IEC 60794-1-22

Edition 2.0 2017-10

INTERNATIONAL STANDARD

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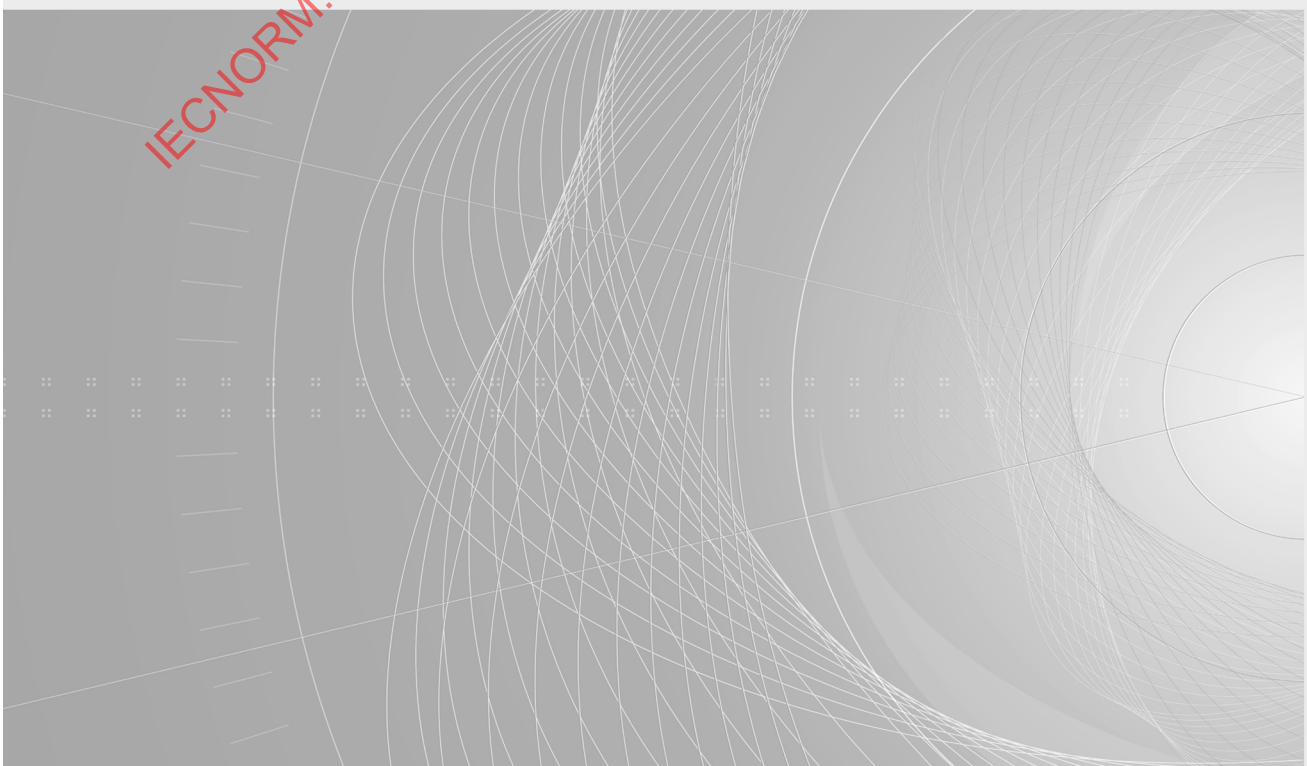
Optical fibre cables –
Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods



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Optical fibre cables –
Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods

INTERNATIONAL
ELECTROTECHNICAL
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OPTICAL FIBRE CABLES –

Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods

FOREWORD

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International Standard IEC 60794-1-22 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2012. It constitutes a technical revision.

This second edition includes the following significant technical changes with respect to the previous edition:

a) new test method designation F16 – Compound flow (drip) [E14 in IEC 60794-1-21];
b) new test method F17 – Cable shrinkage test (fibre protrusion);
c) new test method F18 – Mid-span temperature cycling test.

NOTE Missing numbers in the test methods sequence are intentional. They can suggest a deleted test method or a test method that was never published.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
86A/1813/FDIS	86A/1827/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60794 series, published under the general title *Optical fibre cables*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC 60794-1-2:2003 has been split into five new documents:

- IEC 60794-1-2, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures – General guidance*
- IEC 60794-1-21, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods*
- IEC 60794-1-22, *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental tests methods*
- IEC 60794-1-23, *Optical fibre cables – Part 1-23: Generic specification – Basic optical cable test procedures – Cable elements tests methods*
- IEC 60794-1-24, *Optical fibre cables – Part 1-24: Generic specification – Basic optical cable test procedures – Electrical tests methods*

OPTICAL FIBRE CABLES –

Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods

1 Scope

This part of IEC 60794 defines test procedures to be used in establishing uniform requirements for the environmental performance of

- optical fibre cables for use with telecommunication equipment and devices employing similar techniques, and
- cables having a combination of both optical fibres and electrical conductors.

Throughout this document, the wording "optical cable" can also include optical fibre units, microduct fibre units, etc.

See IEC 60794-1-2 for a reference guide to test methods of all types and for general requirements and definitions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

IEC 60544-1, *Electrical insulating materials – Determination of the effects of ionizing radiation – Part 1: Radiation interaction and dosimetry*

IEC 60793-1-40, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-1-46, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

IEC 60793-1-54, *Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation*

IEC 60794-1-1, *Optical fibre cables – Part 1-1: Generic specification – General*

IEC 60811-503, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 503: Mechanical tests – Shrinkage test for sheaths*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-3, *Plastics – Methods of exposure to laboratory light sources – Part 3: Fluorescent UV lamps*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Method F1 – Temperature cycling

4.1 Object

This measuring method applies to optical fibre cables, which are tested by temperature cycling in order to determine the stability behaviour of the attenuation of cables submitted to temperature changes. This method can also be used for evaluation of buffer tubes or other elements independent of a cable construction, as defined by a detail specification.

Changes in the attenuation of optical fibre cables, which can occur with changing temperature, are generally the result of buckling or tensioning of the fibres resulting from differences between their thermal expansion coefficient and the coefficients of the cable strength and sheath members. Test conditions for temperature-dependent measurements shall simulate the worst conditions.

This test can be used either for monitoring cable behaviour in the temperature range, which can occur during storage, transportation and usage, or to check, in a selected temperature range (usually wider than that required for the above-mentioned case), the stability behaviour of the attenuation connected to a substantially microbend-free situation of the fibre within the cable structure.

NOTE 1 Method F12 is a specialized subset of this method, specifically addressing cables for use in patch cords.

NOTE 2 The ageing test, F9, uses method F1 as its pre- and post-test temperature cycle. Often these tests are done together.

NOTE 3 The cable shrinkage test, F17, uses method F1 as temperature cycling. These tests can be done together.

4.2 Sample

The sample shall be a factory length or a sample of sufficient length as indicated in the detail specification but, nevertheless, of length appropriate to achieve the desired accuracy of attenuation measurements. The sample is additionally defined as the cable sample as deployed for testing.

In order to gain reproducible values, the cable sample shall be brought into the climatic chamber in a manner such that the deployment does not affect the measurement. Such methods could be a loose coil or on a reel with large diameter coils, cushioned reels with a soft layer or a zero tension facility device.

The ability of the fibre(s) to accommodate differential expansion and contraction (e.g. by slipping within the cable) could be influenced by the bending radius of the cable. Sample conditioning should, therefore, be realized as close as possible to normal usage conditions. The bend diameter of the cable sample shall not violate the minimum bend diameter of the cable, tube or other unit as specified by the detail specification.

Potential problems are due to an actual difference between the expansion coefficients of the test sample and of the holder (e.g. reel, basket, plate) which can induce, during thermal cycles, a significant effect on the test result if "no effect" conditions are not completely fulfilled. The intent is to simulate the installed condition, in which the cable is generally straight for the majority of its length.

Parameters of influence are mainly the details of conditioning, the type and materials of the holder, and the diameter of the sample coil or reel.

General recommendations include the following.

a) The winding diameter shall be large enough to keep the ability of the fibre to accommodate differential expansion and contraction. A winding diameter substantially greater than the value selected for cable delivery can be necessary.

b) Any risk of cable expansion (or contraction) limitation created by conditioning shall be suppressed. In particular, special care should be taken to avoid residual tension on the cable during the test. For example, a tight winding on a drum is not recommended as it can limit cable contraction at low temperature. On the other hand, a tight multilayer winding can limit expansion at high temperature.

c) The use of loose winding is recommended with large diameter coils and cushioned reels with a soft layer or zero tension facility device.

d) The number of fibres tested shall conform to IEC 60794-1-1.

e) The fixed cable ends as well as connection to the equipment shall be outside of the temperature chamber to avoid negative influences.

When necessary, in order to limit the length of the cable under test, it is permissible to concatenate several fibres of the cable and to measure the concatenated fibres. The number of connections shall be limited and they should be located outside the climatic chamber.

4.3 Apparatus

The apparatus shall consist of the following.

a) An appropriate attenuation measuring apparatus for the determination of attenuation change (see the test methods of IEC 60793-1-40 and 60793-1-46).

b) a climatic chamber of a suitable size to accommodate the sample and whose temperature shall be controllable to remain within ±3 °C of the specified testing temperature. One example of a suitable chamber is given in Clause 8 of IEC 60068-2-14:2009.

c) A temperature sensing device to measure the temperature of the sample, when applicable. Samples with a large thermal mass can require measurement to verify temperature stability rather than utilizing a specified exposure period, t_1 (see Table 1).

4.4 Procedure

4.4.1 Initial measurement

The sample shall be visually inspected and a basic value for attenuation at the initial temperature shall be determined.

4.4.2 Pre-conditioning

Pre-conditioning conditions shall be agreed between customer and supplier.

4.4.3 Conditioning

Figure 1 and Figure 2 show graphically the initial cycle(s) and the final cycle. Together, they illustrate the temperature cycle sequence to be used. If only one high and low temperature is specified, use Figure 1; for cycles with multiple high and/or low temperature steps, use Figure 2.

NOTE The language of the conditioning procedure is written in reference to Figure 1, for clarity. If Figure 2, with multiple low and/or high temperatures, is used, the appropriate steps are repeated for each temperature. That is, steps (2) to (4) would be repeated for each additional low temperature and/or steps (5) to (7) would be repeated for each high temperature.

1) The sample at ambient temperature shall be introduced into the climatic chamber which is also at that temperature.

2) The temperature in the chamber shall then be lowered to the appropriate low temperature T_{A2} at a rate of cooling not to exceed 60 ºC per hour, unless otherwise specified.

NOTE The initial cycles use the temperature extremes, T_{A2} and T_{B2}, regardless of whether the cycle Figure 1 or Figure 2 is being used.

3) After temperature stability in the chamber has been reached, the sample shall be exposed to the low temperature conditions for the appropriate period t_1 (see (4), below).

4) A minimum soak time is given in Table 1; however, the soak time, t_1, shall be sufficient to bring the complete cable to equilibrium with the specified temperature.

5) The temperature in the chamber shall then be raised to the appropriate high temperature T_{B2} at a rate of heating not to exceed 60 ºC per hour, unless otherwise specified.

6) After temperature stability in the chamber has been reached, the sample shall be exposed to the high temperature conditions for the appropriate period t_1.

7) The temperature in the chamber shall then be lowered to the value of the ambient temperature at the appropriate rate of cooling. This procedure constitutes one cycle (see Figure 1 or Figure 2). If this is the intermediate step in a series of cycles, no soak is required, but no measurements shall be taken.

8) Continue to the next cycle, using steps 2) through 7). The sample shall be subjected to at least two cycles unless otherwise required by the relevant detail specification. The initial cycle(s) shall comprise one low temperature and one high temperature, as per Figure 1. The final cycle shall comprise one low temperature and one high temperature, as per Figure 1, as required by the relevant detail specification. If multiple low or high temperature steps are required, the final cycle shall comprise two or more low temperatures and two or more high temperatures, as per Figure 2. On the last cycle, if multiple temperatures are specified, the sample shall be held at each intermediate temperature (T_{A1} or T_{B1}) for the appropriate time t_1. At the end of the cycling sequence, hold the sample at ambient temperature for the appropriate period t_1.

9) The attenuation shall be measured at ambient temperature at the start of the first cycle, at the end of the soak time t_1 at each of the specified temperature steps (T_{A1}, T_{A2}, T_{B1}, T_{B2}) in the final cycle, and at ambient temperature at the end of the final cycle. If measurement at intermediate cycles is required by the detail specification, the measurements shall be performed in the same manner.

10) Before removal from the chamber, the sample under test shall have reached temperature stability at ambient temperature.

Table 1 – Minimum soak time t_1

Minimum soak times for a given sample mass	
Sample mass kg	**Minimum soak time, t_1** h
Under 0,35	0,5
0,36 to 0,7	1
0,8 to 1,5	2
1,6 to 15	4
16 to 100	8
101 to 250	12
251 to 500	14
Over 501	16
NOTE It is the responsibility of the tester to assure that the soak time is long enough to bring the cable to equilibrium with the specified temperature.	

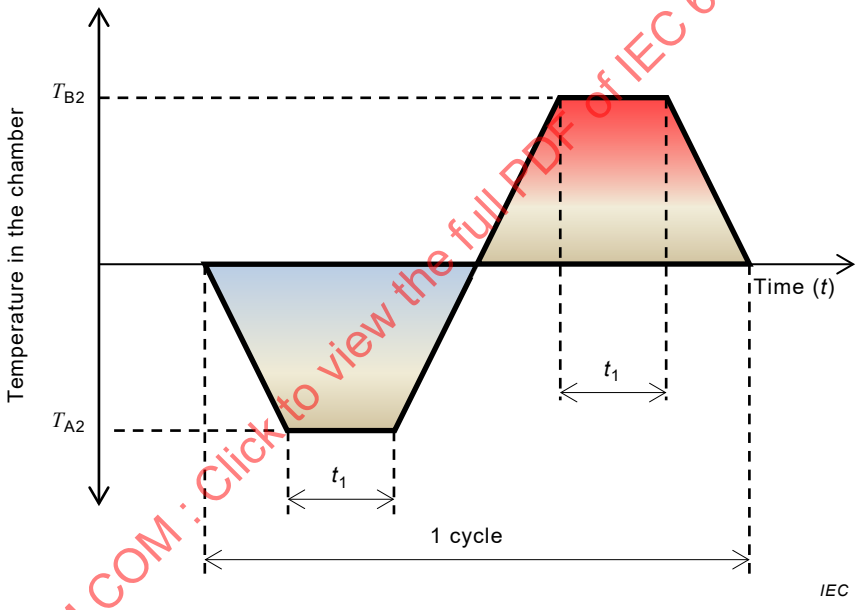

Figure 1 – Initial cycle(s) procedure

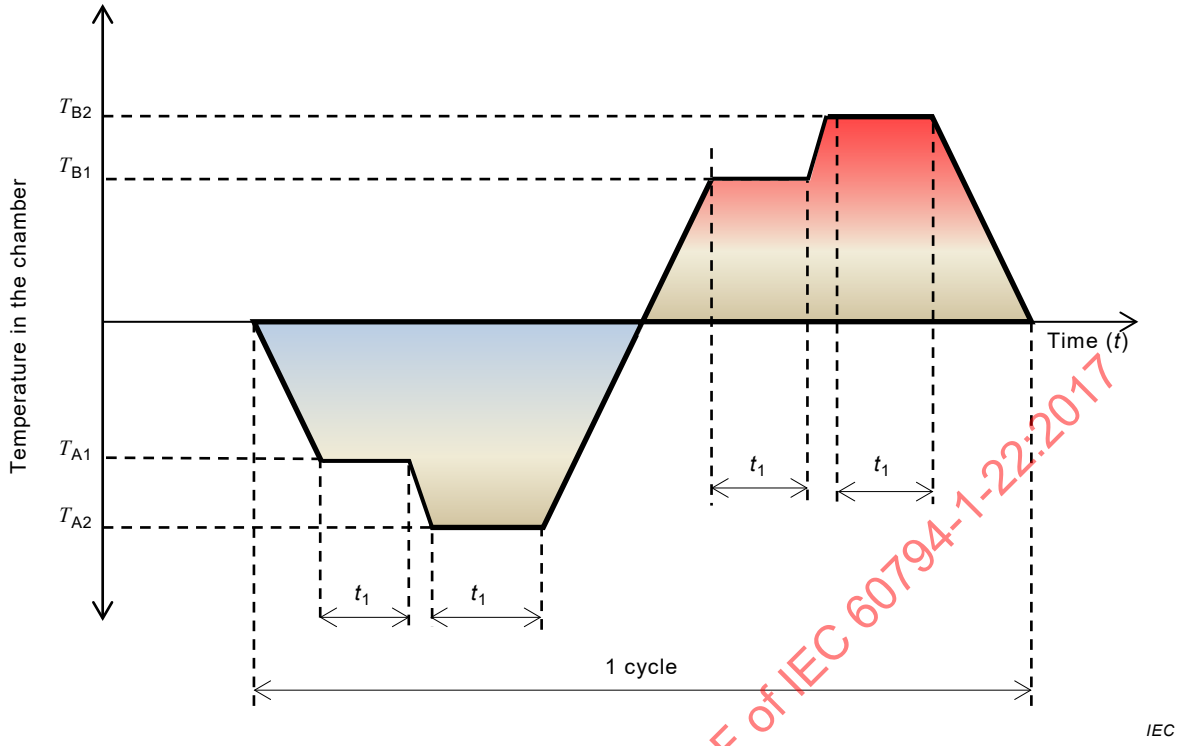

Figure 2 – Final cycle procedure

4.4.4 Recovery

If the ambient temperature is not the standard atmospheric condition to be used for testing after removal from the chamber, the sample shall be allowed to attain temperature stability at this latter condition.

The relevant detail specification can call for a specific recovery period for a given type of sample.

4.5 Requirements

The acceptance criteria for the test shall be as stated in the detail specification. Typical failure modes include loss of optical continuity, degradation of optical transmittance or physical damage to the cable. Unless otherwise specified, the change in attenuation shall be calculated with respect to the attenuation value attained at ambient conditions prior to the start of the temperature cycling test (4.4.1).

4.6 Details to be specified

The detail specification shall include the following:

a) cable sample length;
b) number of fibres tested if different from 4.2;
c) length of the fibre under test;
d) type of connection between concatenated fibres (optional);
e) temperature limits:
   i) T_{A2} and T_{B2} (Figure 1), or
   ii) T_{A1}, T_{A2}, T_{B1} and T_{B2} (Figure 2);
f) number of cycles;
g) humidity levels at each temperature extreme (if specified);

h) maximum change of attenuation (see 4.5) at a specified wavelength as a function of temperature cycling.

4.7 Details to be reported

Type of winding:

a) coil, reel, other (to be stated, in case of a cushioned reel, the type of cushioning and material used);

b) winding diameter;

c) single or multilayer;

d) winding tension and zero tension facility device (if any).

Soaking time, t_1, if different, as specified in Table 1.

5 Method F5 – Water penetration

5.1 Object

This test applies to continuously water-blocked cables. The purpose is to determine the ability of a cable to block water migration along a specified length.

- F5A evaluates radial ingress of water due to sheath damage.
- F5B evaluates longitudinal ingress of water down the entire cable cross-section designed to be water-blocked, from an undefined water exposure at a cable end.
- F5C also evaluates longitudinal ingress of water from cable end and is applicable for cables with swellable water blocking material.

Compliance shall be checked on samples of cable using one of the three following methods (F5A, F5B or F5C), as stated in the detail specification. Method F5A tests for water migration between the outer interstices of the optical core and the outer sheath, whereas methods F5B and F5C test for water migration over the entire cross-section designed to be water-blocked. Method F5C includes a precondition step, a restricted-flow apparatus, or longer sample to simulate gradual water exposure at a location along the length of a cable or at a cable end. Multiple sheath designs, for example armoured cables, are not necessarily designed to be water blocked. If so, then remove the outer layers before application of the seals.

5.2 Sample

5.2.1 Method F5A

A circumferential portion of sheath and wrapping 25 mm wide shall be removed 3 m from one end of a sample length of cable and a watertight sleeve shall be applied over the exposed core so as to bridge the gap in the sheath and allow a 1 m height of water to be applied.

The opposite end of the sample shall be capped to block any water leakage in that direction.

The sample shall be long enough to include the test end length, the length of removed sheath, and length sufficient to cap the opposite end. Generally, 3,1 m should be sufficient.

5.2.2 Method F5B

A cable sample that shall not exceed 3 m is used.

A watertight seal shall be applied to one end of the sample to allow a 1 m height of water to be applied.

NOTE 1 If the armour in armoured cables is not designed to be water-blocked, the armour can be removed at the end before the application of the seal.

NOTE 2 Water pressure can force the fibre and filling compound out of the core tubes of filled cables. Such an occurrence would be a “test void” result. Therefore, the core can require that the fibres be restrained at the exit end – as with a screen or cloth covering. Since the filled tubes exhibit robust water blocking ability, testing can focus on the water penetration characteristics of the rest of the cable. In this case, it is suggested that the core tube(s) be plugged at either end to avoid this problem.

5.2.3 Method F5C (for cables with swellable water blocking material)

A cable sample, which shall not exceed 3 m, is used for pre-soak or orifice procedure. Unless one of these procedures is selected, a longer cable sample, which shall not exceed 40 m, can be used.

A watertight seal shall be applied to one end of the sample to allow a 1 m height of water to be applied.

NOTE 1 If the armour in armoured cables is not designed to be water-blocked, the armour can be removed at the end before the application of the seal.

NOTE 2 Water pressure can force the fibre and water-blocking material out of the core tubes of filled cables. Such an occurrence would be a “test void” result. Therefore, the core can require that the fibres be restrained at the exit end – as with a screen or cloth covering.

5.3 Apparatus

5.3.1 Test fixtures and set-up

Suitable test arrangements are shown in Figures 3 to 8: for method F5A – Figure 3; method F5B – Figure 4, and method F5C – Figures 5 to 8. Unless otherwise specified in the detail specification, the sample shall be supported horizontally.

5.3.2 Water

Water shall be potable water, either common tap water or deionized or distilled water, at the option of the cable manufacturer.

A water soluble fluorescent dye or other suitable colouring agent may be used to aid in the detection of water seepage at the option of the cable manufacturer. Care should be taken in choosing a fluorescent dye that does not react with any of the cable components.

NOTE Fluorescent dyes inhibit the action of many swellable water blocking materials to some degree, which can bias test results.

If required by the detail specification, water simulating sea water (or other) may be used for the test. Note that special design considerations and test limits should apply to cables designed for salt water or brackish water exposure.

5.3.3 Orifice (method F5C)

An orifice may be placed in the tube connecting the water source to the sample to limit the water flow rate.

The orifice, if used, shall be 1,50 mm ± 0,25 mm diameter, and a maximum length of 30 mm (see Figure 7).

5.4 Procedure

5.4.1 Method F5A and F5B

1 m height of water shall be applied for 24 h.

5.4.2 Method F5C

5.4.2.1 Pre-soak (alternative)

If the pre-soak procedure is used, one end of the sample shall be pre-soaked in a bucket of water to a depth of 100 mm ± 10 mm for 10 min. After the pre-soak and at the same end, a watertight seal shall be applied to allow a 1 m height of water to be applied.

After the pre-soak procedure, 1 m height of water shall be applied for 24 h.

5.4.2.2 Orifice (alternative)

The orifice, if used, may be placed in any part of the tube connecting the water head source to the sample.

1 m height of water shall be applied for 24 h.

5.4.2.3 Longer sample (alternative)

1 m height of water shall be applied for 24 h.

5.5 Requirements

For methods F5A, F5B and F5C, no water shall be detected at the unsealed end of the sample. If a fluorescent dye is used, an ultraviolet light may be used for the examination.

NOTE The test procedure 5.4 is a basic compliance requirement. For process evaluation, test samples of shorter lengths can be tested for a shorter time.

5.6 Details to be specified

The detail specification shall include the following:

a) method used – F5A, F5B, or F5C (see Figures 3 to 8);

b) any alternative test length, water head, water type, or test duration;

c) alternative test lengths, preconditioning or leakage requirements if salt water (or other) is to be used.

5.7 Details to be reported

- If method F5C is used, which alternative procedure was used – pre-soak, orifice, or longer length.
- Details of dye, if used.
- Test length, if different.
- Duration of test, if different.

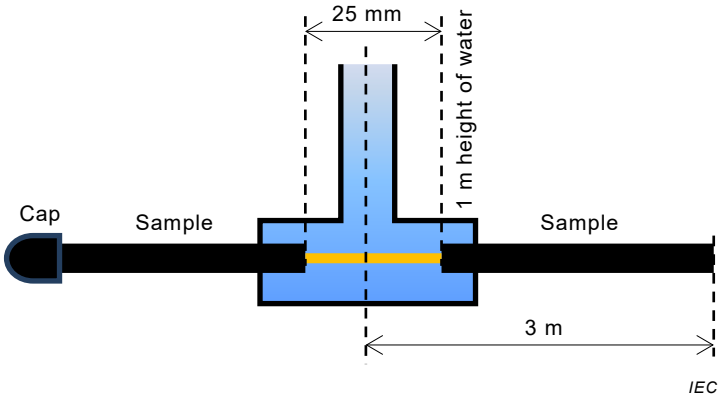

Figure 3 – Test arrangement for method F5A

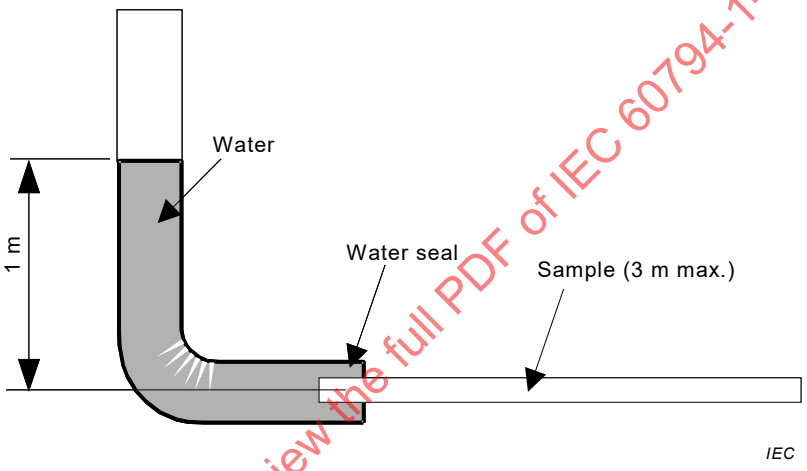

Figure 4 – Test arrangement for method F5B

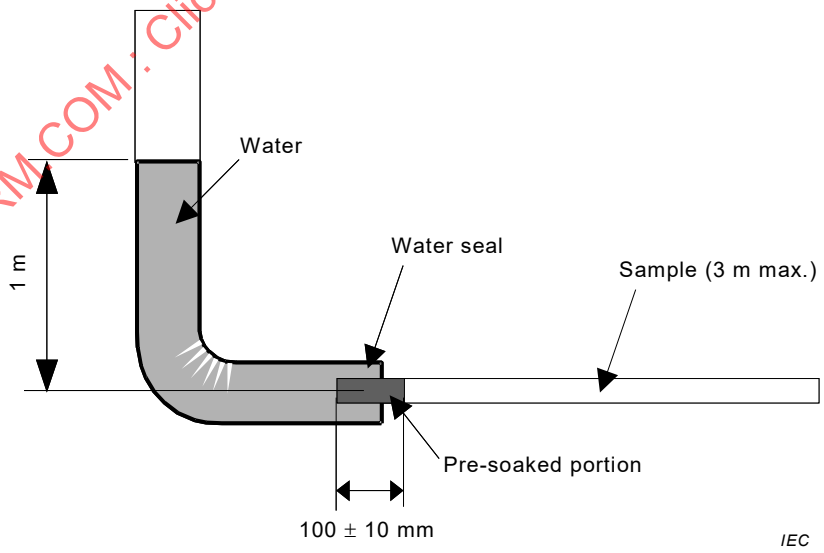

Figure 5 – Test arrangement for method F5C: pre-soaked sample

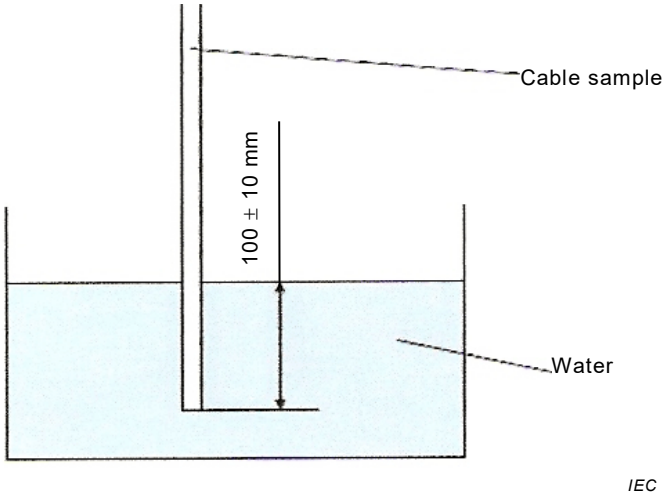

Figure 6 – Test arrangement for method F5C: pre-soak procedure

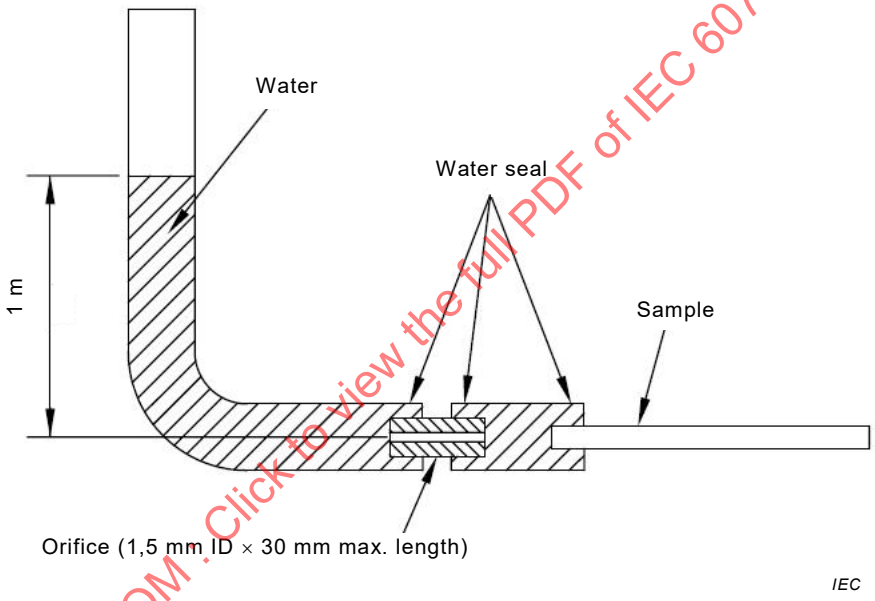

Figure 7 – Test arrangement for method F5C: orifice

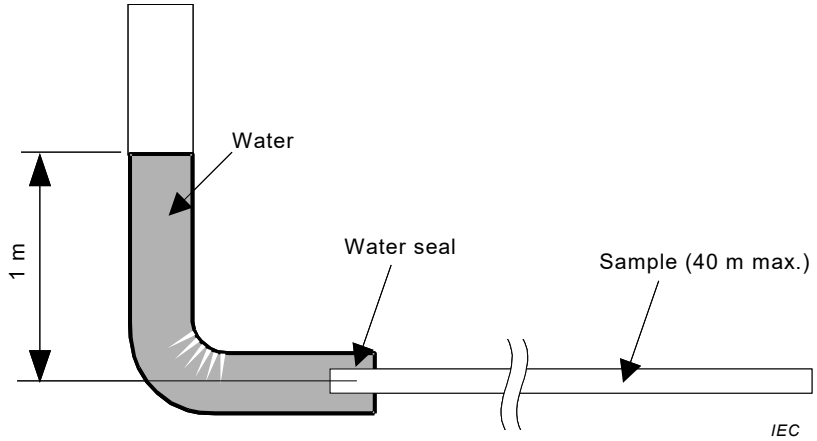

Figure 8 – Test arrangement for method F5C: longer sample

6 Method F7 – Nuclear radiation

6.1 Object

Exposure of optical fibre cables to nuclear radiation can cause a change in the attenuation of the fibres and a change in the physical characteristics of the materials used in the cable construction. Typically, attenuation is more sensitive than change in the physical characteristics.

The attenuation of fibres and cabled optical fibres generally increases when exposed to radiation, due mainly to the trapping of radiolytic electrons and holes at defect sites in the glass. Exposure of polymeric materials to radiation generally produces degradation in properties such as tensile strength, elongation at break and impact performance as the material becomes brittle (although some materials can show an initial improvement at relatively low levels of exposure due to crosslinking).

In special cases where the cable operational environment includes exposure to nuclear radiation, for example military applications and cables for use in certain areas in nuclear power stations and nuclear laboratories, fibres and materials with an appropriate radiation response can be chosen, and cable constructions incorporating metal sheaths or composite screens can be considered.

6.2 Sample

The sample shall be as defined in IEC 60793-1-54.

6.3 Apparatus

The apparatus description is given in IEC 60793-1-54.

6.4 Procedure

6.4.1 Fibres

For the radiation response of fibres, including cabled fibres, use the nuclear radiation method of IEC 60793-1-54.

6.4.2 Materials

For the radiation response of materials, the methodology given in IEC 60544-1 shall be used.

6.5 Requirements

The nuclear radiation resistance shall comply with the maximum value given in the detail specification.

6.6 Details to be specified

Details to be specified are given in IEC 60793-1-54.

7 Method F8 – Pneumatic resistance

7.1 Object

This test applies only to unfilled cables which are protected by gas pressurization. The purpose is to measure the pneumatic resistance to gas flow of such cables. The pneumatic resistance of pressurized cables is required to assure adequate functioning of the gas pressurization process and systems. The results obtained using dry air can be used to calculate the performance using other gases.

7.2 Sample

The sample of finished cable shall have a length sufficient to carry out the test specified.

7.3 Apparatus

The apparatus shall consist of the following:

a) pneumatic equipment to supply a regulated pressure of air to the sample;

b) a flow-meter;

c) a barometer;

d) a thermometer.

7.4 Procedure

The ambient temperature and barometric pressure shall be measured.

The length of finished cable shall have one end connected to a steady state source of dry air to be measured by the flow-meter, supplied by a pressure regulated source providing air with a dryness of 5 % RH or lower, at +20 °C. The other end of the cable shall be open to the atmosphere.

The pressure applied across the cable should be 62 kPa with a relative tolerance of ±2 %, and the steady state air flow shall be recorded using a flow-meter calibrated to ±10 %. Other pressures may be applied in accordance with particular user requirements and specified in the detail specification.

Only those air paths which access the interior of the sheath shall be used in the measurement.

A second measurement shall be made with the air flow direction reversed, and the results shall be recorded separately.

The pneumatic resistance is derived from the following formula:

$$R = \frac{3\,720}{f \times L} \quad \mathrm{kPa \times s / (m^3 \times m)}$$

where

L is the sample length, in metres (m);

f is the flow, in cubic metres per second (m^3/s).

7.5 Requirement

The pneumatic resistance shall comply with the maximum value given in the detail specification.

7.6 Details to be specified

The detail specification shall include the following:

a) maximum pneumatic resistance;

b) sample length;

c) pressure, if different from 62 kPa.

8 Method F9 – Ageing

8.1 Object

This test method applies to optical fibre cables which are tested by high temperature exposure and temperature cycling in order to simulate life-time behaviour of the attenuation of cables, or physical attributes specified in the detail specification.

End of life performance is not predicted by this test. However, the data may be useful in modelling performance over the lifetime of the cable.

8.2 Sample

The sample shall be the same as for method F1: Temperature cycling. If this ageing method is used in series with method F1, and F1 is performed first, the same sample may be used for this ageing test.

8.3 Apparatus

The apparatus shall be as described in method F1.

8.4 Procedure

Method F9 is frequently used as part of an overall procedure with method F1. If this is the case, method F9 shall be carried out after the temperature cycling test described in method F1. In this case, the initial attenuation value for F9 shall be that measured at the last ambient point per step 9) of F1. If method F9 is not used in conjunction with method F1, measure the attenuation at the ambient temperature.

The cable shall be exposed to the temperature and during the time specified in the detail specification. Optical measurements are not required during this phase.

After the ageing steps, perform a temperature cycling test according to method F1. Perform two cycles. At the end of the last cycle, the temperature shall be lowered to ambient temperature, which shall be maintained for 24 h, and the attenuation shall be measured.

8.5 Requirement

Calculate the change in attenuation from the initial measurement (8.4). Unless otherwise agreed between customer and supplier, the maximum allowable attenuation increase shall be

a) for single-mode fibre, tested at 1 550 nm: 0,25 dB/km, maximum, and 0,10 dB/km, average, and

b) for multimode fibre, tested at 1 300 nm: 0,6 dB/km, maximum, and 0,4 dB/km, average.

After measuring attenuation, an appropriate section of the cable shall be dissected. Any elements of the cable which are colour coded (fibres, buffer tubes, sheath) shall be examined as per Annex A.

8.6 Details to be specified

The detail specification shall include the following:

a) the exposure temperature;

b) the exposure time;

c) the maximum change in attenuation allowed, if other than as in 8.5;

d) any tests of physical attributes in addition to those of 8.5.

9 Method F10 – Underwater cable resistance to hydrostatic pressure

9.1 Object

The purpose of this test is to determine the ability of an underwater optical fibre cable to withstand hydrostatic pressure, by measuring the attenuation or by monitoring changes in optical transmission.

9.2 Sample

The sample shall be of a sufficient length to be terminated outside each end of the pressure tube vessel.

9.3 Apparatus

The test apparatus shall consist of the following:

a) appropriate attenuation measuring apparatus for determination of attenuation change (see test procedure of IEC 60793-1-40 or IEC 60793-1-46);

b) pressure tube vessel: the size of the pressure tube vessel shall be sufficient to accommodate the minimum length required by the detail specification.

9.4 Procedure

The test is to be carried out at ambient temperature. The pressure shall be maintained for 24 h or a period agreed between the user and the manufacturer.

The cable shall be installed in the pressure vessel. The water pressure in the pressure vessel during the test shall be 1,1 times higher than the water pressure at the seabed where the cable shall be installed.

The attenuation shall be measured before, during and after the test.

Special care should be taken for the tube end seals not to affect the results.

9.5 Requirements

Unless otherwise specified in the detail specification, there shall be no increase in attenuation during or after the test.

Other requirements may be agreed between the manufacturer and the user.

9.6 Details to be specified

The detail specification shall include the following information:

a) sample length;

b) pressure;

c) application period of pressure.

10 Method F11 – Sheath shrinkage (cables intended for patch cords)

10.1 Object

The purpose of this test is to measure the shrinkage behaviour of the sheath due to ageing of simplex and duplex optical fibre cables intended for use in patch cords.

This test method IEC 60811-503 shall be used with modifications related to the sampling and measuring method.

10.2 Sample

A 2 m length of cable shall be removed from the supply reel and disposed of, before cutting the test sample lengths. Five test samples of the length specified in the detail specification shall be cut from the cable.

- For test samples of a nominal 1 m length, cut 1 050 mm ± 5 mm.
- For test samples of a nominal length of 150 mm, cut 160 mm ± 5 mm.

10.3 Apparatus

A container (with typical dimensions 0,5 m × 0,5 m) into which the test sample is placed. The base of the container shall be covered with talc or paper to minimise frictional forces on the test sample and to permit free movement of the sheath.

A temperature chamber able to accommodate the test sample container and maintain the specified temperature within ±3 °C, as described in Clause 8 of IEC 60068-2-14:2009.

A length measuring device with a minimum resolution of 0,1 %.

10.4 Procedure

The cable on the supply reel shall be conditioned for 24 h at ambient temperature of before cutting the test samples.

Two marks separated by the distance of the nominal test length per the detail specification, ± 0,5 mm, shall be applied to each test sample.

The distance (L_1) between the marks on each test sample shall be measured and recorded.

A test samples are placed approximately horizontally in the container. When space allows, the sample also can be placed into the chamber in a straight configuration. If the samples shall be coiled, the test samples shall be coiled with a radius of not less than 150 mm and in such a manner as to permit free movement of the sheath.

The temperature chamber shall be heated up to the specified temperature.

The container with horizontally positioned samples is then placed in the temperature chamber.

After the specified exposure time (minimum 1 h, if not otherwise specified), the container with samples shall be removed from the chamber and allowed to cool to room temperature for a period of 1 h, if not otherwise specified.

A minimum of four such cycles shall be carried out.

After each cycle (preferably more than one sample has to be measured), the distance (L_2) between the marks on each test sample shall be measured and recorded. If the samples have been coiled, straighten them for this measurement. If the coiled samples cannot be effectively straightened for measurement, the test is rendered invalid.

The sheath shrinkage of each test sample is calculated after each cycle as:

$$\Delta L_{x,i} = (L_1 - L_{2x,i}) \text{ mm}$$

where

L_1 is the initial distance measured between the marks;

$L_{2x,i}$ is the distance measured between the marks;

i is the sample number (i = 1 to 5);

x is the cycle number (x = 1 to 4).

The average value ΔL_x = 1/5 ($\Delta L_{x,1}$+ $\Delta L_{x,2}$ +$\Delta L_{x,3}$ +$\Delta L_{x,4}$ +$\Delta L_{x,5}$) should be calculated after each temperature cycle.

Continue the test cycles until the shrinkage exhibits a variation less than ±1 mm.

10.5 Requirements

The sheath shrinkage shall not exceed the value given in the relevant detail specification.

10.6 Details to be specified

The detail specification shall include the following information:

a) details of temperature chamber and exposure high temperature;
b) duration of exposure to high temperature, if other than 1 h;
c) method of marking and length measurement;
d) sample configuration and fixing in the container;
e) number of cycles.

10.7 Details to be reported

The test report shall include the following information:

a) individual shrink values of all samples;
b) average sheath shrinkage;
c) any deviations from this test method.

11 Method F12 – Temperature cycling of cables to be terminated with connectors

11.1 Object

The purpose of this test is to examine the attenuation behaviour (change in attenuation) when optical fibre cables that are terminated with connectors are subjected to temperature cycling.

NOTE Method F1 is a general temperature cycling test for cables.

11.2 Sample

The sample shall be taken from a finished cable length. The sample length shall be as specified in the detail specification, typically 10 m.

11.3 Apparatus

The apparatus shall consist of the following:

a) a temperature chamber suitable to accommodate the sample and to maintain the specified temperature within +3 °C, as described in Clause 8 of IEC 60068-2-14:2009;
b) attenuation monitoring equipment according to IEC 60793-1-40 and IEC 60793-1-46.

11.4 Procedure

The sample shall be placed in the test chamber with a method of storage that shall not affect the optical fibre with respect to expansion or contraction. At both ends of the sample inside the chamber, all components of the cable shall be fixed together to avoid any relative movement between the cable elements at the fixing point. The fixing may be by means of clamps, or adhesive injection, or attachment with connectors, for example. Such fixing shall not affect the attenuation of the test sample. The optical fibre ends (outside the chamber) may be temporarily joint to pigtails. The deployment of the sample outside the chamber shall not affect the results.

Preconditioning procedures, if any, shall be performed as agreed between the customer and the supplier.

The temperature cycling shall be performed in accordance with method F1: Temperature cycling with the first cycle procedure as follows:

- the temperature of the chamber shall be decreased to the lower temperature T_{A1}/T_{A2} at an appropriate cooling rate;
- as soon as the temperature in the chamber has reached stable condition, the sample shall be exposed to the lower temperature during an appropriate time interval t_1;
- the temperature in the chamber is then increased to the specified high temperature T_{B1}/T_{B2} at an appropriate heating rate;
- as soon as the temperature in the chamber has reached stable condition, the sample shall be exposed to the high temperature during an appropriate time interval t_1;
- the temperature in the chamber is then decreased to ambient temperature.

This procedure corresponds to one cycle. The cooling and heating rate shall not exceed 60 °C/h.

11.5 Requirements

The maximum increase in attenuation during and after the test shall be as shown in the relevant detail specification. As in method F1, the change in attenuation shall be calculated relative to the initial attenuation at ambient before the start of the test.

11.6 Details to be specified

The detail specification shall include:

a) method of sample storage in the temperature chamber;
b) preconditioning procedures;
c) method of fixing cable ends;
d) data of test equipment including method of measurement and launching conditions;
e) number of cycles;
f) values of T_{A1}/T_{A2}, T_{B1}/T_{B2} and t_1.

12 Method F13 – Microduct pressure withstand

12.1 Object

The purpose of this test is to verify that the microduct is capable of withstanding the maximum internal pressure used for blowing the microduct cable or fibre unit.

This test ensures safe operation over a range of temperatures. The test pressure is chosen to be either the maximum working pressure of the microduct or a multiple of this as stated in the

detail specification. The controlled area is a heating/cooling chamber in the event that the detail specification requires testing above or below ambient temperatures. Typical ranges are –20 °C to +60 °C. In general, polymer microducts will have a reduced tolerance to pressure as the temperature is increased.

12.2 Sample

Equal lengths L of microduct approximately 1 m long are cut from a production length. The ends shall be cut carefully, ensuring that they are not crushed. This will prevent air leaks from around the connectors. This test shall be conducted in a controlled area so that there is no danger from flying fragments should the microduct fail.

The microduct samples shall be conditioned at the test temperature for a minimum of four hours before testing.

12.3 Apparatus

The pressure source shall be agreed between customer and supplier. Typically, it is a compressor or gas bottle. Personal protective equipment (PPE) is recommended (goggles or full-face mask and gloves).

12.4 Procedure

One end of the microduct is inserted into the pressurizing device. A fully blocking end cap (usually metal) is fitted to the opposite end. The pressurizing device is activated and the pressure slowly increased to the specified level. The sample is left pressurised for 30 min (unless otherwise stated in the detail specification).

The sample is observed for leaks at all times; it can be useful to place the microduct in a container of water to look for leaking air bubbles. After 30 min (unless otherwise stated in the detail specification), the air source is disconnected and the sample removed. PPE should be worn when entering the test area.

Ten samples shall be tested, unless otherwise stated in the detail specification.

12.5 Requirements

All samples shall withstand the applied pressure with no leakage during test and no visible damage after test.

12.6 Details to be specified

a) sample length: 1 m (unless otherwise specified);

b) test pressure: according to the detail specification;

c) duration: 30 minutes (unless otherwise specified);

d) number of samples: 10 (unless otherwise specified in the detail specification).

13 Method F14 – Cable UV resistance test

13.1 Object

This test evaluates the ability of cable sheath materials to maintain their integrity when exposed to ultraviolet (UV) radiation due to sunlight or fluorescent light, as applicable. This maintenance of integrity is evaluated by measuring the retention of tensile strength and elongation in the sheath of cable samples.

The test methods ISO 4892-2 and ISO 4892-3 shall be used.

The test of ISO 4892-2 is applicable to outdoor cables and other cables which have significant exposure to sunlight. The test of ISO 4892-3 is applicable to indoor cables which are exposed to fluorescent lighting.

13.2 Sample

Prepare samples and test specimens (six specimens and six as control specimens) as described in ISO 4892-2 or ISO 4892-3, as applicable.

13.3 Apparatus

The apparatus to be used is described in ISO 4892-2 or ISO 4892-3, as applicable.

In addition to the UV exposure apparatus, a tensile testing apparatus appropriate for testing the sheath specimens shall be used.

13.4 Procedure

13.4.1 General

Prior to conditioning, measure the control specimens for tensile strength at break and ultimate elongation in the tensile testing machine.

Condition the test specimens as described in 13.2, as applicable. After exposure, test the test specimens for tensile strength and elongation in the same manner as for the control specimens.

13.4.2 Conditioning for outdoor cables (weatherometer test)

Six test specimens shall be suspended vertically so that the external surface is uniformly exposed to the action of the actinic rays. During the test, the temperature indicated by the black-panel or the black-standard thermometer shall remain in the range +60 °C ± 3 °C and the relative humidity shall remain in the range 50 % ± 5 % (only in the dry period in the case of a test for outdoor application). The rotating drum carrying the test specimens shall turn at a speed of 1 r/min ± 0,1 r/min.

Test specimens are cycled through periods of UV exposure, followed by periods of no radiation during which temperature changes occur. The periods of each cycle, total time of 120 min, are the following: 102 min of dry UV exposure at a temperature of +60 °C ± 3 °C, followed by 18 min of rain exposure, without radiation, at a temperature of +50 °C ± 5 °C.

The overall duration of the test shall be 4 000 h (2 000 cycles), unless otherwise defined in the relevant product standard.

NOTE The MICE (mechanical, ingress, climatic, chemical and electromagnetic) table contains three classifications, ranging from 500 h to 6 000 h.

For coloured compounds, a black panel temperature of +60 °C ± 3 °C shall be used.

After the exposure, the exposed test specimens shall be removed from the equipment and conditioned at ambient temperature for at least 16 h.

The six other test specimens shall be kept at ambient temperature and protected from direct sunlight during the UV treatment and tested at the same time as the exposed test specimens.

13.4.3 Conditioning for indoor cables (QUV test)

Conditioning details for QUV test are to be determined. Refer to ISO 4892-3 for guidance. For method ISO 4892-3, applicable to indoor cables, expose the test specimens for a minimum duration of 720 h.

13.5 Requirements

After exposure, the average tensile and elongation of the test specimens shall be a minimum of 80 % of the original value.

13.6 Details to be specified

The detail specification shall include the following:

a) which method to use – ISO 4892-2 for outdoor cables or ISO 4892-3 for indoor cables;

b) any different exposure conditions or duration from those specified;

c) any compliance requirements different from those specified herein.

14 Method F15 – Cable external freezing test

14.1 Object

This test determines the ability of a cable to withstand the effects of freezing water (ice) that can immediately surround the optical fibre cable sheath by observing any changes in the physical appearance of the sheath, or in the measured cable optical attenuation.

NOTE The external freezing test simulates freezing of the medium surrounding a buried cable, as in wet earth or water. It is not intended to simulate freezing of a cable in a duct or pipe. This external freezing test has little use for evaluating an outdoor cable, since such cables rarely fail the test. The aggregate of other requirements for outdoor cables results in a cable that is sufficiently robust to easily withstand this test. Evaluation of microcables in microducts using this test is under consideration. It can be useful for evaluating cables not normally intended for outdoor installation. Users are encouraged to refer to national standards in effect in applicable regions.

14.2 Sample

A 50 m minimum length of cable shall be loosely coiled in the water to be frozen. Contact between the cable coil and the water tank wall shall be random. Additional length sufficient to make the required optical measurements and to connect the cable from the apparatus to the measuring equipment shall be provided.

14.3 Apparatus

The apparatus shall be a water tank suitable to contain the sample gauge length covered with water.

The water shall be common tap water. This procedure is written in view of the use of tap water. Other types of water, such as sea water or the like, shall be as specified by the detail specification. In these cases, the detail specification can prescribe temperatures other than those specified herein.

The water tank shall be positioned in an apparatus suitable for freezing the water and maintaining it at the specified temperature ±3 °C. An environmental chamber is a common example. Optionally, a temperature monitoring device may be used to monitor the cable temperature. In this case, the device shall be in close proximity to the sample under test.

14.4 Procedure

1) Place the cable gauge length in the water tank, either as a coil or by coiling it into the tank. Cover the cable with water.

2) Perform initial attenuation measurements as indicated by the detail specification.
3) If the optional temperature monitoring device is used, the chamber temperature may be lowered so far as to –40 °C until the ice is completely frozen and the ice temperature is –10 °C or lower.
4) Raise the chamber temperature to –2 °C and hold this temperature for 1 h.

NOTE This is the temperature at which pure water experiences its greatest volume expansion as ice.

5) Measure the attenuation as indicated by the detail specification.
6) If the optional temperature monitoring device is used, the chamber temperature may be raised so high as to +65 °C, in order to accelerate the ice melting. Maintain the high temperature until the water reaches +15 °C. Then, return the chamber temperature to +23 °C and hold this temperature until the water reaches +23 °C ± 5 °C.
7) Measure the attenuation as indicated by the detail specification.
8) Remove the cable from the water tank and examine the exterior of the gauge length for any physical damage.

14.5 Requirements

After exposure, there shall be no visible cracks or other openings in the cable sheath. The maximum increase in attenuation during and after the test shall be as shown in the relevant detail specification, when frozen and no change after thawing.

14.6 Details to be specified

The detail specification shall include the following:

a) change of attenuation during and after the test;
b) any deviations from the criteria specified herein.

15 Method F16 – Compound flow (drip)

15.1 Object

This test (E14 in IEC 60794-1-21) is intended to verify that filling and flooding compounds will not flow from a filled or flooded fibre optic cable, at stated temperatures.

15.2 Sample

a) Number and type of specimens

Unless otherwise specified in the detail specification, prepare two cable specimens for testing from each cable sample to be evaluated. Each cable specimen shall be representative of the cable type specified by the detail specification.

b) Specimen length

Unless otherwise specified in the detail specification, each specimen shall be 200 mm ± 5 mm in length.

c) Specimen preparation

Prepare each cable specimen as follows, making any modifications as required in item d).

1) Remove a 100 mm ± 2,5 mm section of the outer sheathing material from one end.
2) Remove all remaining non-intrinsic cable elements (e.g. armour, screens, inner sheaths, helically applied strength elements, water blocking tapes, other core wraps, etc.) for a length of 80 mm ± 2,5 mm from the same cable end. Do not disturb the remainder of the cable (e.g. the final buffer tubes which contain the optical fibres or fillers used for roundness).

3) Remove loosely adhered quantities of filling or flooding material disturbed in 1) or 2), but ensure that the specimen remains essentially coated by the filling or flooding material (i.e. do not wipe clean).

4) For cable designs containing components such as fibre bundles or ribbons which might move under their own weight during the test, secure such components at the unprepared end of the specimen in a manner which does not disturb the remainder of the specimen. Such components may be secured by clamps, epoxy plugs or other means meeting the objectives of the procedure.

5) When permitted by the detail specification, the upper ends of buffer tubes or loose tubes may be sealed to simulate long length cable sections.

d) Specimen termination

If allowed by the detail specification, terminate the lower end of the cable specimen according to the manufacturer's recommendations for terminating the cable in actual use. Parts of item c) procedure may be affected by this termination, but the objective of item c) is to be followed.

15.3 Apparatus

The following apparatus and equipment are required to perform this test.

a) Chamber

A temperature chamber large enough to hold the specimens in a vertical position, with sufficient thermal capacity to maintain the specified temperatures for the duration of the test. If the temperature chamber is of a circulating air type, the air shall not blow directly on the test specimens.

b) Container

A non-hygroscopic container to catch dripping material.

c) Analytical balance

15.4 Procedure

The following steps shall be taken.

a) Preheat the chamber to the temperature specified in the detail specification.

b) Place each prepared specimen in the oven, suspended in a vertical position with the prepared end down. Place a pre-weighed clean collection container directly under (but not contacting) the suspended specimen.

c) If permitted by the detail specification, preconditioning may be performed as defined in 1) to 3) below; otherwise, continue with d) below.

1) Stabilize the chamber temperature and, unless otherwise specified in the detail specification, precondition each specimen for a period of 1 h.

2) At the end of the specified preconditioning time, replace the collection container with another pre-weighed clean collection container. Weigh the preconditioning collection container to measure the quantity of filling or flooding compound which may have dripped out of the cable during the preconditioning. A measured quantity greater than the specified preconditioning limit shall constitute a failure. Unless otherwise specified in the detail specification, the preconditioning limit shall be 0,5 % of the total cable specimen weight or 0,5 g, whichever is the smaller;

3) Continue testing for 23 h, unless otherwise specified in the detail specification, and continue with e).

d) Stabilize the chamber temperature and, unless otherwise specified in the detail specification, test for a period of 24 h.

e) At the end of the specified time, remove and weigh the collection container to calculate the quantity of filling or flooding compound which may have dripped out of the cable.

f) Record this as the quantity of dripped filling or flooding compound for each cable specimen. Unless otherwise specified in the detail specification, report "no flow" for measured quantity changes less than or equal to 0,005 g.

15.5 Requirements

Unless otherwise specified in the detail specification, the cable specimens shall be permitted a maximum flow quantity of 0,050 g. If the flow quantity from one of the cable specimens exceeds 0,050 g, but is less than 0,100 g, prepare two additional cable specimens in accordance with item c) of 15.2, and test as per items a) to f) of 15.4. The test shall be considered successful if neither of the second set of specimens has flow quantities which exceed 0,050 g.

15.6 Details to be specified

The detail specification shall include the following:

a) test temperature;

b) preconditioning details (if permitted):
   - statement that preconditioning is permitted (if permitted);
   - exceptions to default preconditioning procedure as defined in 15.4 c);
   - preconditioning pass/fail criteria if other than above.

c) any exceptions to be applied to the requirements of this procedure;

d) acceptance (pass/fail) criteria, if other than default.

16 Method F17 – Cable shrinkage test (fibre protrusion)

16.1 Object

The purpose of this test is to measure the fibre protrusion compared against the cable elements and cable sheath due to temperature changes.

Low shrinkage of cable elements and cable sheath is important in most cable installations. The effect of fibre protrusion may occur when cables are used in areas with large temperature changes. Cable designs with poor stabilization elements and high material shrinkage may cause excessive fibre protrusion that can lead to an attenuation increase, cable fixing and sealing weakening and in worst cases fibre breakage.

16.2 Sample

The test sample shall have a minimum length of 10 m.

16.3 Apparatus

According to method F1.

16.4 Conditioning

The cable test sample shall be coiled in loose windings with a minimum diameter of 0,6 m, unless otherwise specified. The cable coils shall be loosely fixed at two opposite places in a way that the cable elements are free to move (expand and shrink). The coiled cable shall be put in the chamber.

The cable outer sheath shall be removed over a length of 200 mm from the cable end as shown in Figure 9. Also the strength members, inner sheath and other cable elements should be stripped closely to the end of the cable outer sheath. The secondary fibre protection or fibre tubes shall be removed over a length of 100 mm from the end of the cable outer sheath