides of the regulator.

9.3.2 *Requirement*

After a period of 72 h, with the regulator isolated from the high-pressure supply, there shall be no variation in the initial readings other than that caused by ambient temperature.

9.4 Safety valves

9.4.1 *Procedure*

Each safety valve shall be operated ten times with nitrogen gas pressure.

9.4.2 *Requirement*

Upon each operation, each safety valve shall show a relief pressure greater than the maximum operating pressure but not more than 3.5 bar above this value and shall reset without leakage at a pressure not less than the normal operating pressure.

10 Sample tests on accessories

10.1 Procedure

Watertight fittings and accessories shall be either:

a) immersed in water to a depth of not less than 1 m at the highest point of the enclosure; or

b) subjected to an external pressure of 10 kPa (100 mbar) for a period of 1 h.

The temperature of the apparatus during the test shall not exceed the temperature of the water in which it is immersed. The water used for the test shall be tap water at (20 ± 10) °C unless otherwise specified at the time of ordering.

10.2 Requirement

After the test the fittings and accessories shall show no signs of leakage or damage.

11 Type tests on cables and accessories

11.1 General

For single core cables, tests shall be conducted on three test assemblies, each containing one joint and two terminations. Tests shall be undertaken on the largest conductor size for which approval is being sought.

11.2 Electrical test sequence

Electrical tests shall be undertaken in the following sequence:

— cold tan δ measurement/voltage test (**11.3**);

— three-cycle bend test (**11.4**);

— load cycle voltage test (**11.5**);

— thermal stability (**11.6**);

— switching impulse (132 kV systems only) (**11.7**);

— lightning impulse (**11.8**).

11.3 Cold tan δ measurement/voltage test

11.3.1 *Test installation*

The test assembly shall consist of at least 100 m of cable. The assembly shall be situated indoors in a draught-free environment of steady ambient temperature.

11.3.2 *Test conditions*

When the measurements are made, the gas pressure of a gas-filled cable installation shall be at the minimum design operating pressure.

11.3.3 *Procedure*

11.3.3.1 *General*

The normal power frequency dielectric loss angle and the capacitance of the test core of the test assembly shall be measured at 0.5, 1, 1.33 and 1.67 times normal working voltage at ambient temperature.

11.3.3.2 *Detailed*

The tan δ of each core of the test assembly shall be measured at 0.5, 1, 1.33 and 1.67 times normal working voltage and the ambient temperature noted; the capacitance of the test cores of the assembly shall then be calculated from the bridge measurements at normal working voltage.

If the tan δ measurements are made at a temperature below 20 °C, the results shall be corrected at 20 °C, using one of the following methods:

a) subtract from the measured value 2 % of this value per degree Celsius (°C) of the difference between the test temperature and 20 °C; or

b) use a correction curve appropriate to the insulation, if agreement on such a curve has been reached between the purchaser and the manufacturer.

No correction shall be made if the test temperature is 20 °C or higher.

11.3.4 *Requirement*

The capacitance per unit length and dielectric loss angle shall not exceed their guaranteed maximum values.

11.4 Three-cycle bend test

11.4.1 *General*

Where the test is being carried out as a sample test in accordance with **8.2**, then the requirements specified in **11.4.2**, **11.4.3**, **11.4.4**, **11.4.5** to **11.4.6** shall be met. The samples for this test shall be selected according to **6.2.2**.

Where the test is being carried out as part of a type approval test in accordance with Clause **11**, then only the test specified in **11.4.2** shall be carried out.

NOTE In this case a greater length of test cable might be required as one turn of the test cylinder might not be sufficient cable for the type approval test procedure.

11.4.2 *Bending test*

The bending test specified in **8.2** shall be carried out on all cables before they are subjected to any further tests.

11.4.3 *Electrical test*

After the above cycle of operations has been completed, the sample of cable shall withstand for 15 min the high-voltage test with an a.c. test voltage specified in **7.5**.

11.4.4 *Examination of the metal sheath, reinforcing tapes and oversheath*

After the high-voltage power frequency test in accordance with **11.4.3**, a specimen of about 1 m in length, taken from the middle of the sample of cable which has been tested, shall be dismantled and examined. The anti-corrosion covering and reinforcement shall not be seriously displaced or damaged, and the pressure-retaining sheath shall be free from cracks and splits.

11.4.5 *Examination of insulation*

After examination of the coverings in accordance with **11.4.4**, a piece of cable 300 mm long shall be cut from the central part of the sample. The metal sheath and the inner binders (if any), fillers, etc., shall be removed, thus obtaining one test piece in the case of a single core cable or three test pieces in the case of a 3-core cable.

The insulation shall be removed by taking off a small number of paper tapes at a time, and the tapes examined for tears and gaps. The following requirements shall be met for all papers except carbon-black papers:

a) the number of insulating paper tapes which, in the 300 mm length, contain longitudinal or edge tears exceeding 7.5 mm, shall be not more than two per core; and

b) at no point throughout the insulation shall there be more than either:

   1) two coincidental tears of any length in adjacent insulating papers; or

   2) two coincidental gaps of any length in adjacent insulating papers, or three if these coincide with the reversal of the direction of the lay.

11.4.6 *Re-test procedure*

If the requirements specified in **11.4.5** are not met, a new sample shall be taken from another manufacturing length and the whole test procedure specified in **11.4** shall be repeated. If the requirements specified in **11.4.5** are met in the re-test, the cable shall be deemed to conform.

11.5 Load cycle voltage test

11.5.1 *Test installation*

The test assembly shall consist of one sample of each accessory with the lengths between accessories totalling at least 30 m of main cable. There shall be at least 4 m of cable between adjacent accessories.

The assembly shall be situated indoors, in reasonably still air away from direct sunlight.

11.5.2 *Test conditions*

11.5.2.1 *Gas pressure*

Before any measurements are made, the gas pressure of a gas-filled cable installation shall be adjusted to the minimum design operating value at ambient temperature; the installation shall then be sealed off and the external gas supply disconnected.

11.5.2.2 *Thermocouples*

Thermocouples used for the measurement of cable sheath temperature shall be spaced at intervals not exceeding 1.2 m along the cable length.

11.5.2.3 *Thermal insulation*

In order to ensure that there is adequate variation in conductor temperature between the hot and cold condition, the application of thermal insulation shall not be used to increase the overall thermal resistance of the insulation.

11.5.2.4 *Current loading*

The current loading method for assemblies in which the conductor is available for current loading purposes shall be one of the following:

a) **either** a conductor current shall be applied that is sufficient to produce the steady temperature conditions specified;

b) **or** a conductor current of 700 mA to 800 mA per mm^2 of copper conductor cross-section or 550 mA to 650 mA per mm^2 of aluminium conductor cross-section shall be applied continuously throughout the 8 h loading current period. Assuming a maximum conductor temperature midway between the upper and lower maximum conductor temperatures specified in **11.5.3.1**, the equivalent maximum sheath temperature shall be calculated to the satisfaction of the appropriately qualified officer from consideration of the conductor current, conductor resistance, cable thermal resistance and dielectric power loss, assuming stable temperature conditions. Sheath current shall be applied to raise the maximum sheath temperature to the value determined above, as quickly as possible, the sheath current then being progressively reduced to maintain the maximum sheath temperature at this value. Stable thermal conditions shall be deemed to exist when the sheath current reaches a constant value.

The current loading method for assemblies in which the conductor is not available for current loading purpose (e.g. installations containing an oil immersed sealing end) shall be as follows: sheath current shall be applied to raise the maximum sheath temperature to the maximum conductor temperature specified in **11.5.3.1** less an allowance for the temperature gradient due to dielectric power loss, as quickly as possible, the sheath current then being progressively reduced to maintain the maximum sheath temperature at this value. Stable thermal conditions shall be deemed to exist when the sheath current reaches a constant value.

11.5.3 ***Procedure***

11.5.3.1 *General*

The test assembly shall undergo 20 loading cycles with a continuously applied test voltage of 1.5 times the normal working voltage. Each loading cycle shall have a duration of 8 h with conductor current loading. During the last 3 h of each current loading period the maximum conductor temperature shall be maintained at not less than the design maximum conductor temperature plus 5 °C and not greater than the design maximum conductor temperature plus 10 °C. One cold and one hot dielectric loss angle shall be measured at the test voltage on each assembly during each loading cycle.

11.5.3.2 *Detailed*

The dielectric loss angle of each assembly shall be measured at $0.5U_0$, $1.33U_0$ and $1.67U_0$ at ambient temperature.

During the 20 loading cycles, the desired maximum conductor temperature shall be maintained within the stated limits (see **11.5.3.1**) for the last 3 h of each current loading period.

If the cable sheath temperature does not reach steady values within the first 4 h or more of the current loading period, another measurable quantity shall be employed to indicate the maximum conductor temperature of the test assembly, as follows.

NOTE 1 This is a relationship that can be established between the maximum conductor temperature and the mean conductor temperature, deduced from conductor resistance measurements.

When the test assembly has stood for several hours at a steady ambient temperature, the conductor resistance shall be measured. The test assembly shall then undergo one current loading period, without test voltage, at a constant current of the value estimated to produce the required maximum conductor temperature. This constant loading current shall be maintained until the cable sheath temperatures have been steady, i.e. within 3 °C for at least 2 h. The test core conductor resistance shall then be measured and the mean conductor temperature calculated. The maximum conductor temperature shall be calculated from consideration of conductor current and resistance, the maximum sheath temperature and the design value of cable thermal resistance.

The temperature difference between mean and maximum conductor temperatures, established by the above procedure, shall be assumed constant throughout the last 3 h of each of the following current loading periods.

NOTE 2 The assumption of continuity permits the use of mean conductor temperature measurement to establish maximum conductor temperature values with negligible error when the cable sheath temperatures have not reached steady values.

The 20 loading cycles at test voltage shall then be applied. At the beginning of each loading current period, sufficient loading current shall be applied to raise the maximum conductor temperature to its required value within the first 3 h. Thereafter the loading current shall be progressively reduced to maintain the maximum conductor temperature within the required limits until the end of the 8 h period. The loading current shall then be removed and the test assembly allowed to cool naturally for a period of 16 h with test voltage still applied to complete the loading cycle.

One cold[5)] tan δ measurement and one hot[5)] tan δ measurement shall be made at test voltage for every loading cycle. At least once every hour, ambient and maximum cable sheath temperatures shall be recorded during the current loading period. Gas pressure shall be measured and recorded at the beginning and end of each current loading period.

11.5.4 ***Requirement***

A graphical interpretation of the tan δ measurements shall not show a progressive increase of tan δ.

11.6 Thermal stability test

11.6.1 ***Test installation***

The identical assembly that has been used for the loading cycle test (**11.5**) shall be tested.

11.6.2 ***Test conditions***

The test conditions shall be the same as those specified for the loading cycle test (**11.5**).

11.6.3 ***Procedure***

11.6.3.1 *General*

Immediately following the 20th loading cycle of the loading cycle test (**11.5**), the test assembly shall undergo a further current loading period with a continuously applied test voltage of $1.33U_0$. When the maximum conductor temperature is between the limits of the design maximum conductor temperature plus 5 °C and plus 10 °C respectively, and the cable sheath temperatures have become steady, the loading current shall be maintained at a constant value.

11.6.3.2 *Detailed*

At the beginning of the test period, sufficient loading current shall be applied to raise the maximum conductor temperature ±5 °C to the value specified by the manufacturer [see Clause **5**g)]. Thereafter the loading current shall be reduced to the value shown by the previous loading cycle test to give the temperature required under constant loading current conditions. This loading current shall be held constant until the requirement specified in **11.6.4** has been met. During the constant current period, observations of sheath and ambient temperatures shall be made at least once an hour. Immediately following the completion of this 12 h period, with the same loading current maintained, the tan δ of the test assembly shall be measured at test voltage.

11.6.4 ***Requirement***

Following a continuous 12 h period of a constant load current, the total variation of sheath temperature shall not exceed 2 °C after due allowance has been made for ambient temperature variations.

11.7 Switching impulse voltage test

11.7.1 ***General***

This test shall be performed only if requested, and shall be performed only on 132 kV systems and above.

11.7.2 ***Test installation***

Only a test installation that has already satisfactorily completed the loading cycle (**11.5**) and thermal stability (**11.6**) tests shall be submitted to this test.

[5)] A "cold" tan δ measurement is made immediately prior to the beginning of the loading current period. A "hot" tan δ measurement is made immediately prior to the end of the loading current period.

11.7.3 ***Test conditions***

The test conditions shall be the same as those specified for the loading cycle test in **11.5**, except that the allowance for dielectric loss referred to in **11.5.2.4** shall not be made.

11.7.4 ***Procedure***

11.7.4.1 *General*

Current loading shall be applied to the test assembly until for constant current the cable sheath temperatures have been steady (i.e. variations not greater than 2 °C after due allowance has been made for ambient temperature variations) for at least 2 h with the maximum conductor temperature not less than the design maximum conductor temperature and not greater than the design maximum temperature plus 5 °C. With this current loading maintained, each test assembly shall be submitted to ten successive positive and ten successive negative impulses of the required waveshape and peak voltage, as shown in Table 4 and Table 5.

Table 4 — Waveshape

Parameter	Requirement
Time to peak (T_p)	250 µs ± 20 %
Time to half value	25 00 µs ± 60 %

Table 5 — Voltage levels

3-phase system voltage kV	Switching impulse withstand test voltage kV
132	380
275	850

11.7.4.2 *Detailed*

The test assembly shall be connected to the impulse generator and its associated voltage divider system. The circuit values of the system shall be adjusted to produce impulse voltage waveshapes conforming to **11.7.4.1**. Oscillograms shall be made on suitable time sweeps to record both the time to peak and wave tail duration of the wave.

The circuit values of the impulse generator shall remain unaltered for the remainder of the test period.

In the case of 3-core power cable systems, all three cores shall be tested in sequence at each voltage level.

Loading current shall be applied to the test assembly to raise the maximum conductor temperature to its required value. This current shall then be maintained constant until the cable sheath temperatures have been steady (i.e. variations not greater than 2 °C after due allowance has been made for ambient temperature variations) for at least 2 h.

During the period when the temperature of the cable is maintained at a constant value, before commencement of the withstand test, the impulse generator system, with the test installation connected, shall be calibrated using either a sphere gap conforming to IEC 60230 or an impulse voltage divider system of known ratio. The choice of method shall be at the discretion of the manufacturer.

11.7.4.3 *Calibration using a sphere gap*

For every given setting of the sphere gap the charging voltage of the generator shall be adjusted so as to give 50 % sparkover of the gap, and an oscillogram of the impulse voltage shall be taken. This procedure shall be carried out for at least three different settings of the sphere gap using positive polarity impulses. The gap setting shall be selected such that their 50 % sparkover voltages are, approximately, 50 %, 65 % and 80 % of the specified test level.

A curve shall be drawn showing the charging voltage as a function of the sphere gap sparkover voltage. The curve shall then be extrapolated to establish the necessary charging voltage to obtain the specified test level.

The ratio of the voltage divider shall be determined from consideration of the oscillograms and the calibration curve determined as described above.

11.7.4.4 *Calibration using a impulse voltage divider system, of known ratio*

A series of measurements shall be made, using a calibrated impulse voltage divider with either a cathode ray oscillograph or an impulse crest voltmeter, to establish the relationships between generator charging voltage and generator output voltage. These measurements shall be made using positive polarity impulses at output voltage levels corresponding to approximately 50 %, 70 % and 90 % of the specified withstand level.

A curve shall be drawn showing the charging voltage as a function of output voltage. This curve shall then be extrapolated to establish the necessary charging voltage to obtain the specified test level.

11.7.4.5 *Applications of impulse at the withstand voltage specified*

With the cable maintained at the required temperature, the sample shall be subjected to a series of ten positive impulses at the withstand voltage specified. The time interval between successive impulses shall be the minimum possible, but shall be adequate to ensure that the impulse generator is charged at the correct voltage.

Immediately after the application of the first ten negative impulses, the generator shall be recalibrated for positive polarity using the conditions specified in **11.7.4.2** and the method specified in **11.7.4.3** or **11.7.4.4** and a series of ten positive impulses of the same specified voltage shall be applied to the cable. The time interval between successive impulses shall be the minimum possible, but shall be adequate to ensure that the impulse generator is charged at the correct voltage.

Oscillograms shall be made of at least the first and the tenth impulses of each sequence of ten impulses, and each shall include base and voltage calibration lines and a timing oscillation. Readings shall be taken at least once an hour, of cable sheath and ambient temperatures throughout the test period. Gas pressure shall be measured and recorded before current loading is applied and also immediately before the impulse voltage test.

11.7.5 ***Requirement***

The test assembly shall undergo the switching impulse voltage test without failure.

11.8 Lightning impulse voltage test

11.8.1 ***Test installation***

Only a test installation that has already satisfactorily completed the loading cycle test (**11.5**), the thermal stability test (**11.6**) and, where applicable, the switching impulse test (**11.7**) shall be submitted to this test.

11.8.2 ***Procedure***

Current loading shall be applied to the test assembly until for constant current the cable sheath temperatures have been steady (i.e. variations not greater than 2 °C after due allowance has been made for ambient temperature variations) for at least 2 h with maximum conductor temperature not less than the design maximum conductor temperature and not greater than the maximum temperature plus 5 °C.

With this current loading maintained, each test assembly shall be subjected to ten successive positive and ten successive negative impulses applied between conductor and core screen. The peak value of the impulse test voltage (see **6.3.3**) shall be as specified in Table 6 and equal to the value declared in accordance with Clause **5**b).

Table 6 — Lightning impulse test voltage levels

System voltage kV	Test level kVp
33	190
66	342
132	640
275	1 050

The calibration of the impulse generator and the detailed test procedure shall be in accordance with the requirements of IEC 60230.

11.8.3 ***Requirement***

During the test, no breakdown of the cable insulation shall occur.

11.9 Dielectric security test

A piece of cable at least 10 m in length, excluding the terminals, shall be subjected at ambient temperature to a power-frequency test voltage applied between conductor and screen. The value of the test voltage shall be $2.5U_0$ for fully-impregnated cables and $2.0U_0$ for not-fully-impregnated cables, and it shall be applied for 24 h.

No breakdown of the insulation shall occur during the test.

NOTE Other forms of dielectric security test are under consideration.

12 Non-electrical type tests on cables

12.1 General

The additional type tests specified in **12.2**, **12.3**, **12.4** and **12.5** shall be carried out on cables.

12.2 Internal thermal resistance of complete cable

12.2.1 ***Sampling***

A sample shall be taken that consists of at least 11 m of cable excluding terminations.

12.2.2 ***Procedure***

Potential connections, for the purpose of conductor resistance measurements, shall be made to the cable conductor at distances of 3 m and 4 m from, and on both sides of, the mid-point of the cable length.

Thermocouples shall be attached to the metallic sheath of the cable sample at intervals not exceeding 0.5 m over the central 10 m sample.

The sample shall be subjected to a constant direct current loading of the conductor until all test conditions are steady (i.e. total variation of sheath temperature not greater than 1 °C after due allowance has been made for ambient temperature variations) for 2 h with the conductor temperature not less than 90 °C and not greater than 95 °C.

12.2.3 ***Requirement***

The internal thermal resistance as determined by conductor load, measured temperature and dimensions shall not exceed the declared value by more than 10 %.

12.3 Test on pressure-retaining sheath

12.3.1 ***General***

For lead or lead alloy sheaths one sample shall be tested at each voltage level. For aluminium sheaths, samples shall be tested as specified in **12.3**.

For aluminium sheaths a cable sample shall be tested that has the size of sheath for which approval is required, or if approval is required for a range of sizes, the following samples shall be tested:

a) single core cables: one sample having a diameter of 50 mm or less and one sample having a diameter equal to the largest diameter for which type approval is sought;

b) 3-core cables: one sample having a diameter of 75 mm or less and one sample having a diameter equal to the largest diameter for which type approval is sought.

The diameter shall be measured over the crest of the corrugations.

Where approval is granted for sheaths on 3-core cables, single core cables with the same profile of corrugations shall also be deemed to be approved, with the exception that if the smaller of the sizes tested was more than 50 mm in diameter, the lower limit of the range of approval shall be restricted to that diameter. If it is desired to extend the lower limit to cover all sizes, a cable with a sheath diameter of 50 mm or less shall be subjected to and shall pass the appropriate bend test.

Where approval is granted for sheaths on single core cables, 3-core cables with the same profile of corrugations shall be deemed to be approved only if the bend test drum diameter was applicable to the 3-core cables.

12.3.2 ***Test installation***

The test sample shall consist of at least 5 m of cable suitably terminated and situated indoors away from direct sunlight. The sample shall first have been subjected to the bending test (**11.4**).

12.3.3 ***Test conditions for cable terminations***

Within the cable test termination the pressure retaining sheath and reinforcement, if any, shall be terminated as in the normal accessory practice.

12.3.4 ***Procedure***

12.3.4.1 *General*

The test sample shall be maintained for 7 days at an internal pressure equal to twice the design maximum static pressure of the cable system.

12.3.4.2 *Detailed*

The test sample shall be pressurized to the required test value and left undisturbed for a period of at least 24 h. The pressure shall then be re-adjusted to the required value and maintained at this value by a pressure accumulator system for the next 7 days. Pressure gauges shall be connected to both ends of the cable sample and readings of pressure and ambient temperature shall be taken regularly, at least twice a day for the next 7 days.

12.3.5 ***Requirement***

The mechanical integrity of the pressure retaining sheath shall be deemed to be satisfactory if the 7 day period is completed without leakage.

12.4 Test on tail cable sheaths

12.4.1 ***General***

This test shall be performed on reinforced lead tubes and aluminium tubes over single core terminations from splitter boxes.

12.4.2 ***Test installation***

The test shall be performed on tube complete with its anti-corrosion covering, having a length of at least 15 m. One sample of each type of tube shall be tested, in association with a cable core that gives a diametral clearance within the tube not greater than 110 % of the minimum design clearance.
The minimum design clearance shall be declared by the manufacturer at the time the test is performed. The diametral clearance shall be determined from measurements of the overall dimensions of the protected core and the inside diameter of the tube and these shall be taken prior to the bending and supplementary handling operations. Where the test is undertaken with an oval core, the diametral clearance shall be established by reference to the core dimension across the major axis.

12.4.3 ***Procedure***

12.4.3.1 *General*

The test sample shall be subjected to the bending and supplementary handling operations and shall then be maintained for 7 days at an internal pressure equal to twice the design maximum static pressure of the cable system. Two pieces of core, each 1 m long, shall be removed for visual examination.

12.4.3.2 *Detailed*

12.4.3.2.1 *Bending*

The tube shall undergo a single bending cycle around a drum having a barrel diameter not greater than $35d$, where d is the external diameter over smooth aluminium tubes, or over the reinforcement for lead or lead alloy tubes and over the corrugations for corrugated aluminium tubes (or to the metal tubes not having a smooth contour).

For this operation, the drum shall be mounted on a horizontal or vertical axis about which it is free to rotate. The tube shall be laid out straight and level, and one end secured to the drum. A reference line shall now be drawn along the top of the tube parallel to its longitudinal axis. The drum shall be rotated steadily so that all the tube is wound on in a close wrapped coil, care being taken to prevent the tube from twisting. The drum shall be rotated so that the tube is unwound and again laid out straight and level. The tube shall then be turned through 180° about its longitudinal axis and the winding process repeated.

12.4.3.2.2 *Supplementary handling*

After completion of the bending operation, the tube shall be unwound from the drum, laid out on the floor of the test bay and straightened. A gland tube of the appropriate size shall be plumbed (or fitted) to one end of the tube in accordance with the manufacturer's normal practice. The gland and tube shall then be pulled by hand over a cable core to which protective tapes, as normally used by the manufacturer, have been applied. The cable core shall remain stationary during this operation.

The ends of the cable core and the tube shall then be suitably terminated for the pressure test.

With the test sample still in a horizontal position, a 90° bend shall be formed near the middle of the length, having the minimum bending radius which is permissible where a former is used.

12.4.3.2.3 *Overpressure test*

The test assembly shall be pressurized by means of a pressure accumulator system and the pressure adjusted to the required test value. Pressure gauges or transducers shall be connected to the sample and the readings of pressure and ambient temperature shall be taken regularly, at least twice a day, for the next 7 days.

A piece of core and tube approximately 1 m long shall be cut from the middle of the 90° bend in the test assembly and a similar piece taken from the end where the core has passed through the entire tube. The core shall be removed and stripped of protective tapes, after which it shall be examined visually.

12.4.4 ***Requirement***

The mechanical performance of the tube and the maintenance of the declared minimum design clearance shall be deemed to be satisfactory when:

a) the 7 day period of the overpressure test is completed without leakage;

b) visual examination of both pieces of core show that the screening tapes and insulating papers have not suffered significant damage.

12.4.5 ***Range of approval***

The approval range shall cover all sizes of tube of similar design to that tested, up to and including the internal diameter of the test specimen.

NOTE The approval relates to the use of such tubes in conjunction with all sizes of core up to and including that which gives the minimum design clearance declared by the manufacturer.

12.5 Oversheath tests

12.5.1 ***General***

A sample shall be subjected to the bending test specified in **11.4** and the abrasion test specified in IEC 60229. The sample shall then be subjected to the following tests as appropriate.

12.5.2 ***Penetration test***

A toothed wheel, free to rotate, at a pitch circle diameter of 61.087 mm and with a total of 15 teeth, and in accordance with BS 228:1994, Annex A, shall be loaded and dragged once along the cable. The wheel shall be loaded with a force of $(0.20D + 2.5)$ 9.81 N, subject to a maximum loading of 176 N, where D is the diameter of cable under oversheath, in millimetres. The wheel shall be dragged 600 mm along the cable oversheath, at a speed of between 150 mm/s and 300 mm/s, on an axis at right-angles to the axis used for bending tests and opposite that used for the abrasion test. There shall be no breakdown of the oversheath.

12.5.3 ***Electrical test***

A saline bath shall be made up as specified in IEC 60229:1982, **4.1.2.2**.

The portion of the cable sample which has been subjected to the abrasion and toothed wheel test shall be laid in a U-shape with the centre immersed to a depth of 500 mm in the saline bath and its ends above the surface of the solution. The metal sheath shall be connected to the negative pole of a supply of 10 V d.c. with the positive pole connected to a metal electrode immersed in the solution. After 24 h immersion the oversheath leakage current shall be measured. The initial measured value of leakage current shall not exceed its theoretical value calculated from the design resistivity of the extruded oversheath.

The solution shall then be heated to a temperature of not less than 75 °C and not greater than 80 °C for a period of not less than 5 h and then allowed to cool naturally to the ambient temperature. This cycle shall be repeated 100 times. Prior to each heating period the oversheath leakage current shall be measured to an accuracy of 0.5 μA and the solution temperature noted. The leakage current shall not increase by more than 10 μA over the test period.

The sample shall then be subjected to the sheath electrical test specified in IEC 60229:1982, **4.1.2.2**.

12.5.4 ***Corrosion spread test (aluminium sheathed cables only)***

The corrosion spread test shall be as specified in IEC 60229:1982, **4.3**.

13 Non-electrical type tests on accessories

13.1 General

The additional type tests specified in **13.2** to **13.4** shall be carried out on accessories.

13.2 Buried joints

13.2.1 ***General***

Protective joint boxes and the joint oversheath material such as dip-coated PVC, heatshrink and tapes shall be subjected to the following tests unless otherwise agreed with the purchaser.

The tests shall be carried out in the following sequence:

— mechanical test (**13.2.2**);

— water immersion and heat cycling test (**13.2.3**);

— d.c. voltage withstand test (**13.2.4**);

— impulse voltage test (**13.2.5**).

13.2.2 ***Mechanical test***

The test area shall be a pit or open-topped container that will not deform when filled and when the required additional mass is applied.

The joint, complete with power cable and any gas pipes or bonding leads, shall be assembled in the test area and the appropriate covering placed around them and if appropriate filled with compound to the manufacturer's instructions. The test area shall then be filled with consolidated dry sand such that the highest point of the protective covering is buried to a depth of (100 ± 25) mm. Concrete cable protection covers shall then be placed in the normal manner over the sand such that they overlap the protective box in all directions by at least 50 mm.

Additional mass, in kilograms (kg), equal to the total area of covers, in square metres (m^2) multiplied by 5 000, shall then be applied evenly over the concrete cable protection covers for a period of not less than 30 min.

The test rig shall then be carefully dismantled and examined. There shall be no visible evidence of deformation, fracture or disturbance to any part of the protective cover.

13.2.3 ***Water immersion and heat cycling test***

The joint encased with the protective cover shall be immersed in water to a depth of not less than 1 000 mm above the highest point of the protective covering.

The water shall then be reheated and maintained at a temperature not less than 75 °C and not greater than 80 °C for a period of not less than 5 h and then allowed to cool naturally to within 10 °C, or 30 °C if this is greater, of ambient temperature. This cycle shall be repeated seven times.

13.2.4 ***D.C. voltage withstand test***

With the assembly still immersed, a withstand test voltage of 25 kV d.c. shall be applied for 5 min as follows.

a) For test assemblies without sheath sectionalizing insulation, the test voltage shall be applied between the cable sheath and the earthed exterior of the protective covering.

b) For test assemblies with sheath sectionalizing insulation, the test voltage shall be applied between the sheaths of the power cables at either end of the accessory and also between each sheath and the earthed exterior of the protective cover.

13.2.5 ***Impulse voltage test***

These tests shall be applied between the sheaths of the power cable at either end of the accessory and also between each sheath and the earthed exterior of the protective box. The testing shall be in accordance with IEC 60230 as far as possible. The impulse level requirements shall be as specified in Table 7.

Table 7 — Impulse voltage level requirements

System voltage kV	**Between halves** kVp	**Each half to earth** kVp
33	35	17.5
66	35	17.5
132	45	22.5
275	75	37.5

If it is not practicable to carry out the impulse test on the assembly whilst immersed, it shall be removed from the water and impulse tested with the minimum of delay. For this purpose a conductive coating shall have been previously applied over the entire exterior surface of the test assembly.

13.3 Outdoor terminations

13.3.1 ***Salt fog test***

The method and requirements shall be as specified in IEC 60507. The salt solution shall have a salinity to be agreed between the purchaser and the supplier, and the test voltages shall be as specified in Table 8.

Table 8 — Test voltages for salt fog test

Nominal voltage kV	**Test voltage** kV
132	84
275	173

13.3.2 ***Heavy wetting test***

This test shall be undertaken immediately after the salt fog test. The insulators shall be subjected to artificial rain at a rate of 2 mm/min at an angle of 45° to the vertical and conductivity of 1 000 μs/cm with test voltages as in Table 8.

The acceptance requirements shall be as specified in IEC 60507:1991, Clause **12**.

13.4 Gas-immersed terminations

13.4.1 *General*

Cable connections for SF_6 switchgear shall be in accordance with IEC/TS 60859 and the following additional requirements.

13.4.2 *Cantilever load test*

The connection shall be subjected to a bending moment of 4 500 N·m at its base, for not less than 1 min at ambient temperature, without sustaining any damage.

13.4.3 *Mechanical endurance test*

The connection shall be jointed to at least 10 m of cable. The cable switchgear termination shall be mounted vertically and subjected to vibration having a frequency of 100 Hz ± 5 % and acceleration of a minimum of 5 g peak-to-peak in all three perpendicular axes.

Where each axis is tested individually the test period shall be 30 min and where two axes are tested together the duration shall be 45 min.

On completion of the mechanical endurance test the cable shall be subjected to a hydraulic pressure test of twice the working pressure without leakage.

The cable connection shall then be subjected to an ultrasonic examination during which no abnormal reflections shall be measured.

Visual examination shall show no distortions or damage.

14 Tests after installation

14.1 High voltage d.c. test

If parts of the switchgear directly connected to the cable connection assembly cannot withstand a rated density of insulating gas at the direct voltage specified in Table 9 for 15 min, or if in the judgement of the switchgear manufacturer it is not acceptable to apply direct voltage to the switchgear, the switchgear manufacturer shall make appropriate provisions for the testing of the cable, for example disconnecting facilities and/or increasing of gas pressure in the cable connection enclosure.

NOTE 1 Increasing the gas pressure is not a reliable method of improving the electrical strength at the surface of an insulator when tested with direct voltage.

If required by the purchaser, the switchgear manufacturer shall provide the location for a suitable test bushing and shall provide the purchaser with all necessary information for mounting of such a bushing to the cable connection enclosure.

NOTE 2 If the electrical clearances are considered by the manufacturer to be inadequate, the bushing should include a suitable insulated connection and test terminal.

The test bushing shall be as specified by the purchaser at the time of enquiry.

NOTE 3 In some cases the cable test can be carried out using a.c. voltage.

Table 9 — High voltage test levels

System voltage kV	Test level kV
33	66
66	132
132	264

14.2 Conductor d.c. resistance

On completion of each circuit, the conductor resistance and ambient temperature at the time of measurement shall be measured to an accuracy of at least three significant figures.

14.3 Voltage test on oversheath and other sheath insulation

14.3.1 *Systems in general*

All the sheath-insulating provisions, including external joint insulation, terminal base insulation, sheath-sectionalizing insulation (if any), the insulation of bonding leads and link boxes, and insulating sections in gas feed pipes etc., shall be subjected to a voltage test, the procedure of which shall be agreed between the manufacturer and the purchaser, and shall conform to the requirements agreed between the manufacturer and the purchaser.

14.3.2 *Specially bonded systems*

After the temporary disconnection of sheath voltage limiters (SVLs) (each comprising three star-connected non-linear resistors) which otherwise would be damaged or destroyed by the test voltage, such systems shall meet the specified requirements.

14.4 Sheath voltage limiters

Sheath voltage limiters (SVLs) shall be tested in accordance with procedures agreed between the manufacturer and the purchaser, and shall conform to the requirements agreed between the manufacturer and the purchaser.

The reconnection of the SVLs shall be witnessed by an authorized representative of the engineer.

14.5 Link contact resistance test

A contact resistance test across all link contacts in each link box shall be carried out, and the link contacts shall conform to the specified requirements.

14.6 Positive and zero sequence impedances

14.6.1 *General*

Measurements shall be made and recorded on all single core cable circuits at system voltages of 132 kV and above, where the route length exceeds 400 m, to determine positive and zero sequence impedances. To do this, 3-phase and single-phase current injection tests shall be carried out, preferably in the range 25 A to 100 A, together with measurements of current, voltage and power or alternatively current, voltage and phase angle.

All sheath bonding and earthing connections shall be as for normal circuit operation.

Where there is more than one cable per phase, the conductors and sheaths shall be connected as for normal operations and the test detailed below carried out on the total circuit.

Particular care shall be taken to ensure that contact resistances are small compared with the resistance of the conductors. At the time of the tests, an estimate shall be made of cable temperature so that allowance can be made for the temperature dependence of resistance.

For measurements of positive sequence impedance, the cable conductors shall be bonded together and earthed at the end remote from the test. A 3-phase star-connected supply with the star point unearthed shall be used for this test. If the supply is not so isolated, the three cable conductors at the remote end shall be bonded together to form an unearthed star point.

For measurements of zero sequence impedance, the conductors shall be shorted together at the test end. At the remote end, the conductors shall be bonded together and to the cable sheaths and to earth.

A single-phase supply shall be applied between the shorted conductors and the earthed cable sheaths.

NOTE One phase of the transformer used for the measurement of positive sequence impedance may be used for this purpose.

14.6.2 ***Positive sequence impedance*** (Z_1)

Three-phase currents shall be injected, equalizing the magnitudes of the currents so far as possible. Measurements of current, voltage and either power or phase angle shall be made on each of the single core cables. From these measurements, the following shall be calculated.

Using wattmeter

$$Z_p = \frac{V_p}{I}$$

$$R_p = \frac{W_p}{I_p^{\,2}}$$

$$X_p = \sqrt{Z_p^{\,2} - R_p^{\,2}}$$

Using phase angle meter

$$Z_p = \frac{V_p}{I}$$

$$R_p = \frac{V_p}{I_p}\cos\phi$$

$$X_p = \frac{V_p}{I_p}\sin\phi$$

and $Z_1 = \dfrac{\sum Z_p}{3}$ ohms/phase

and $R_1 = \dfrac{\sum R_p}{3}$ ohms/phase

and $X_1 = \dfrac{\sum X_p}{3}$ ohms/phase

where:

I_p is the measured phase current, in amps (A);
R_p is the phase resistance;
R_1 is the positive sequence resistance;
V_p is the measured phase voltage, in volts (V);
W is the measured phase power, in watts (W);
X_p is the phase reactance;
X_1 is the positive sequence reactance;
Z_p is the phase impedance;
Z_1 is the positive sequence impedance;
ϕ is the measured phase angle, in degrees (°).

14.6.3 ***Zero sequence impedance*** (Z_0)

Single-phase currents shall be injected into the cables connected in parallel, with the test current returning through the sheaths and earth.

Measurements of current, voltage and either power or phase angle shall be made, from which the following shall be calculated:

Using wattmeter

$$Z_0 = \frac{3V}{I}$$

$$R_0 = \frac{3W}{I^2}$$

$$X_0 = \sqrt{{Z_0}^2 - {R_0}^2}$$

Using phase angle meter

$$Z_0 = \frac{3V}{I}$$

$$R_0 = \frac{3V}{I} \cos\phi$$

$$X_0 = \frac{3V}{I} \sin\phi$$

giving Z_0, R_0 X_0 in ohms/phase;

where:

- I is the measured total current, in amps (A);
- R_0 is the zero sequence resistance;
- V is the measured conductor to earth voltage, in volts (V);
- W is the measured total power, in watts (W);
- X_0 is the zero sequence reactance;
- Z_0 is the zero sequence impedance;
- ϕ is the measured phase angle, in degrees (º).

14.7 Pneumatic test

The gas pressure on each complete circuit, including all associated accessories, shall be raised to 17 bar (gauge) for 7 days. The cables shall then be maintained at normal gas pressure for a further 7 days. Throughout the latter 7 days, there shall be no leakage of gas.

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