IEC 60794-1-21

Edition 1.0 2015-03

INTERNATIONAL STANDARD

colour inside

Optical fibre cables –
Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods

IEC 60794-1-21:2015-03(en)

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CONTENTS

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OPTICAL FIBRE CABLES –

Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods

FOREWORD

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International Standard IEC 60794-1-21 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This first edition of IEC 60794-1-21 cancels and replaces the mechanical tests part of the second edition of IEC 60794-1-2, published in 2003. It constitutes a technical revision.

It has been decided to split the second edition of IEC 60794-1-2 into six new documents:

– IEC 60794-1-2, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures*
– IEC 60794-1-20, *Optical fibre cables – Part 1-20: Generic specification – Basic optical cable test procedures – General and definitions*

- 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*

The text of this standard is based on the following documents:

FDIS	Report on voting
86A/1638/FDIS	86A/1655/RVD

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

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

This standard is intended to be used in conjunction with IEC 60794-1-1.

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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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A bilingual version of this publication may be issued at a later date.

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OPTICAL FIBRE CABLES –

Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods

1 Scope and object

This part of IEC 60794 applies to optical fibre cables for use with telecommunication equipment and devices employing similar techniques, and to cables having a combination of both optical fibres and electrical conductors.

The object of this standard is to define test procedures to be used in establishing uniform requirements for mechanical requirement performance.

Throughout this standard the wording "optical cable" may also include optical fibre units, microduct fibre units, etc.

General requirements and definitions are given in IEC 60794-1-20 and a complete reference guide to test method of all types in the IEC 60794-1-2.

2 Normative references

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

IEC 60227-2, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60793-1-22:2001, *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*

IEC 60793-1-32:2010, *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*

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

IEC 60793-1-46:2001, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

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

IEC 60794-1-2:2013, *Optical fibre cables – Part 1-2: Generic specification – Cross reference table for optical cable test procedures*

IEC 60794-1-20:2014, *Optical fibre cables – Part 1-20: Generic specification – Basic optical cable test procedures – General and definitions*

IEC 60794-1-22:2012, *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods*

IEC TR 62691, *Guide to the installation of optical fibre cables*

IEC 61300-2-44, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-44: Tests – Flexing of the strain relief of fibre optic devices*

3 Method E1: Tensile performance

3.1 Object

This test method applies to optical fibre cables which are tested at a particular tensile strength in order to examine the behaviour of the attenuation and/or the fibre elongation strain as a function of the load on a cable which may occur during installation and operation. This method is intended to be non-destructive.

3.2 Sample length

Length under tension ≥ 50 m unless otherwise defined in the relevant specification. For cables requiring specialized anchoring devices (e.g. OPGW, all-dielectric self-supporting (ADSS), heavy wire armored cables, etc.), the minimum length shall be 25 m.

Short lengths in the tensile test will adversely affect the accuracy of the measurement. The lengths shown above are the recommended minimum lengths for this test.

Total sample length is longer than the length under tension to allow for clamping and connection to test equipment.

3.3 Apparatus

The apparatus consists of

a) an attenuation measuring apparatus for the determination of attenuation changes (see IEC 60793-1-40), and/or a fibre elongation strain measuring apparatus (see IEC 60793_1_22:2001, Method C: Fibre elongation);
b) a tensile strength measuring apparatus which is able to accommodate the minimum length to be tested. Transfer devices may be used for testing longer samples under tension (see Figure 2). The diameters of sheaves in the transfer device shall be no smaller than the minimum bending diameter of the cable under test; typically 1 m diameter;
c) a load cell with a maximum error of ± 3 % of its maximum range;
d) a clamping device to secure all cable components at the ends of the length under test: care should be taken that the specific method of capturing the cable components does not affect the results. A mandrel is frequently an appropriate device, with a diameter typically 1 m, but not less than the minimum bending diameter specified for the cable;
e) if required, mechanical or electrical means for measuring the cable load or elongation, per the detail specification shall be provided.

Examples of suitable apparatus are shown in Figure 1 and Figure 2.

3.4 Procedure

3.4.1 General requirements

a) Unless otherwise specified, the conditions for testing shall be in accordance with the expanded test conditions as defined in IEC 60794-1-20.

b) Load the cable onto the tensile rig and secure it. At both ends of the tensile rig, a method of securing the cable shall be used, which uniformly locks the cable so that all components of the cable, including fibres, are restricted in their movement. For most cable constructions (e.g. stranded type cables), clamping on cable elements, except the fibres, is practical and sufficient to obtain attenuation changes and/or both the maximum allowable pulling load and the strain margin of the cable. However, for certain cable constructions (e.g. single loose tube), it may be necessary to prevent the fibres from slipping in order to obtain the correct strain margin figures.

For aerial cable types, if required by the detail specification, the fixing of the cable may be made by means of the anchoring devices relevant to the type of cable considered. For certain heavily armoured cables, a clamping device involving a stocking grip or similar anchoring device may be used.

c) Connect the test fibre of the cable under tensile test to the measurement apparatus. For the pulse delay (time of flight) technique of Method C of IEC 60793-1-22:2001, care shall be taken that, during the pulling of the sample, the reference length does not change.
d) The tension shall be continuously increased to the required value(s) given in the relevant specification.
e) The change of attenuation and/or fibre strain shall be recorded, as a function of cable load or elongation.
f) For cables with a large number of fibres, a multiple attenuation and/or fibre strain measuring device can be used.
g) A representative number of fibres and/or a number of test cycles (typically one) shall be agreed between manufacturer and customer.
h) The readings taken at the end of the time periods stated in 3.4.2 should be stable (i.e within measurement uncertainty) before the loads are changed or the test completed. If the readings are still fluctuating then the load holding period should be extended until they are stable.

3.4.2 Procedure

Measure the optical attenuation and/or determine the fibre strain before the start of the test as a baseline:

a) apply the short-term load to the cable;
b) hold this load for 10 min;
c) determine fibre strain, if required;
d) if required, change the applied load to the long term load
   - hold this load for 10 min,
   - measure the attenuation and/or determine the fibre strain;
e) remove the load;
f) allow the cable to rest for 5 min;
g) measure the attenuation and/or determine the fibre strain.

Different steps and load levels can be used if agreed between customer and supplier.

3.5 Requirements

The attenuation change and/or fibre strain of the sample shall not exceed the values given in the relevant specification.

3.6 Details to be specified

The relevant specification shall include the following:

– length under tension if different from this method;

- T_L long term load: load applied, limits on fibre strain, and/or change of attenuation;
- T_S short term load: load applied, limits on fibre strain (if required);
- $T_{after\ the\ test}$: limits on fibre strain and/or change in attenuation.

3.7 Details to be reported

Values for all attributes from 3.6 shall be reported plus the following:

- end preparation;
- rate of tension increase;
- temperature, if different from that indicated for standard test conditions.

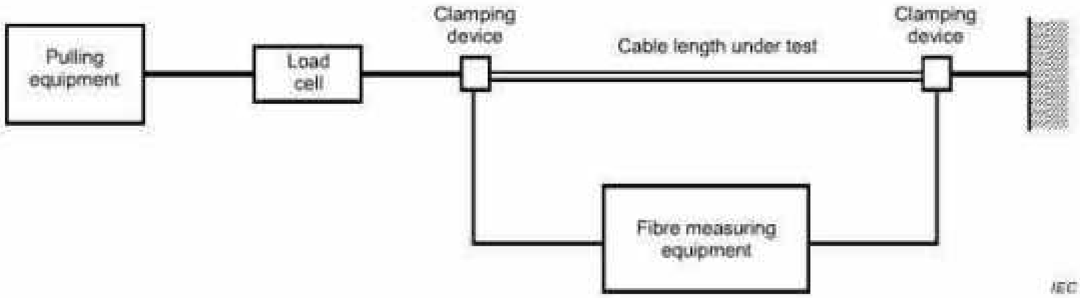


Figure 1 – Tensile performance measuring apparatus

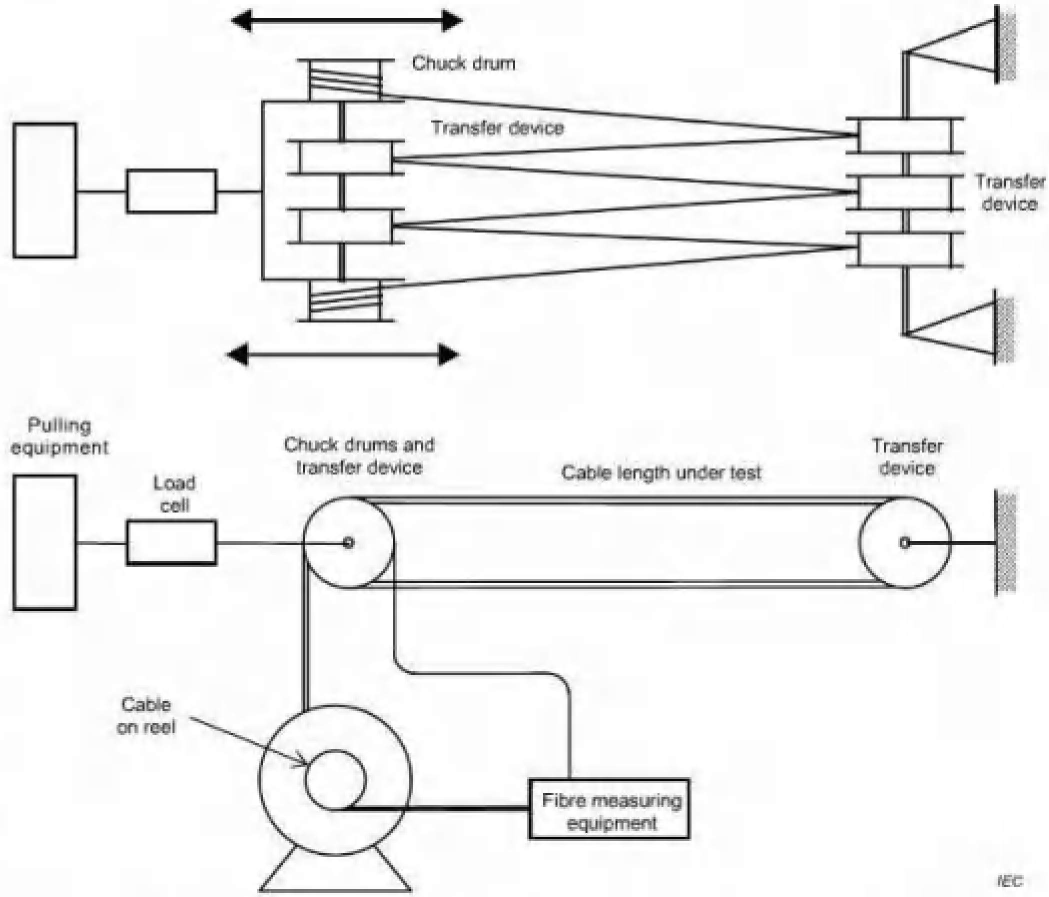


Figure 2 – Example of tensile performance measuring apparatus using transfer devices and chuck drums

4 Method E2: Abrasion

4.1 Object

The abrasion resistance of optical fibre cables has two aspects:

a) the ability of the sheath to resist abrasion, E2A;

b) the ability of cable markings to resist abrasion, E2B.

The purpose of this test is to determine the ability of an optical fibre cable sheath or sheath markings to resist abrasion.

4.2 Sample

The sample shall be of a length sufficient to carry out the specified test. A typical length is 750 mm.

4.3 Method E2A: Abrasion resistance of optical fibre cable sheaths

4.3.1 Apparatus

The abrasion test rig consists of a device designed to abrade the surface of the cable in both directions parallel to the longitudinal axis of the cable over a length of (40 ± 1) mm at a frequency of (55 ± 5) cycles/min. One cycle consists of one abrading edge movement in each direction.

The abrading edge shall be a steel needle with a diameter of 1,0 mm or as specified in the detail specification

A typical apparatus is shown in Figure 3.

4.3.2 Procedure

The following steps shall be taken:

a) Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions, as defined in IEC 60794-1-20.
b) Securely attach the cable sample to the supporting plate by means of cable clamps. The abrading edge shall be loaded with 4 N whilst avoiding shock to the cable. The initial position shall be such that there is length available for the subsequent movement of the sample, per c) below.
c) Four tests shall be made on the sample, with the sample moved forward 100 mm between tests and rotated through an angle of 90°, always in the same direction.

4.3.3 Requirements

There shall be no perforation of the sheath after performing the number of cycles specified in the detail specification.

4.3.4 Details to be specified

The detail specification shall include the following:

a) number of cycles;
b) force applied if other than specified herein; and
c) diameter of needle if other than specified herein.

4.4 Method E2B: Abrasion resistance of optical fibre cable markings

4.4.1 Apparatus

4.4.1.1 Method 1

As specified in E2A.

4.4.1.2 Method 2

The apparatus follows the intent of that specified in E2A and in E2B, Method 1, with the needle replaced by a wiping felt. The following changes are made in the apparatus:

a) a test set-up, to apply a force to the wool felt. A typical example is shown in Figure 4;
b) a wool felt, colour white;

   NOTE Common felts are a blend of wool and other fibres, commonly rayon. Blends from 100 % to 30 % wool, or as specified by the relevant specification, meet the purpose of this method.

c) masses to apply a force to the sample;
d) the apparatus shall allow a stroke length of 100 mm at a frequency of 6 to 12 cycles/min.

4.4.2 Procedure

4.4.2.1 General

Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions.

4.4.2.2 Method 1

As specified in E2A, but all four tests shall be made on the cable marking.

4.4.2.3 Method 2

A sample of cable containing markings shall be laid between the two parts of the wool felt or between the wool felt and a supporting surface. In either case, the wool felt shall wipe the printed section of the cable.

The wool felt shall be thoroughly impregnated with water.

The normal force (F) of 5 N (or as given in the detail specification) shall be applied to the markings on the sample which is moved back and forth over a length of 100 mm. The number of cycles shall be specified in the detail specification.

4.4.3 Requirements

The marking shall be legible at the completion of the test after the number of cycles specified in the detail specification.

4.4.4 Details to be specified

The detail specification shall include the following:

a) number of cycles;
b) method used;
c) force applied if other than specified herein.

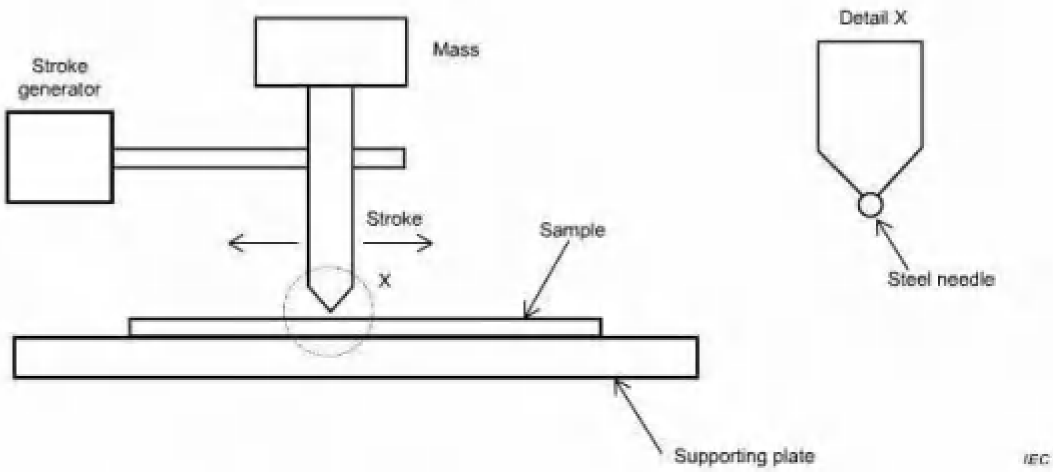


Figure 3 – Typical test set-up for tests E2A and E2B method 1

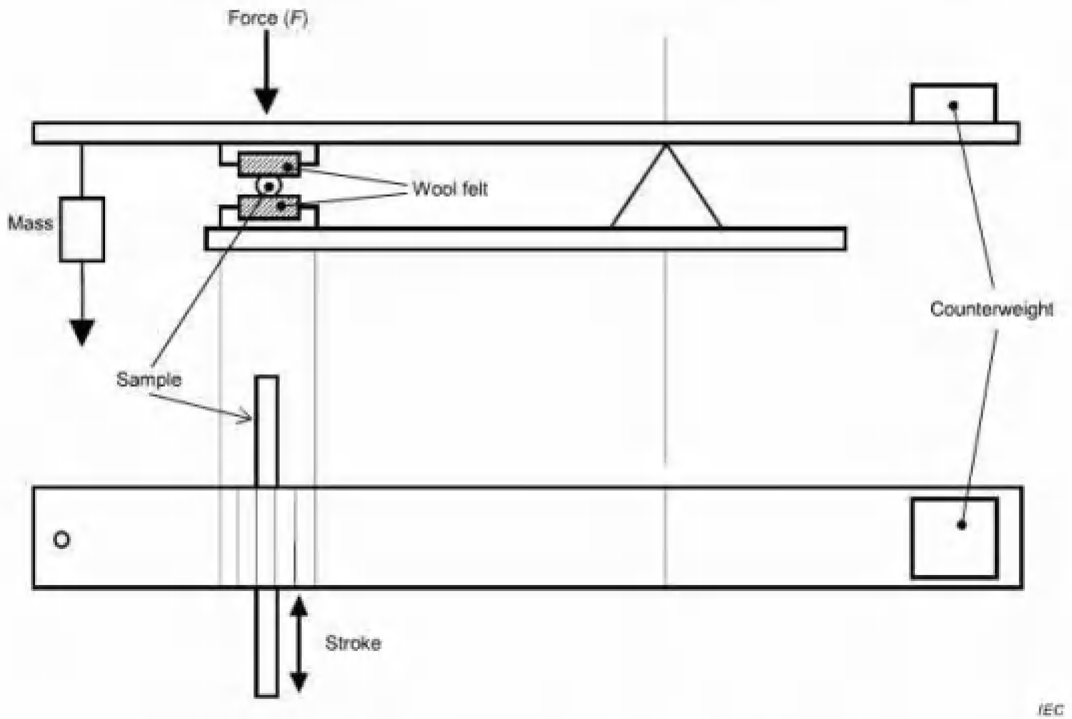


Figure 4 – Typical test set-up for test E2B, apparatus 2

5 Method E3: Crush

5.1 Object

The purpose of this test is to determine the ability of an optical fibre cable to withstand crushing for long term and for short-term loads.

NOTE Method E3A corresponds to the default method, Method E3 Crush, defined in IEC 60794-1-2:2013.

5.2 Sample

The sample shall be of a length sufficient to carry out the specified test.

5.3 Method E3A: Plate/plate

5.3.1 Apparatus

The apparatus shall allow a sample of cable to be crushed between a flat steel base plate and a movable steel plate which applies the crushing force uniformly over a 100 mm length of the sample.

The edges of the movable plate shall be rounded with a radius of about 5 mm. The edges are not included in the 100 mm flat part of the plate. A suitable apparatus is shown in Figure 5.

5.3.2 Procedure

The cable sample shall be mounted between the plates so that lateral movement is prevented, and the force shall be applied gradually without any abrupt change. If the force is applied in incremental steps, these shall not exceed a ratio of 1,5:1.

The force shall be maintained stable at the specified test value at a specified time. This time is typically 1 min (short-term) or 10 min (long-term) if not specified in the detail specification. Attenuation measurement shall be performed before the force is released.

Unless otherwise specified in the detail specification, the test shall be performed three times, the force being applied on the specimen at three different places, without rotating the cable. The distance between each crush shall be not less than 500 mm apart and different from the lay length of the cable core.

Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions.

5.4 Method E3B: Mandrel/plate

5.4.1 Apparatus

The same apparatus as for Method E3A shall be used, but a steel mandrel with a diameter of 25 mm (unless otherwise specified in the detail specification) is inserted perpendicular to the sample or replaces the movable plate in Figure 6.

5.4.2 Procedure

The procedure is the same as for Method E3A but a steel mandrel with a diameter of 25 mm (unless otherwise specified in the detail specification) is inserted perpendicular to the sample.

5.5 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.

NOTE Imprints or scratches on sheath and cable elements are not regarded as a failure.

5.6 Details to be specified

The detail specification shall include the following:

a) total force applied, F;

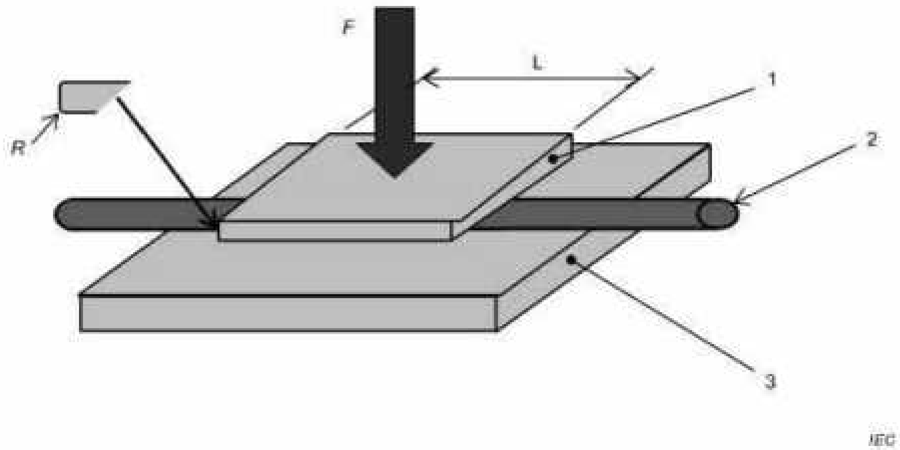
b) duration of application of the force;

c) number of tests;

d) spacing between test places;

e) configuration of mandrel, if used;

f) maximum allowable change in optical transmittance for short- and long-term load during and after the test.



Key

R radius of edge of movable plate, 5 mm

F force on movable place, as defined in relevant specification

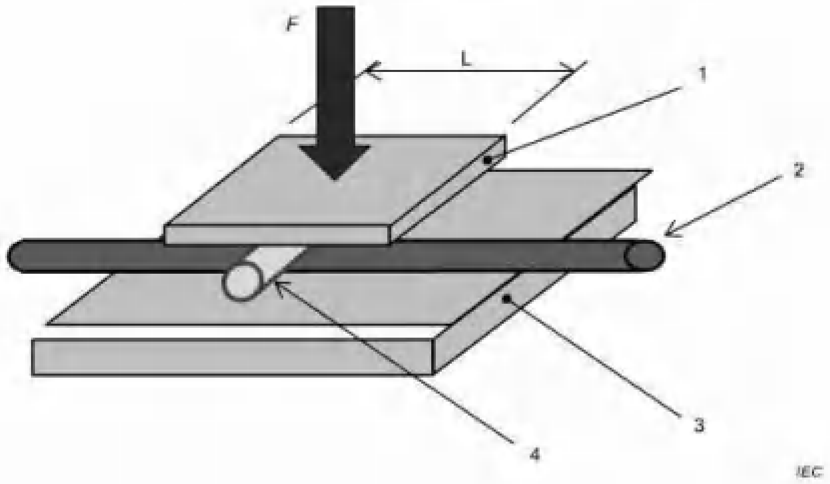
L length of plate, 100 mm

1 movable plate

2 cable under test

3 fixed plate

Figure 5 – Apparatus for crush test, Method E3A, details of plate/plate option



Key

F force on movable place, as defined in relevant specification

L length of plate, 100 mm

1 movable plate

2 cable under test

3 fixed plate

4 mandrel (cylinder or half-cylinder), 25 mm diameter

Figure 6 – Apparatus for crush test, Method E3B, details of plate/mandrel option

6 Method E4: Impact

6.1 Object

The purpose of this test is to determine the ability of an optical fibre cable to withstand impact.

6.2 Sample

6.2.1 Sample length

The sample length shall be sufficient to carry out the specified test. When only physical damage is to be evaluated, the length may range from 1 m (for example for small diameter jumper cords or duplex cables) to 5 m (for larger diameter cables). Longer lengths may be necessary to permit optical measurements.

6.2.2 Termination

The sample shall be terminated at each end in a connector, or in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner. Clamps on the impact apparatus may be used, or the sample may be long enough so that no restraint is needed.

6.3 Apparatus

The apparatus shall allow an impact to be imparted to the cable sample which is fixed to a flat substantial steel base. When a single or only a few impacts are required, a suitable apparatus, as shown in Figure 7a, is used. This allows a weight to drop vertically onto a piece of steel which transmits the impact to the cable sample. When repeated impacts are required (say, more than five), a more practical apparatus, as shown in Figure 7b, is used, which allows multiple impacts by a drop hammer. The apparatus shall be arranged to impart minimal friction to the moving weight/hammer.

NOTE This issue of friction has been found to be a particular problem when the apparatus is used at temperature extremes.

In both cases, other equivalent apparatus may also be used.

The striking surface shall either be flat or have a curved surface with curvature radius of no less than 300 mm. If using a flat striking surface, the edges of the face shall be radiused to avoid a stress concentration riser, Figure 7c, detail B. If using a 300 mm curvature radius striking surface, then the surface may also be a spherical segment, as shown in Figure 7c, detail A, since for such a large curvature radius this gives an equivalent test method to that when using a rounded cylinder,.

The radius on the edge on the flat striking surface and on the 300 mm curvature radius striking surface shall be approximately 0,5 mm.

The apparatus shall include any optical test equipment needed to measure the changes in optical performance as required in the detail specification, and specified in Method A (Transmitted power) of IEC 60793-1-46:2001.

6.4 Procedure

Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions.

The mass of the weight or drop hammer and the height from which it falls shall be adjusted to give the value of impact energy shown in the detail specification. The number and rate of impacts, and their location on the sample shall be as specified in the detail specification.

6.5 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.

6.6 Details to be specified

The detail specification shall include the following:

a) number of impacts;

b) impact energy;

c) test temperature;

d) radius of the striking surface if other than specified herein;

e) frequency of multiple impacts (if any);

f) location of impacts on the sample;

g) if optical continuity or change in transmittance is to be measured.

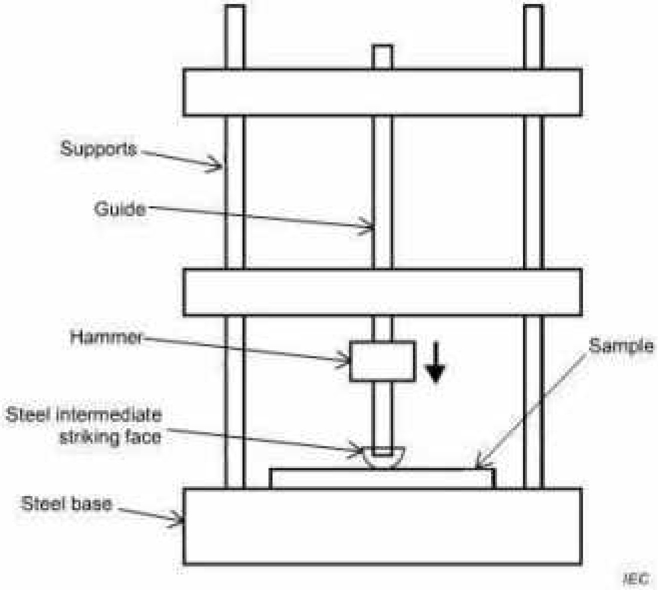


Figure 7a – Impact test – Apparatus for a few impacts

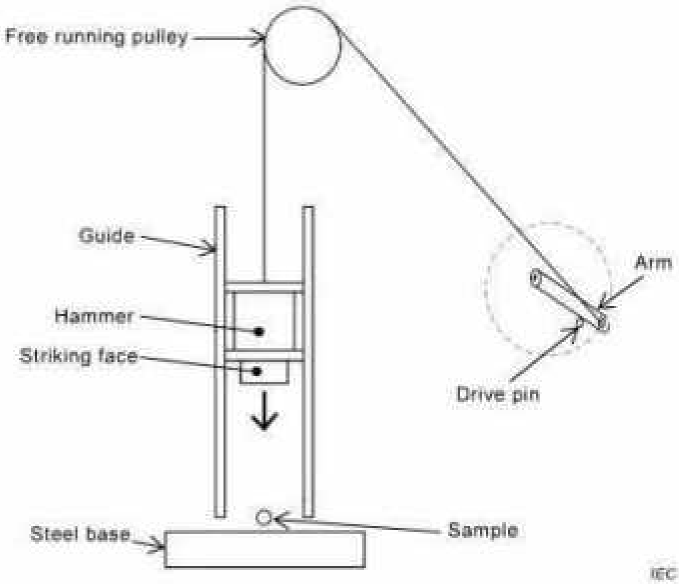


Figure 7b – Impact test – Apparatus for multiple impacts

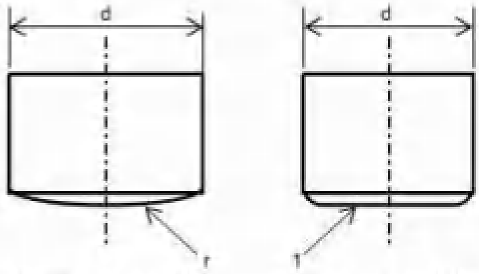


Figure 7c – Impact test – Details of the striking surface

Key

d hammer diameter, 20 mm ± 1 mm

r striking surface curvature radius, 300 mm, minimum

1 flat striking surface, with radiused edges

Figure 7 – Impact test

7 Method E5A: Stripping force stability of cabled optical fibres

7.1 Object

This test determines the stability of the stripping force of the coating of cabled fibres by measuring the change in fibre strippability after exposure to specified environmental conditions.

7.2 Sample

7.2.1 Sample length

The length of the cable or fibre sample shall be sufficient to carry out the specified test.

7.2.2 Sample preparation

The cable from which the fibres shall be taken is preconditioned, as specified in the detail specification, prior to withdrawal of the fibres.

The test shall be carried out on fibres taken from a sample of cable which is further divided into two lengths (minimum 2 m). One length is for testing and the other for reference measurements.

Sufficient samples shall be provided to allow tests to be carried out on 10 test pieces of fibre, conditioned as specified in the detail specification, and compared with test results for fibres taken from the reference cable length.

After withdrawal, any filling compound adhering to the fibres shall be carefully removed (e.g. by wiping with a soft tissue).

7.3 Apparatus

The apparatus consists of conditioning equipment (if necessary) and a fibre strippability apparatus (see the strippability test method of IEC 60793-1-32:2010).

7.4 Procedure

The optical fibre strippability shall be measured on the environmentally conditioned samples using the strippability method of IEC 60793-1-32, after the recovery time and reconditioning as given in the detail specification. The same method shall be used to measure the strippability of fibre samples taken from the reference cable length and the change in stripping force shall be determined from a comparison of the results.

Alternatively, samples may be taken from cable aged according to Method F9 of IEC 60794-1-22:2012.

7.5 Requirements

The change in stripping force shall meet the requirements specified in the detail specification.

7.6 Details to be specified

The detail specification shall include the following:

a) cable preconditioning;

b) fibre conditioning;

c) recovery time and reconditioning;

d) permissible change in stripping force.

8 Method E5B: Strippability of optical fibre ribbons

8.1 Object

The purpose of this test is to evaluate the strippability of optical fibre ribbons in terms of fibre cleanliness after coating removal and fibre breakage due to ribbon stripping.

8.2 Sample

The test sample shall be representative of the population of ribbons under evaluation.

Samples may be taken sequentially along a length of ribbon but sections of the ribbon previously in the grips of the stripping tool shall be excluded.

The length of the sample shall be sufficient to allow the matrix and fibre coatings to be removed over a minimum length of 25 mm with a maximum of ten and a minimum of five strips per sample.

Sample environmental conditioning requirements shall be agreed between customer and supplier.

8.3 Apparatus

8.3.1 General

A ribbon stripping apparatus and conditioning equipment (if necessary).

8.3.2 Stripping tool

The results of the test are strongly dependent upon the design of the stripping tool used and the following tool design guidelines shall be taken into account:

– The mechanical stripping tool shall provide a heated surface that operates at a temperature in the range +70 °C to +140 °C. The heated surface, once set to the specified temperature, shall maintain that temperature within ± 5 °C during the stripping operation. The heated surface(s) shall be located behind the stripping blades and positioned to heat the part of the ribbon in which the coating is to be removed.

Heat-up time and dwell time for the tool may be important and the tool manufacturers recommendations shall be followed.

Follow the ribbon manufacturer's recommendations for setting the tool temperature.

- The stripping tool or loading fixture shall maintain a constant pressure sufficient for proper stripping. Care shall be taken that the tool does not begin to open during stripping.
- The size of the gap between the blades shall be known. This dimension and its tolerance shall ensure that the blades cut through the matrix material and fibre coatings without damaging the fibre cladding.
- The condition of the blades can greatly affect the peak strip force and stripping action. The edges of the blades shall be inspected for notches and burrs under normal vision before and after use.
- Replace the blades when they become damaged or blunt or whenever wear is sufficient to affect the results.

8.3.3 Motor and slide (if used)

The motor and slide shall allow repeatable motion with low vibration and fast acceleration. They shall be capable of imparting constant motion, without jerking, to the test ribbon or stripping tool.

If a manual tool is used, the stripping action shall follow these same criteria.

8.3.4 Positioning and holding equipment

The test sample shall be firmly held in place so that no slippage occurs (a capstan is recommended). The sample ribbon fibres shall be in line (vertically, horizontally and rotationally) with the plane of the stripping motion.

8.3.5 Alcohol wipe

A non-abrasive cloth or paper material saturated with a suitable alcohol solution shall be used to wipe the fibres after stripping.

8.4 Procedure

Unless otherwise specified, the condition for testing shall be in accordance with controlled ambient conditions. The strip length shall be ≥ 25 mm and the strip velocity shall be as given in the detail specification (between 100 mm/min and 500 mm/min).

Turn on the test apparatus and allow the tool temperature to stabilize.

Ensure that the area around both blades of the stripping tool is free from debris from any previous use and that the blades are clean.

Strip the ribbon following the manufacturer's recommendation on heating dwell time prior to stripping.

After stripping wipe the stripped fibres with the alcohol wipe and inspect them visually at a magnification of at least 2X.

Assess the cleanliness and integrity of the fibres after stripping as indicated in Table 1.

Table 1 – Condition of stripped samples

Rating	Condition of stripped sample
1	Coating and matrix materials leave no residue after one or two alcohol wipe
2	Coating and matrix material crumbles or breaks up leaving a heavy residue upon stripping and multiple alcohol wipes are required to remove residue on the fibres. Fibres are capable of being wiped clean without a second strip.
3	Incomplete strip, some fibre coating remains intact. Multiple strips and alcohol wipes are required to remove all visible residue from the fibres.
4	Failed strip: – One or more fibres break. – Fail to strip within the required speed.

Carry out the number of strips as given in the detail specification and calculate the average cleanliness rating for each sample, rounded to the nearest whole number.

8.5 Requirements

The average cleanliness rating shall comply with the values given in the detail specification.

No fibres shall break.

8.6 Details to be specified

The detail specification shall include the following:

a) type of stripping apparatus;
b) average dwell time;
c) stripping tool temperature;
d) stripping velocity;
e) strip length;
f) sample environmental conditioning;
g) required average cleanliness rating;
h) number of fibres in the ribbon.

9 Method E5C: Strippability of buffered optical fibres

9.1 Object

This test determines the stability of the stripping force of buffered optical fibres.

Tests to evaluate two types of buffers are included: tight buffer fibres, where the buffer is in intimate contact with the fibre's outer coating, and loosely-bound buffer fibres, wherein the buffer is designed to be removable while leaving the fibre coating intact.

9.2 Sample

Samples of buffered fibre to be tested shall comply with the requirements of Method E5A.

9.3 Apparatus

The apparatus shall comply with the requirements of Method E5A.

The fibre stripping apparatus shall have sufficient clearance to accommodate the buffer to be stripped.

In the case of loosely-bound buffer, the cutting surfaces of the fibre stripping apparatus shall be sized such that the coating of the fibre beneath the buffer is not cut or damaged by the stripping operation.

9.4 Procedure

Follow the procedure of Method E5A.

If comparison of unaged and aged samples is specified, perform the procedure as follows, following the intent of Method E5A:

– Set aside unaged control samples for later test.
– Age the buffered fibre in the cable or in a representative environment in the lab (in fill, or the like, as appropriate) as specified in the detail specification. Ageing according to Method F9 of IEC 60794-1-22:2012 is generally appropriate.
– After ageing, remove the samples from the cable or other for strip testing.
– Perform the stripping of the control samples and the aged samples per method E5A.

9.5 Requirements

The buffered fibres shall meet the strippability or strippability stability requirements of the detail specification.

9.6 Details to be specified

The detail specification shall include the following:

a) cable preconditioning, if any;
b) fibre conditioning;
c) recovery time and reconditioning;
d) permissible change in strip force or maximum/minimum strip force.

10 Method E6: Repeated bending

10.1 Object

The purpose of this test is to determine the ability of an optical fibre cable to withstand repeated bending.

Repeated bending of connectorized optical fibre cable involves testing as a unit, testing both the capabilities of the cable and the connector. This testing is defined by IEC 61300-2-44. Refer to that standard for testing of connectorized assemblies.

10.2 Sample

10.2.1 Sample length

The sample length shall be sufficient to carry out the specified test. When only physical damage is to be evaluated the length may range from 1 m (for example for small diameter cords or duplex cables) to 5 m (for larger diameter cables). Longer lengths may be necessary to permit optical measurements.

10.2.2 Termination

The sample shall be terminated at each end in a manner such that the fibres, sheathings and any strain members are clamped together in a representative manner. The clamps on the bending apparatus may be adequate, a connector may be used or the sample may be long enough that no restraint is needed.

10.3 Apparatus

The apparatus shall permit a sample to be bent backwards and forwards through angles up to 180°, the two extreme positions making an angle of 90° on both sides of the vertical, whilst the sample is subjected to a tensile load. If no tensile load is specified, a manual tension sufficient to keep the sample in contact with the mandrel may be used. For testing cable, a suitable apparatus is shown in Figure 8. Other equivalent apparatus may be used.

Unless otherwise specified in the detail specification, the bending radius of curvature shall be a maximum of 20 times the cable diameter or the minimum mandrel radius, whichever is greater. The minimum mandrel radius shall be 75 mm for outdoor cables, and 75 mm or 25 mm shall be agreed for indoor cables between the customer and the supplier

The bending arm shall have an adjustable clamp or fixture to permit holding the cable securely during the entire test, without crushing the optical fibres or inducing optical loss. A connector may be used to hold the cable on the bending arm, but for this test it is not considered part of the specimen under test. See IEC 61300-2-44 for an appropriate apparatus.

The apparatus shall be capable of cycling. Displacing the sample from the vertical position to the extreme right position, then oscillating to the extreme left position and returning to the original vertical position is considered to be one cycle. Unless otherwise specified in the detail specification, the bending rate shall be approximately one cycle in 2 s to 5 s.

The apparatus shall include any optical test equipment needed to measure the changes in optical performance as required in the detail specification, and specified in Method A (transmitted power) of IEC 60793-1-46:2001.

10.4 Procedure

Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions.

The procedure can be defined as followed:

a) precondition the sample at standard atmospheric conditions for 24 h;
b) fix the sample to the apparatus, as such shown in Figure 8;
c) apply the load, as required by the detail specification;
d) measure acceptance criteria parameters to establish baseline values;
e) carry out the number of cycles of repeated bending specified;
f) carry out acceptance criteria parameter measurements. If necessary, the sample may be removed from the apparatus for visual examination.

10.5 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.

10.6 Details to be specified

The detail specification shall include the following:

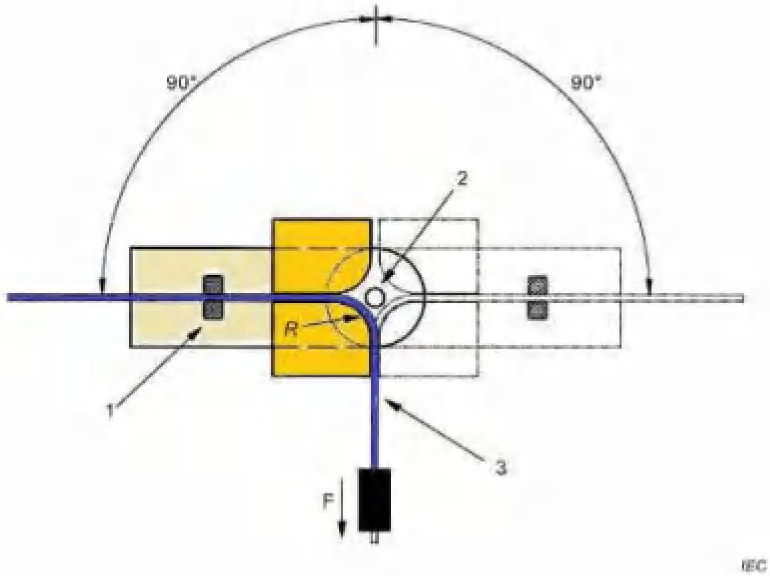
a) number of cycles;

b) mass of the weight tensile load, if applicable;

c) bending radius R, if different to that already specified;

d) specific temperature if other than standard atmospheric conditions;

e) maximum allowable change in optical transmittance, during and after the test if required.



Key

1 clamp

2 axis of rotation

3 sample

R bending radius

F load, if required

Figure 8 – Repeated bending test for cable/connector assembly

11 Method E7: Torsion

11.1 Object

This test method is intended to establish the ability of a fibre optic cable to withstand mechanical twisting. The primary purpose of this procedure is to measure any variation in the optical power transmittance of a fibre when the cable is subjected to torsional forces external to the cable sheath. A secondary purpose is to evaluate the possibility of physical damage that may occur as a result of such stresses.

11.2 Sample

The specimen shall be a sample of fibre optic cable having a total length sufficient to permit the appropriate clamping and twisting, and long enough to permit optical transmittance measurements as required by the detail specification.

11.3 Apparatus

The twisting apparatus consists essentially of two cable gripping devices or clamps, one fixed and one that can rotate, supported as appropriate, the distance between them being adjustable. The rotating clamp is connected to suitable turning equipment (e.g. a torquing lever). Any clamp supports, gripping devices or torquing equipment used shall all be such as to permit access to both ends of the cable specimen for optical testing as may be required. Suitable apparatus is illustrated in Figure 9, Figure 10, and Figure 11.

The cable gripping devices shall be such that

- they may be tightened around the cable sufficiently to prevent movement within the grip,
- the clamps hold the cable firmly in a straight line,
- the clamps induce neither localized twisting damage on the cable caused by the inside edge of the clamp nor undue localized concentration of pressure on the cable,
- the process of clamping does not induce any significant or accurately measurable attenuation increase (or no more than a negligible increase) in the specimen.

If required by the detail specification and/or to minimize specimen bending from a straight configuration, use weights or an appropriate loading mechanism to apply a tensile load to the cable gripping fixture (see Figure 10, Figure 11). In any case, one end of the gripping fixtures shall be free to move longitudinally to respond to foreshortening of the cable.

The apparatus shall include optical transmittance equipment to measure the change in optical throughput as required in the detail specification, and specified in Method A (transmitted power) of IEC 60793-1-46:2001.

11.4 Procedure

Install the specimen in the test apparatus such that the test length L (see Figure 9, Figure 10 and Figure 11) is as required by Table 2 or by the detail specification.

Table 2 – Typical test gauge length

Cable type		Maximum gauge length	
1	Outdoor cable	2	2 m
3	Indoor cable	4	1 m
5	Indoor cable	6	Greater of 0,3 m or 125 d (d = cable diameter in mm)

Take care to insure that no initial stress is applied to the specimen. Except for the necessary twisting operation, take care not to move or disturb the specimen ends throughout the test. Intrinsically torque-resistant cables may need a longer gauge length to be agreed between customer and supplier.

Minimize specimen sag (Figure 9 or Figure 10) or vertical deviation from a straight line (Figure 11) as much as possible.

If change of optical performance is required by the detail specification, measure the unstressed specimen. Compare results with those after clamping to ensure that the clamping has not significantly degraded the cable performance.

If not prohibited by the detail specification, specimen sag or bend may be minimized by supporting the test length or by applying tension to the specimen cable. If required, apply tension as specified in the detail specification to keep the specimen straight.

If a determination of optical transmittance changes is required by the detail specification, measure optical output power for the specimen after clamping and application of tensile load, if any.

Rotate the movable cable clamp as follows:

a) 180° clockwise;
b) return to the starting position;
c) 180° counter-clockwise;
d) return to the starting position.

This total four-part movement constitutes one cycle. Complete each cycle within 1 min maximum, for a total of 10 cycles.

Carry out the acceptance criteria parameters measurements. Allow the specimen to rest for a minimum period of 5 min. If necessary, the sample may be removed from the apparatus for visual examination using normal corrected vision.

11.5 Requirements

The acceptance criteria for the sample under test shall be as stated in the detail specification. Typical failure modes include loss of optical continuity, increase in fibre loss and damage to the cable sheath or core components.

11.6 Details to be specified

The detail specification shall include the following:

a) test length, *L*, if other than specified herein;
b) any tension which is to be applied, if applicable;
c) number of cycles, if other than specified herein;
d) number of fibres to be monitored for optical transmittance;
e) maximum allowable change in optical transmittance, if required;
f) rotating angle, if other than specified herein;
g) temperature of the specimen, if other than specified herein.

11.7 Details to be reported

The following details shall be reported:

a) number of cycles;
b) cycle time.

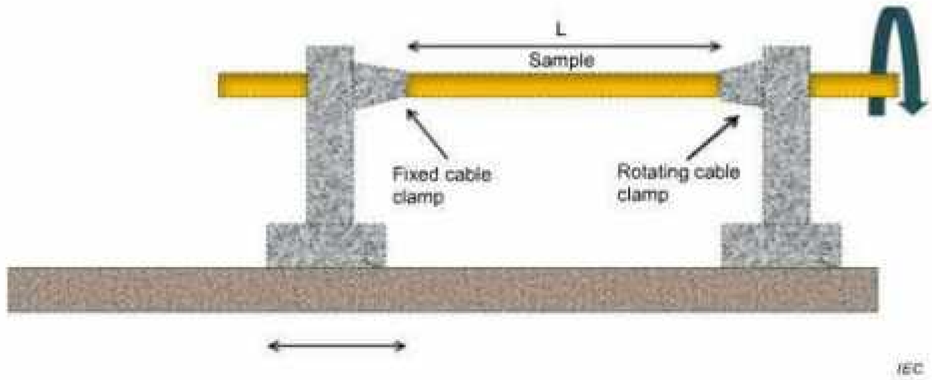


Figure 9 – Cable torsion apparatus

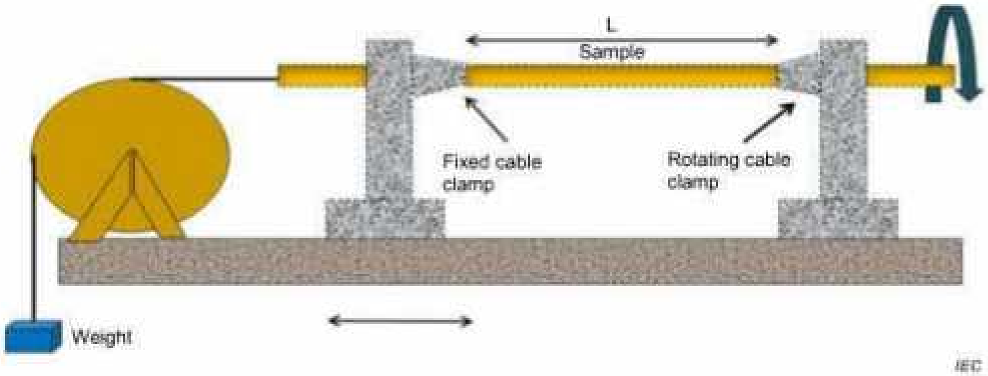


Figure 10 – Cable torsion apparatus with tension applied

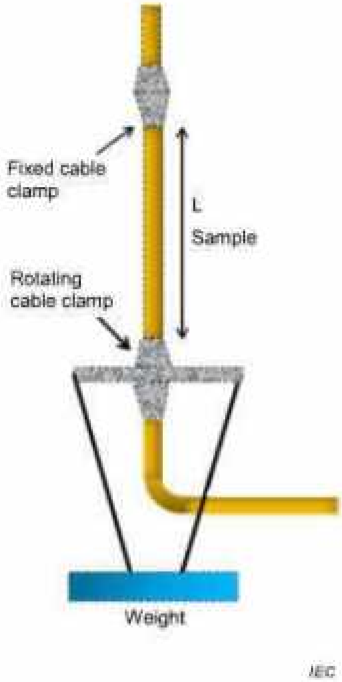


Figure 11 – Alternative cable torsion apparatus with tension applied

12 Method E8: Flexing

12.1 Object

The purpose of this test is to determine the ability of an optical fibre cable to withstand repeated flexing in service. This is a specialized test intended for specific types of cable, such as elevator cable or the like.

NOTE See the related tests, Method E18A, bending under tension and Method E18B, the sheave test. See also Method E6, the repeated bending test.

12.2 Sample

The sample shall be terminated in a manner such that the fibres, sheaths and any strain members are clamped together in a representative manner. It shall be of a length sufficient to carry out the specified test.

12.3 Apparatus

The test is carried out using the apparatus shown in Figure 12. Any other arrangements shall be specified in the detail specification.

The pulleys shall have a semicircular shaped groove for circular cables and a flat groove for flat cables. The restraining clamps, D, shall be fixed so that the pull is always applied by the weight from which the carriage is moving away. An equivalent apparatus may be used, for example that shown in IEC 60227-2.

12.4 Procedure

Unless otherwise specified, the conditions for testing shall be in accordance with standard atmospheric conditions.

The sample shall be routed over the pulleys, each end being loaded with a weight. The mass of these weights and the diameters of pulleys A and B (or other) shall be as specified in the detail specification.

The sample shall be flexed for the number of cycles specified in the detail specification. A cycle is defined as the movement of the carriage away from its starting position to one end of the traverse, followed by movement in the opposite direction to the other end and then back to the starting position. Ensure that the length of the cable is moved over the wheels.

The speed of the carriage movement or the total time for the traverse shall be specified in the detail specification.

The acceleration and deceleration of the carriage shall be limited to avoid additional inertial loads.

12.5 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.

12.6 Details to be specified

The detail specification shall include the following:

a) diameter of pulley A and B and the orienting pulleys;

b) mass of weights;

c) number of cycles;
d) speed of carriage or total time for traverse;
e) acceleration and deceleration of the carriage;
f) traverse length of the carriage;
g) minimal distance of pulleys A and B to the nearest fixed pulley;
h) maximum allowable change in optical transmittance, during and after the test if required.

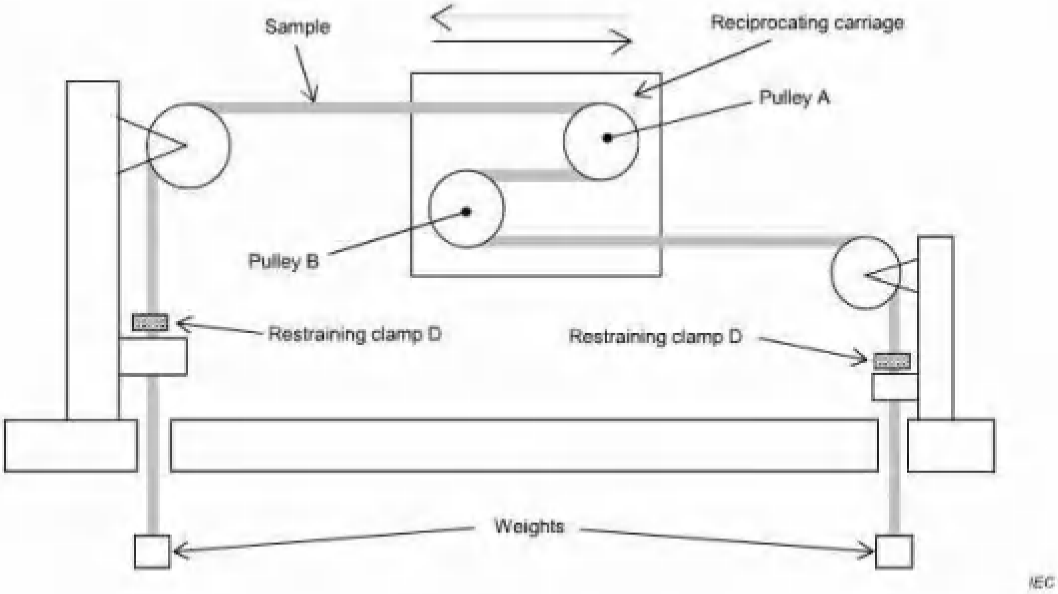


Figure 12 – Flexing apparatus

13 Method E9: Snatch (deleted)

NOTE This test – now deleted – was to evaluate the effects of a sudden load being applied to a short section of a suspended cable. Effectively, a hook with a weight would be dropped such that the hook engaged a cable suspended in a manner to be determined. It is not clear what the original intent of the test was, what the details of the apparatus and procedure were, or why it was decided to remove it.

14 Method E10: Kink

14.1 Object

The purpose of this test is to determine the minimum loop diameter at the onset of the kinking of an optical fibre cable.

NOTE Testing has indicated that the results of this test for cable have limited reproducibility. It is advised that it should be used with caution and that any minimum kink requirement be conservative.

14.2 Sample

The sample length shall be sufficient to carry out the specified test.

14.3 Apparatus

No particular apparatus is required. It is useful to loosely restrain the cable at the crossing point of the loop.

15 Method E11: Bend

15.1 Object

The purpose of this test is to determine the ability of an optical fibre cable or cable element to withstand bending around a test mandrel.

NOTE This test may be utilized at any specified temperature, including the low or high temperature limits for the cable.

15.2 Sample

The sample shall be terminated at each end in a manner such that the fibres, sheath(s) and any strain members are clamped together in a representative manner, or the sample may be long enough that no restraint is needed.

15.3 Apparatus

A single mandrel apparatus shall enable the sample to be wrapped tangentially in a close helix around a test mandrel. See Figure 14.

15.4 Procedure

As indicated in the detail specification, one of the following procedures shall be used.

15.4.1 Procedure 1 – Test method E11A (standard test procedure)

The sample shall be wrapped in a close helix around the mandrel at a uniform rate. Sufficient tension shall be applied to ensure that the sample contours the mandrel. The sample shall then be unwrapped.

The intent of test method E11A is to specify the test using the apparatus in Figure 14a1, that is, the total number of coils in the helix. Either apparatus may be used for testing per test method E11A.

Use of the apparatus in Figure 14a2 applies two helixes, therefore twice the number of coils as for the apparatus in Figure 14a1.

Therefore, if the apparatus as shown in Figure 14a2 is used, the number of turns of the mandrel or upon the mandrel [15.6 d)] should be one-half of those specified to achieve the correct number of coils in the combined helixes.

When using the apparatus in Figure 14a1, the cable involved in the helix is to be applied without twists.

A cycle consists of one wrapping and one unwrapping of the helix.

The diameter of the test mandrel, the number of turns per helix and the number of cycles shall be shown in the detail specification.

The test shall be carried out at the specified temperature.

15.4.2 Procedure 2 – Test method E11B (alternative test procedure)

The sample shall be bent around a mandrel through 180° and kept taut during the bending. A cycle consists of one U bend followed by a reverse U bend, and a return to the straight position. The diameter of the test mandrel and the number of cycles shall be stated in the detail specification.

The test shall be carried out at the specified temperature.

15.5 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.

15.6 Details to be specified

The detail specification shall include the following:

a) procedure to be used (procedure 1 or procedure 2);
b) test mandrel diameter (or ratio of mandrel diameter to cable diameter);
c) number of cycles;
d) number of turns in the helix (for procedure 1);
e) maximum allowable attenuation increase:
   – during the test (if applicable),
   – after the test (if applicable);
f) test temperature, e.g. ambient, low, and/or high, as appropriate.

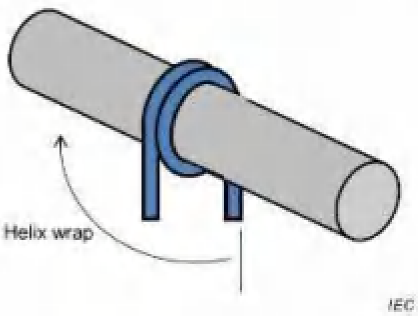


Figure 14a1 – Single-helix configuration

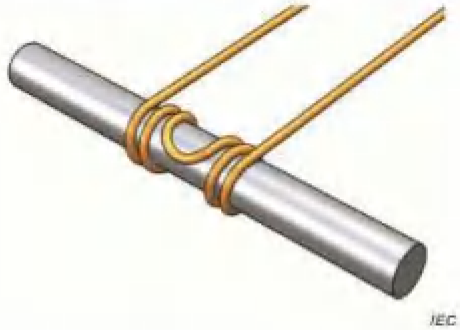


Figure 14a2 – Two-helix configuration

Figure 14a – Apparatus for E11A

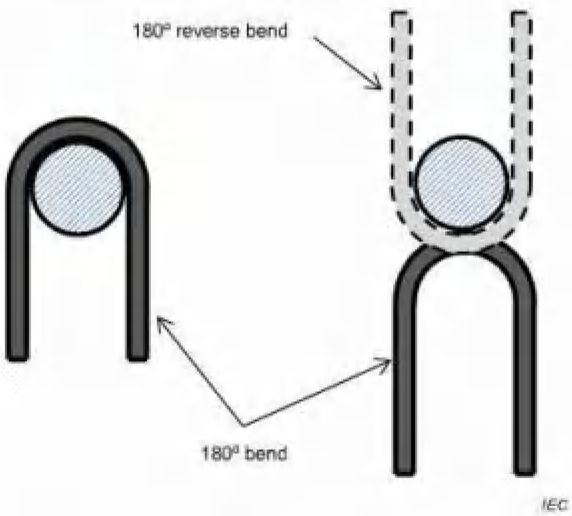


Figure 14b – Apparatus for E11B

Figure 14 – Bend test apparatus

16 Method E12: Cut-through resistance (deleted)

17 Method E13: Shotgun damage

17.1 Object

The purpose of this test is to determine the ability of aerial optical cables to withstand shotgun damage.

NOTE Due to the wide range of possible variations in this test (see 19.3.2 a) and c)), this test is considered a specialty test for very specific applications. Most cables will not be subjected to this test.

17.2 General

Two test methods are described:

a) method E13A, in which a shotgun is fired at a cable sample mounted on a frame;
b) method E13B, which simulates the impact from a shotgun pellet: a single pellet is impacted into a cable sample with the energy equivalent to that of a pellet fired from a shotgun at a given range, up to 40 m.

17.3 Method E13A: Shotgun test

17.3.1 Sample

A length of optical cable (typically 3 m long) is used.

17.3.2 Apparatus

The apparatus consists of

a) a shotgun, as specified in the detail specification,

   NOTE 1 The type of gun is likely to vary from country to country.

b) a frame for holding the cable sample. It is important that the sample be free to move and the test set-up should also take into account that the shot may scatter in an elliptical manner depending on the gun used,
c) gunshot:
   1) as specified in the detail specification.

      The shot size is likely to vary from country to country and should represent the hazard particular to the installation. It is recommended that the shot diameter be recorded.

   2) the shot type shall be specified in the detail specification.

      Typically, lead, steel, or composite materials are used, depending on the country. Lead shot deforms on impact and is less damaging than steel shot. It is recommended that the shot material be recorded.

   3) the cartridge type shall be specified in the detail specification.

17.3.3 Procedure

The cable sample shall be mounted on the frame and shot at from the distance specified in the detail specification. A typical distance is 20 m.

After the test, the sample shall be inspected according to the acceptance criteria specified.

The test report shall include the following information:

a) details of test configuration, including cable orientation;
b) report of damage inflicted, including fibre continuity;

c) number of tests carried out to achieve minimum visible impacts;
d) shot diameter;
e) shot material.
f) cartridge type;
g) data on the shotgun (see 17.3.2 a).

17.3.4 Requirements

The acceptance criteria for the test shall be stated in the detail specification. Typical failure modes include damage to the cable core elements (for example, piercing of loose tubes) and loss of continuity.

17.3.5 Details to be specified

The detail specification shall include the following information:

a) gun type;
b) shot size and diameter;
c) shot type;
d) cartridge type;
e) distance between gun and sample;
f) acceptance criteria.

17.4 Method E13B: Shotgun simulation

17.4.1 Sample

The sample length shall be sufficient to carry out the testing specified. A short length is adequate when only physical damage is to be evaluated, but longer lengths will be necessary to permit optical measurements.

17.4.2 Apparatus

A suitable apparatus is given in Figure 15, Figure 16 and Figure 17. The apparatus comprises the following:

a) A drop weight.

   A schematic of the drop weight, which incorporates the drop-weight body and a shot support pin is given in Figure 16.

   The weight used shall be sufficient to simulate the energy of a shot fired from a given range, when dropped from the relevant height. For information purposes, guidance on the calculation of suitable weights and drop heights for a given shot size is given in 19.4.6.

   The shot support pin should be chosen such that its diameter "B" is not greater than the overall diameter of the shotgun pellet and is typically 0,2 mm smaller. The pin face should be profiled to give a flat landing, shown by "A", in order to reduce the risk of pellet shearing and pin damage.

   For small cables (typically <10 mm), an alternative drop weight and shot support pin may be used for improved test accuracy (see Figure 17), in order to prevent sample rotation and/or shot deflection during the test.

b) A drop-weight guiding tube, to guide the weight towards the test sample. It may be convenient to incorporate release pins to secure the drop weight at the required drop height. Typically, a 25,4 mm square section is used to minimize friction between the inner surface of the guide tube and the outer surface of the cylindrical drop-weight body or vice versa.

c) A location block. The location block may have a target zone hole for convenience in locating the sample.

d) Plastic adhesive or other, for affixing the shot to the drop weight pin.

e) Optical test equipment, if required, to measure the optical performance.

17.4.3 Procedure

The cable sample shall be placed on the location block, directly over the target zone hole, if used. Clamps, fitted to the location block, may be used to secure the sample in place. If optical transmission is being recorded, the sample shall be placed so that the pellet will impact above at least one fibre that is being measured. The pellet is fitted to the pin of the drop weight using a suitable material, such as a reusable plastic adhesive. A small amount should be used such that the impact is not absorbed by the adhesive. The weight is then fixed at the appropriate height in the guide tube, as with the release pins. The drop weight is released allowing the drop weight to impact on the cable sample.

Unless otherwise specified, the test is only carried out once at the same sample location.

17.4.4 Requirements

The acceptance criteria for the test shall be stated in the detail specification. Typical failure modes include damage to the cable core elements (for example, piercing of loose tubes) and loss of continuity.

17.4.5 Details to be specified

The detail specification shall include the following:

a) shot size;

b) shot type;

c) drop weight;

d) drop height;

NOTE: See 19.4.6 for calculating drop weight and height.

e) number of impacts at separate locations;

f) acceptance criteria;

g) test temperature.

17.4.6 Calculation of drop weight and height

Consider a shotgun pellet of mass, m, moving with a velocity, v. It will have a kinetic energy of E_k, given by Equation (2):

$$E_k = \frac{1}{2} mv^2 \tag{2}$$

where

E_k is the kinetic energy, in J;

m is the pellet mass, in kg;

v is the pellet velocity in ms^{-1}.

This can be equated to a drop weight's potential energy (see Equation (3)):

$$E_k = E_p = Mgh \tag{3}$$

where

E_p is the potential energy, in J;

M is the drop-weight mass, in kg;

g is the drop-weight acceleration, in ms^{-2};

h is the distance dropped, in m.

Re-arranging the equation is then possible to define the drop weight's mass in terms of drop height:

$$M = \frac{E_k}{gh} \quad (4)$$

where

E_k is the kinetic energy, in J;

g is the drop-weight acceleration, in ms^{-2};

h is the distance dropped, in m.

Using representative cartridge data, an appropriate test may be defined. For example, a lead pellet with average mass of 0,083 3 g, fired from a range of 25 m, typically has an impact velocity of 234 ms^{-1}. Hence using Equation (2):

$$E_k = \frac{1}{2} 0{,}000\,083\,3 \times 234^2 \text{ J} \quad (5)$$

$$E_k = 2{,}2815 \text{ J} \quad (6)$$

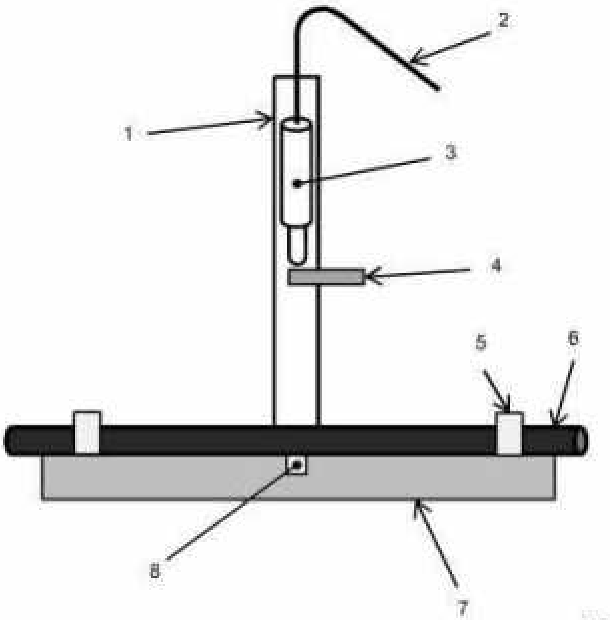
Assuming a convenient drop height of 1 m, and using Equation (3):

$$M = \frac{2{,}281\ \ 5}{9{,}81 \times 1} \text{ kg} \quad (7)$$

$$M = 0{,}233 \text{ kg} \quad (8)$$

As it is preferable to use the same weight, the calculation may be completed for alternative ranges using the drop height as the variable.

If required, for calibration purposes, a plaque of sheathing material can be used to compare the simulation method with actual field trials, for example, a 2 mm plaque of high-density polyethylene shot at from 40 m.



Key

1 guide tube, square section recommended
2 drop pull
3 drop weight, cylindrical
4 drop weight release pin
5 cable clamp
6 cable specimen
7 location block
8 target zone

Figure 15 – Method E13B test set-up

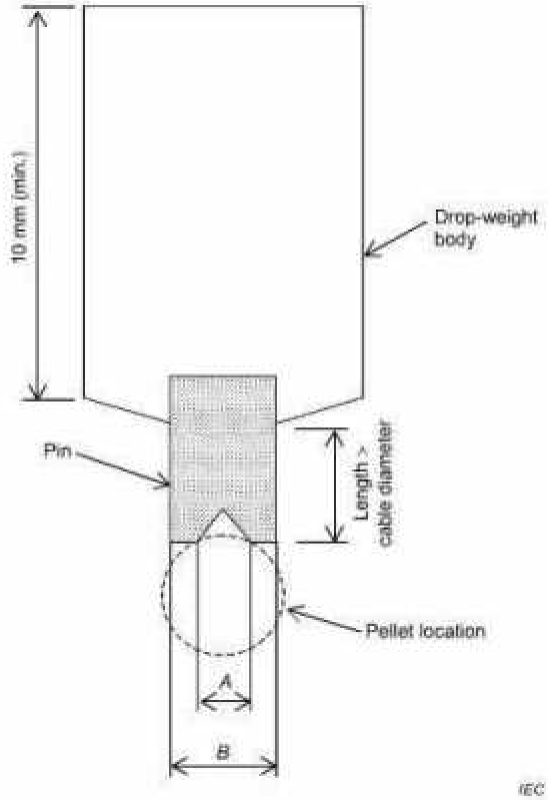


Figure 16 – Drop weight incorporating shot support pin

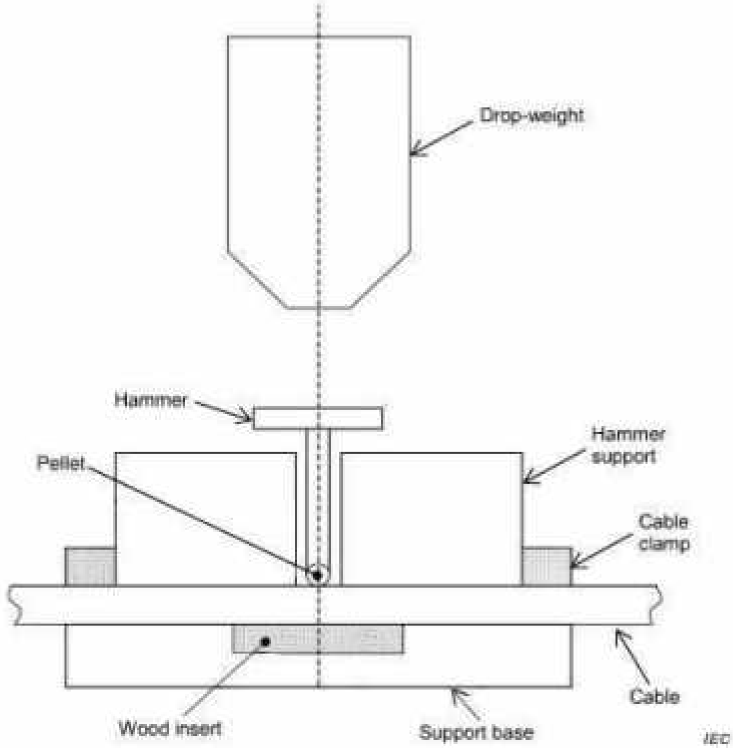


Figure 17 – Alternative drop weight and shot support pin

18 Method E14: Compound flow (drip)

18.1 Object

This test is intended to verify that filling and flooding compounds will not flow from a filled or flooded fibre optic cable, at stated temperatures.

18.2 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.

18.3 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

18.4 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.

18.5 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 18.2, and test as per items a) to f) of 18.4. The test shall be considered successful if neither of the second set of specimens has flow quantities which exceed 0,050 g.

18.6 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 18.4 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.

19 Method E15: Bleeding and evaporation

19.1 Object

The purpose of this test is to measure at high temperature the bleeding and/or evaporation of filling compounds used in contact with optical fibres.

19.2 Sample

Filling compound material intended to be used in contact with optical fibres.

19.3 Apparatus

The apparatus consists of

a) an electric heating cabinet with natural ventilation,

b) an analytical balance with an error limit G = 0,1 mg,

c) the test set-up (see Figure 18) consisting of

   1) cone, nickel, gauze, 60 mesh (holes: 5,6 per mm^2; wire diameter: 0,19 mm; opening: 0,28 mm), with a wire handle. Alternatively the cone may consist of stainless steel (60 mesh, opening 0,25 mm) and the solder width may be more than 1 mm, provided it is proved that the results are not significantly different from the first on,

   2) a beaker, tall-form, without a spout, 200 ml,

   NOTE The cover is not needed when measuring the evaporation.

   3) a desiccator.

19.4 Procedure

Weigh the clean dry beaker and record as M_1 (weighed to within 1 mg). Weigh the assembled beaker, cone and cone support and record as M_2. Add about 10 g of sample to the cone (the upper surface shall be smooth and convex so that fluid is not trapped and there shall be no aggregate materials in the gauze mesh). Weigh the assembled apparatus and sample and record as M_3.

Heat the test set-up in the cabinet at the temperature and for the duration stated in the detail specification. Cool to room temperature in the desiccator. Reweigh the assembled apparatus and record as M_4. Carefully remove the cone support and cone. Reweigh the beaker and record as M_5. Calculate the percentage bleeding and evaporation and report the average of the duplicate results.

Calculations:

$$\text{Bleeding} = \frac{M_5 - M_1}{M_3 - M_2} \times 100\ \% \tag{9}$$

$$\text{Evaporation} = \frac{M_3 - M4}{M_3 - M_2} \times 100\ \% \tag{10}$$

where

bleeding is the amount of compound which has bled into the beaker, %;

evaporation is the amount of compound missing from the system, %.

19.5 Requirements

The reported average results shall not exceed the maximum values given in the detail specification.

19.6 Details to be specified

The detail specification shall include the following:

a) test temperature;
b) duration of test;
c) type of cone to be used if differing from that of 19.3, c), 1);
d) number of samples to be tested.

Dimensions in millimetres

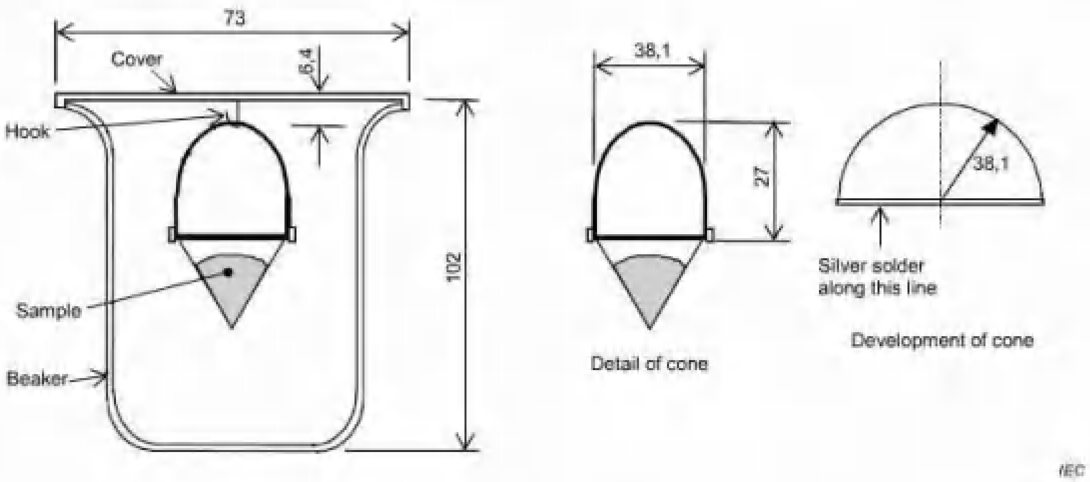


Figure 18 – Bleeding and evaporation test set-up

20 Method E16: [Title unknown] (deleted)

21 Method E17: Bending stiffness

21.1 Object

The purpose of this test is to measure the bending stiffness of an optical fibre cable. Three alternative methods are applicable, depending on the type of cable.

Testing indicates that there may be a significant variation of the result from sample to sample when performing these tests. This is due to the details of the test apparatus and the complexity of interaction of the cable components in bending. Therefore, these tests would be used for investigation and experiment, and not for performance specification. It is advised that they be used with caution and that any stiffness requirements(s) be conservative.

21.2 General

Stiffness in bending is a parameter used to evaluate the performance of a cable when installed using conventional pulling techniques (for example in ducts, trunking, conduit or under floors) and also when using blowing techniques. Stiffness is also used to ensure that jumper and indoor cables are sufficiently rugged yet flexible enough to withstand installation and normal usage. Cable stiffness values determined for any of these tests may not be equivalent to values determined in the other tests.

The three methods involved are

- Method E17A – three-point bend,
- Method E17B – cantilever bend,
- Method E17C – buckling bend.

Methods E17A and E17B are suitable for large cables.

Method E17B is also suitable for smaller cables including lightly armoured cables and indoor cables.

Method E17C is suitable for small cables such as ruggedized single-fibre cables.

21.3 Method E17A: Three-point bend

21.3.1 Sample

The sample length shall be sufficient to carry out the specified test.

21.3.2 Apparatus

The three-point bending test set-up is shown in Figure 19. The sample is placed on two supports which allow free movement of the cable (e.g. the supports may be rotating bars). Means shall be provided to apply a force to the sample at a point midway between the supports and to measure the subsequent displacement. The force is applied at a specified rate or at a rate less than the specified maximum. Typically, this force-displacement apparatus is a tensile testing machine.

21.3.3 Procedure

Set the supports at a distance apart as specified in the detail specification. The test sample is placed on the supports, the force applied and the displacement measured.

NOTE 1 The force may be of a specified value or a menu of values or may be a continual function of the force related to the measured displacement.

The sample shall be longer than the distance between the supports by an amount which ensures that any internal movement of the cable components does not affect the result.

The force can be applied by a blade fixed to a tensile testing machine or by weights hooked to the cable.

If a force F (N) results in a displacement y (m) and if x is the distance (m) between the supports, the stiffness B (in N×m^2) is:

$$B = \frac{x^3 F}{48y} \qquad (11)$$

Since many cables (e.g. armoured cables) can exhibit a change in behaviour from elastic to inelastic, as shown in Figure 20, it is preferable for the force to be increased in increments so that the point of any change can be identified. The stiffness to be specified is the elastic stiffness which is given, in N×m^2, by:

$$B = \frac{x^3}{48} \tan\alpha \qquad (12)$$

where

α is the angle of the linear part of the curve, see Figure 20.

NOTE 2 According to the definition of tan (alpha), it's unit is 1 N/m.

NOTE 3 Installation bends may involve bending in the inelastic region.

21.3.4 Requirements

The cable stiffness shall meet the requirements specified in the detail specification.

21.3.5 Details to be specified

The detail specification shall include the following:

a) cable type;
b) distance between supports;
c) length of sample;
d) maximum force;
e) number of samples tested;
f) loading rate.

21.4 Method E17B: cantilever bend

21.4.1 Sample

The sample length shall be sufficient to carry out the specified test.

21.4.2 Apparatus

The cantilever test set-up is shown in Figure 21. The sample is secured in a clamp and means shall be provided to apply a force to the end of the sample remote from the clamp, and to measure the subsequent displacement.

The sample length and clamp arrangement shall be selected to ensure that any internal movement of the cable components does not affect the result. That is, the clamp may be affixed at a distance sufficiently far from the bending point to allow simulated cable element movement in an actual cable.

In some cases (e.g. small jumper cables), the clamp can be designed to control the bending radius of the sample, as shown in Figure 21b.

21.4.3 Procedure

Fix the sample securely in the clamp, apply the force at a distance, *L*, from the clamp, and measure the displacement.

The force can be applied by a tensile testing machine or by weights.

If a force *F*(N) results in a displacement *y* (m), with a span length *L* (m), the stiffness *B* (in N×m^2) is:

$$B = \frac{L^3 F}{3y} \text{ or } B = \frac{L^3}{3} \tan\alpha \quad (13)$$

where

α is the bending angle.

21.4.4 Requirements

The cable stiffness shall meet the requirements specified in the detail specification.

21.4.5 Details to be specified

The detail specification shall include the following:

a) cable type;

b) cable span (L);

c) force or maximum force;

d) length of sample;

e) number of samples tested.

21.5 Method E17C: Buckling bend

21.5.1 Sample

The sample length shall be sufficient to carry out the specified test.

21.5.2 Apparatus

The test set-up is shown in Figure 22. It provides a means of measuring the force imparted on the test sample when bent into a U-bend. A suitable apparatus is a tensile testing machine fitted with a load cell and capable of maintaining a given jaw separation for a specified duration.

21.5.3 Procedure

The sample is fixed to the apparatus in a straight condition. The jaw separation is reduced to a value given by s×d, where d is the cable diameter and s is the separation factor given in the detail specification. After the duration specified in the detail specification, the force imparted on the test sample is recorded.

NOTE 1 Separation factor is defined as the final jaw separation distance (see Figure 21) and the distance as a multiplier (or other function) of cable diameter.

NOTE 2 The force is that at the end of the specified duration. Typically, a higher force will be exhibited just prior to the initiation of cable buckling

The stiffness B, in N×m^2, is then:

$$B = F\pi r^2 \quad (14)$$

where

F is the measured force, in N;

r is the bend radius of cable at final jaw separation, in m.

21.5.4 Requirements

The cable stiffness shall meet the requirements specified in the detail specification.

21.5.5 Details to be specified

The detail specification shall include the following:

a) separation factor (s);
b) duration of test;
c) length of sample;
d) number of samples tested.

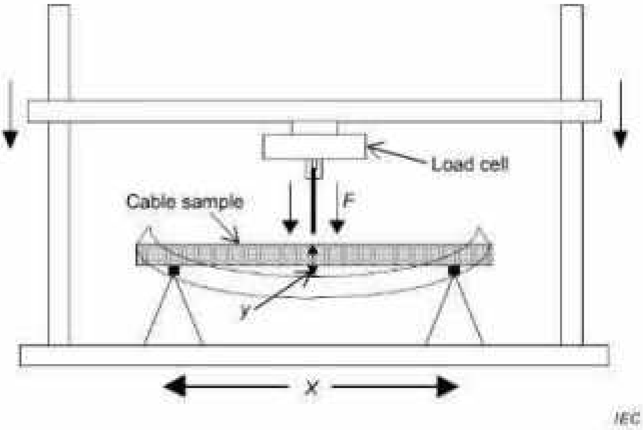


Figure 19 – Method E17A – Test set-up

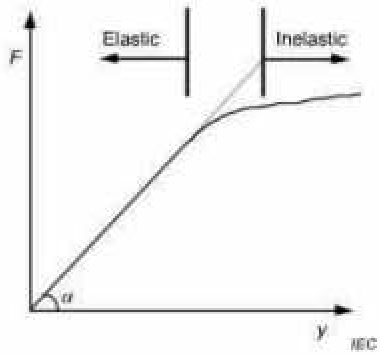


Figure 20 – Example of results of applied force and displacement

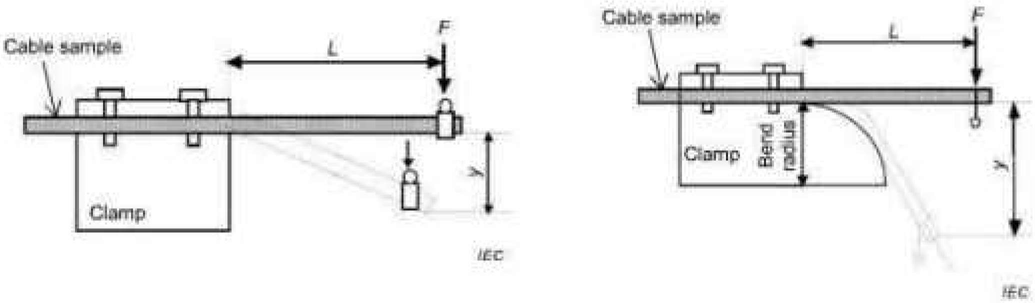


Figure 21a – Simple apparatus **Figure 21b – Apparatus with control of radius**

Figure 21 – Method E17B – Test set-up

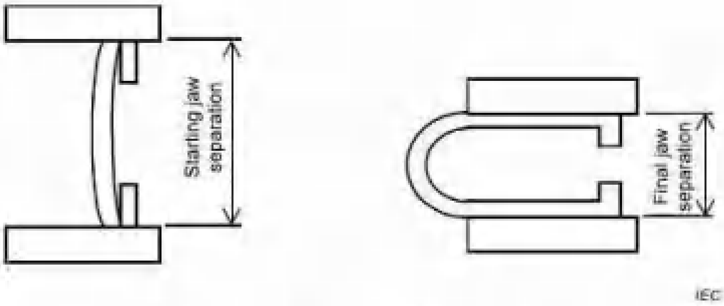


Figure 22 – Method E17C – Test set-up

22 Method E18A: Bending under tension

22.1 Object

The purpose of this test is to determine the ability of an optical fibre cable to withstand bending around rollers or bows during installation, when a specified load is applied.

This test involves either a bend over a roller or similar device at a specified angle (Procedure 1) or a reverse bend over a pair of rollers (Procedure 2). These tests are generally considered to simulate bending that any type of cable may experience during installation.

NOTE See the related test method E18B, sheave test. Method E18B may be used as an alternative to method E18A.

22.2 Sample

The sample shall be taken from one end of a finished cable, without cutting if specified in the detail specification.

Both ends of the specimen shall be terminated in such a way that the specified load can be applied.

The sample shall be marked at points A and B as shown in Figure 23 or Figure 24.

The distance between marks A and B shall be greater than the core and strength member lay length for helically stranded cables and greater than the distance between lay reversals for S-Z stranded cables. It is recommended that this distance be at least three times the lay length.

22.3 Apparatus

The apparatus consists of

- a tensile power device with a maximum error of ±3 %,
- if required for a particular user application, attenuation measuring apparatus for the determination of attenuation change and/or fibre elongation strain measuring apparatus. The length of the optical fibre shall be a length sufficient to perform the test and make optical measurements,

The procedure to be used shall be agreed between customer and supplier and should reflect the most severe installation scenario which may be experienced.

Procedure 1
One roller/sheave with a radius (*r*) as given in the relevant specification and as shown in Figure 22 is used. The included angle of the bend, *θ*, shall be specified in the relevant specification. 180 ° is a commonly used value.

Procedure 2
Two rollers/sheaves with a radius (*R*), and a distance *Y* or a bending angle *θ* as given in the relevant specification and as shown in Figure 24.

22.4 Procedure

The test shall be carried out at ambient temperature.

If optical attenuation testing is specified in the detail specification, the attenuation shall be recorded before the specified load is applied, and after the test when the load is zero.

Depending on the installation method, and as indicated in the detail specification, one of the following procedures shall be used.

Procedure 1

- The cable shall be moved around a cylinder or on a device as specified in the relevant specification, at an angle specified in the relevant specification, as shown in Figure 23 or other values agreed between the customer and the supplier.
- The tension shall be continuously increased to the required value given in the detail specification.
- The cable shall be moved from point A to point B (see Figure 23) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification.

Procedure 2

- The cable shall be bent around two cylinders in an S form manner (S-bend), or on a device as specified in the detail specification, as shown in Figure 24.
- The tension shall be continuously increased to the required value given in the detail specification.
- There are two alternatives as follows:
  - the cable shall be moved from point A to point B (see Figure 23) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification;
  - the apparatus shall be moved relative to the cable from point A to point B (see Figure 24) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification.

22.5 Requirements

Under visual examination without magnification there shall be no damage to the sheath and/or to the cable elements.

If specified, any permanent increase in attenuation after the test shall not exceed the value specified in the detail specification.

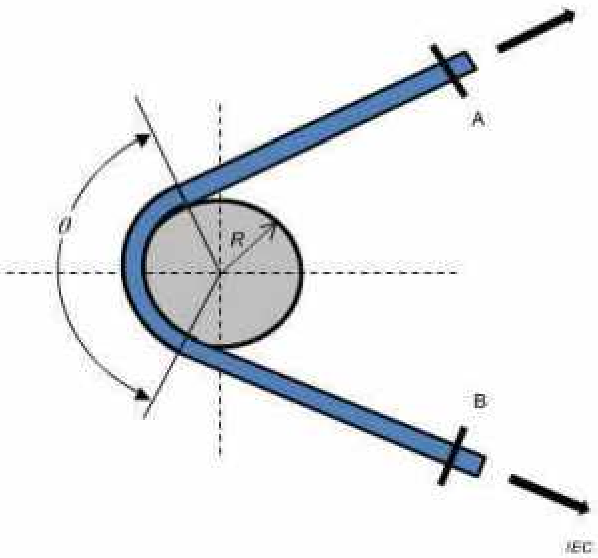
Further detailed requirements should be given in the detail specification.

22.6 Details to be specified

The detail specification shall include the following:

- procedure used (1 or 2);
- maximum tension applied during test (typically the maximum load which may be applied during installation);
- length of the cable and length bent under tension, distance A to B;
- end preparation;

- tension device;
- procedure 1
  - radius (*r*) of rollers,
  - bend angle over roller;
- procedure 2
  - radius (*R*) of rollers/cylinders/mandrels,
  - distance *Y* or bending angle *θ*;
- moving speed (typically ≤ installation speed);
- number of moving cycles;
- maximum allowable attenuation increase after the test (if applicable).



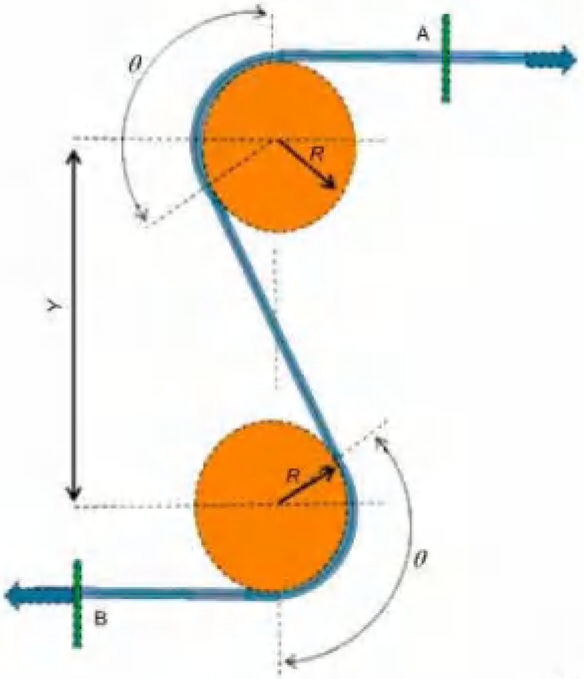
Key

A, B test end points

R radius of roller

θ wrap angle

Figure 23 – Single-bend



Key

A, B test end points

Y separation of rollers

R radius of rollers

θ wrap angle

Figure 24 – S-bend

23 Method E18B: Sheave test (primarily for OPGW and OPAC)

23.1 Object

The purpose of this test is to determine the ability of the optical ground wire (OPGW) or optical attached cable (OPAC) to withstand bending around rollers or bows during installation, when a specified load is applied.

This test involves either a bend over a single sheave or similar device (Procedure 1) or an S-Z bend over three inline sheaves (Procedure 2). These tests are generally considered to simulate bending that an aerial cable may experience during installation.

NOTE See the related test method E18A, bending under tension. Method E18A may be used as an alternative to Method E18B.

23.2 Sample

The sample shall be taken from one end of a finished cable, without cutting if specified in the detail specification.

Both ends of the specimen shall be terminated in such a way that the specified load can be applied.

The sample shall be marked at points A and B as shown in Figure 25 or Figure 26.

The distance between marks A and B shall be greater than the core and strength member lay length for helically stranded cables and greater than the distance between lay reversals for S-Z stranded cables. It is recommended that this distance be at least three times the lay length.

23.3 Apparatus

The apparatus shall consist of

- a tensile power device with a maximum error of ± 3 %,
- the sheave profile shall be semi-circular and of sufficient radius as to not impede free cable motion,
- if required for a particular user application, attenuation measuring apparatus for the determination of attenuation change and/or fibre elongation strain measuring apparatus. The length of the optical fibre shall be a length sufficient to perform the test and make optical measurements.

The procedure to be used shall be agreed between the customer and the supplier and should reflect the most severe installation scenario which may be experienced.

Procedure 1
One sheave with a radius (*R*) and a bending angle θ as given in the relevant specification and as shown in Figure 25.

Procedure 2
Three sheaves with a radius (*R*) and a bending angle θ as given in the relevant specification and as shown in Figure 26.

23.4 Procedure

The test shall be carried out at ambient temperature.

If optical attenuation testing is specified in the detail specification, the attenuation shall be recorded before the specified load is applied, and after the test when the load is zero.

Depending on the installation method, and as indicated in the detail specification, one of the following procedures shall be used.

Procedure 1

- The cable shall be moved around a cylinder or on a device as specified in the detail specification, through an angle as specified in the detail specification as shown in Figure 25.
- The tension shall be continuously increased to the required value given in the detail specification.
- The cable shall be moved from point A to point B (see Figure 25) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification.

Procedure 2

- The cable shall be passed through the cylinders as specified in the detail specification, through an angle as specified in the detail specification as shown in Figure 26.
- The tension shall be continuously increased to the required value given in the detail specification.
- There are two alternatives as follows:
  a) the cable shall be moved from point A to point B (see Figure 26) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification, or
  b) the apparatus shall be moved relative to the cable from point A to point B (see Figure 26) and then returned to point A, with a speed and in a number of cycles as specified in the detail specification.

23.5 Requirements

Under visual examination without magnification there shall be no damage to the sheath and/or to the cable elements. If specified, any permanent increase in attenuation after the test shall not exceed the value specified in the detail specification.

Further detailed requirements should be given in the detail specification.

23.6 Details to be specified

The detail specification shall include the following:

- procedure used (1 or 2);
- maximum tension applied during test (typically the maximum load which may be applied during installation);
- length of the cable and length bent under tension, distance A to B;
- end preparation;
- tension device;
- procedure 1
  - radius (*R*) of rollers/cylinders,
  - bending angle θ;
- procedure 2
  - radius (*R*) of rollers in procedure 2,
  - radius (*R*) of rollers/cylinders/mandrels in procedures 2,
  - bending angle θ;
- moving speed (typically ≤ installation speed);
- number of moving cycles;
- maximum allowable attenuation increase after the test (if applicable).

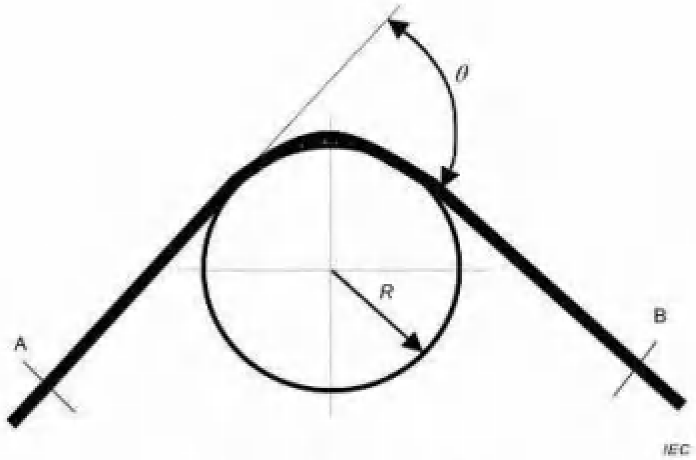


Figure 25 – Partial-bend

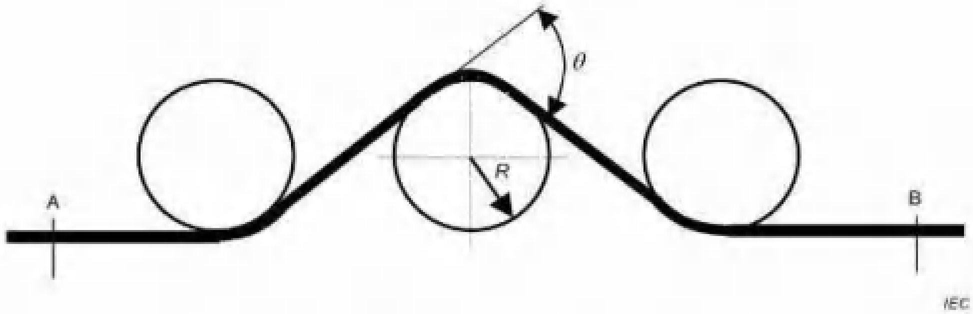


Figure 26 – Partial-bend, multiple pulley

24 Method E19: Aeolian vibration

24.1 Object

The object of this test is to expose overhead cables to dynamic stresses similar to those imposed by laminar wind-flow-induced vibrations in overhead lines.

24.2 Sample

The minimum length of the test sample shall be 50 m or as given in the detail specification. The cable ends are prepared in order to allow transmitted optical power control in one or several fibres (as specified in the detail specification) during the test. The minimum test length of the optical fibres shall be 100 m. If necessary, fibres may be spliced at the cable ends.

24.3 Apparatus

The test apparatus shall consist of

- the test set-up (a typical arrangement is shown in Figure 27),
- electronically controlled shaker,
- dynamometer, load cell, calibrated beam or other device to measure cable tension,

- light source with a nominal wavelength of 1 550 nm in conjunction with a light power meter, able to perform optical power measurements,
- light source with a nominal wavelength of 1 550 nm in conjunction with a light power meter, able to measure power oscillation in the bandwidth range of 0 Hz to 300 Hz minimum,
- optical time domain refleactometer (OTDR), if required in the detail specification.

24.4 Procedure

The test sample shall be terminated at both ends prior to tensioning in such a way that the optical fibres cannot move in relation to the cable. A dynamometer, load cell, calibrated beam or other device shall be used to measure cable tension. Some means should be provided to maintain constant tension to allow for temperature fluctuations during the testing. The cable shall be loaded to approximately 15 % to 25 % of the rated tensile strength (RTS) for OPGW, or to the installation tension rating for the span for ADSS cable, or as given in the detail specification.

The overall span between system terminations shall be a minimum of 30 m. The minimum active span should be approximately 20 m with a suitable suspension assembly located approximately two-thirds of the distance between the two dead-end assemblies. Longer active and/or back spans may be used. The span shall be supported at a height such that the static sag angle of the cable to horizontal is $(1,5 \pm 0,5)°$ in the active span.

Means shall be provided for measuring and monitoring the mid-loop (antinode) vibration amplitude at a free loop, not a support loop.

An electronically controlled shaker shall be used to excite the cable in the vertical plane. The shaker armature shall be securely fastened to the cable so it is perpendicular to the cable in the vertical plane. The shaker should be located in the span to allow for a minimum of six vibration loops between the suspension assembly and the shaker. Apply 10 000 000 vibration cycles, or the number specified in the detail specification.

The test shall be carried out at one or more resonance frequencies in the frequency range for the given wind conditions. Aeolian vibration is normally experienced under laminar wind flows of 0,5 m/s to 7 m/s. The following Equations (15) and (16) apply:

The frequency of vibration f (Hz) is proportional to the wind velocity v (m/s) and inversely proportional to the cable diameter D (m) and is given by the formula:

$$f = k \times \frac{v}{D} \text{ (Hz)} \tag{15}$$

where

k is the Strouhal constant (0,2 for aerial cables and conductors).

The wavelength (λ) of vibration (equal to two loop lengths) is given by the formula:

$$\lambda = \frac{1}{f}\sqrt{\frac{T}{m}} \text{ (m)} \tag{16}$$

where

T is the cable tension, in N;

m is the mass/unit length, in kilograms per meter (kg/m).

If required due to the nature of cable design, the cable should be rid of initial stresses. Therefore, in the initial stages, the test span requires continuous attention and monitoring of the test parameters until the test span is stabilized.

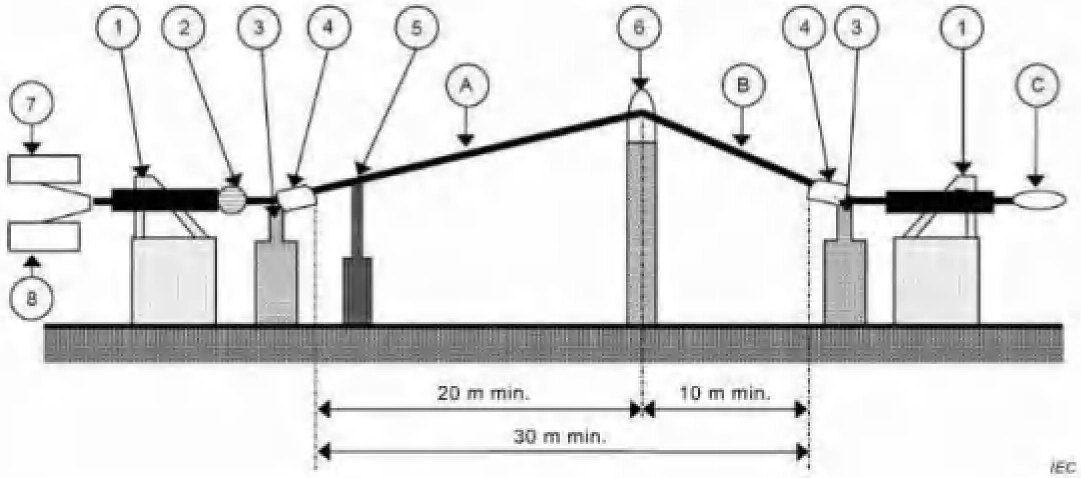
24.5 Requirements

Any sign of temporary or permanent damage to the cable or any of the component parts greater that the value specified in the detail specification shall be a failure. Any short term fluctuations or long term changes in attenuation, if specified, shall not exceed the specified range.

24.6 Details to be specified

The detail specification shall include the following:

- number vibration cycles, if other than 10 000 000;
- characteristics of the vibration test stand;
- length of spans;
- characteristics of the suspension and anchoring devices used;
- cable installation tension, including any overtension coefficient, if applied during the first phase;
- length of cable and fibres tested (characteristics of the splices between fibres if they exist);
- wavelength at which optical monitoring is conducted;
- vibration mode/characteristics maintained during the test;
- preparation of ends;
- characteristics of measuring equipment, including the type of measuring sets and launching conditions;
- ambient temperature and humidity during the test;
- mass/unit length and diameter of the cable.



Key

1 end abutment
2 load cell
3 intermediate abutment
4 dead-end assembly
5 suitable shaker
6 suspension assembly
7 meter – in
8 meter – out
a active span
b back span
c fibre splice

Figure 27 – Aeolian vibration test

25 Method E20: Cable coiling performance

25.1 Object

The purpose of this test is to demonstrate the ability of an armoured underwater optical fibre cable to be coiled and uncoiled for installation purposes.

25.2 Sample

A sufficient length of cable, necessary to make a specified number of coils (for example, 10) with the specified diameter, as agreed between the manufacturer and the user, shall be taken from the cable to be tested.

25.3 Apparatus

The test requires no apparatus except a flat surface large enough to coil the specified number of coils. The diameter of coils shall be in accordance with the minimum specified coiling diameter.

25.4 Procedure

The test is to be carried out at a specified temperature corresponding to ambient temperature for ship-loading and laying conditions, unless otherwise specified.

The sample shall be taken from the production end of the cable and be coiled flat on a suitable surface. The starting end of the cable shall be secured during the test. The coiling should be performed from a height typical for the height envisaged during manufacturing, loading and laying of the cable.

The coiling shall start at a diameter specified by the manufacturer. The direction of coiling should be as indicated by the manufacturer.

25.5 Requirements

The cable shall form a smooth circle and stay flat on the surface all the way around the circumference. Other requirements may be defined by agreement between the user and the manufacturer.

25.6 Details to be specified

The detail specification shall include the following:

- sample length;
- coil diameter;
- number of coils;
- temperature.

26 Method E21: Sheath pull-off force for optical fibre cable for use in patch cords

26.1 Object

The purpose of this test is to measure the force required to remove a length of sheath from an optical fibre cable intended for use in patch cords.

26.2 General

This test method is designed to measure the force required to remove the cable sheath. It can be applied to round simplex and round duplex optical fibre cables for use in patch cords, or round single fibre elements or sub-elements of larger cables.

26.3 Sample

A length of cable long enough to be retained in the tensile rig shall be cut and removed from the supply reel. The sample is prepared as shown in Figure 30, using the following method. At one end of the sample, mark the cable at distances 50 mm and 53 mm from the end. A circumferential cut is then made at the two marked points where the section of sheath is to be removed. A longitudinal cut is then made between the two circumferential cuts. Remove the sheathing between the two cuts. During sample preparation, if any damage is imparted to the cable core, that sample shall be discarded.

26.4 Apparatus

26.4.1 General

A schematic of the test arrangement is shown in Figure 28.

26.4.2 Tensile test rig

A controllable tensile facility shall be used with the ability to pull over a specified distance at a controlled speed.

26.4.3 Recording equipment

A set of measurement equipment shall be used, linked to the tensile test rig that can record the forces required to remove the sheath from the cable core. Measurements shall be recorded in N.

26.4.4 Stripping tools

Tools capable of removing at least a 3 mm length of outer sheath at a distance 50 mm from the end of the cable, leaving the cable core undamaged, may be used.

26.4.5 Pulling

A pulling jig, as shown in Figure 29, shall be designed to fit into the gap formed in the sample sheath by removing the 3 mm section, allowing the 50 mm strip length of sheath to be pulled longitudinally from the prepared end of the cable.

26.4.6 Cable anchor

A method shall be provided to secure the anchor end of the cable while the pull is carried out.

26.5 Procedure

The prepared end of the cable is inserted into the pulling jig (see Figure 28) mounted on the test rig. The opposite end of the sample is then mounted in the cable anchor at zero load. A controlled pull is then carried out at the specified speed. Readings are taken to record the peak values of each test pull.

26.6 Requirements

The force required to remove the sheath from the cable core shall comply with the values given in the detail specification.

26.7 Details to be specified

The detail specification shall include the following:

a) rate of separation (speed of pull);
b) strip length (length of sheath removed) if different than in 28.4;
c) force to strip the length of sheath.

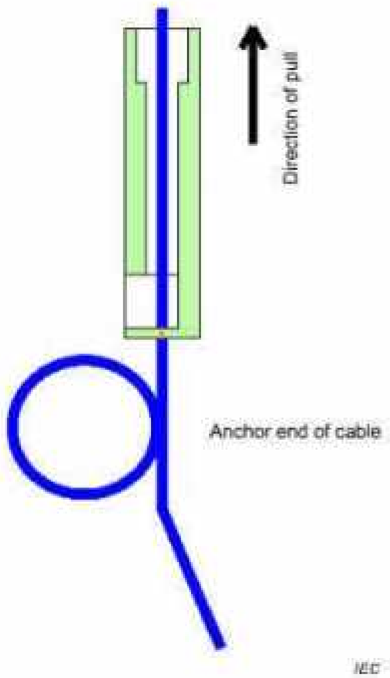
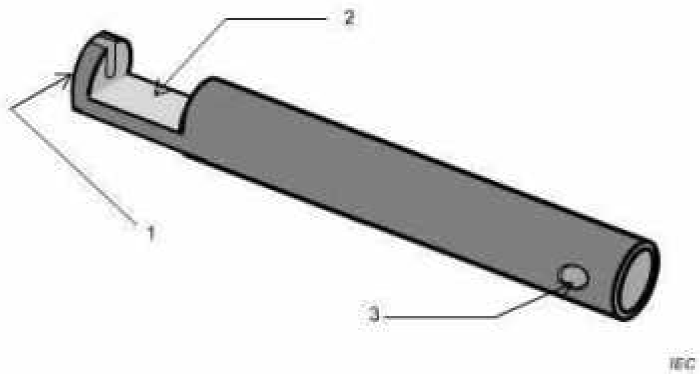


Figure 28 – Schematic of test arrangement



Key

1 pulling end of jig; dimensions appropriate to accommodate prepared specimen

2 window for inserting strip test end

3 attachment to pulling rig; details necessary for attachment per the particular rig

Figure 29 – Example of pulling jig

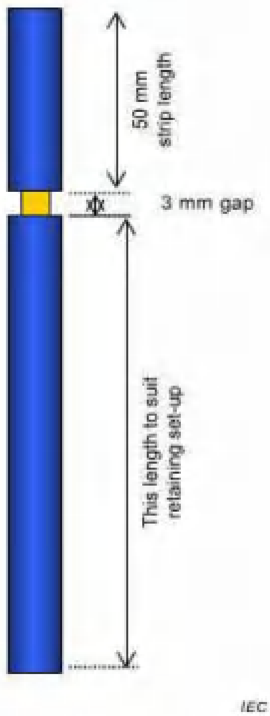


Figure 30 – Cable sample preparation

27 Method E22: Buffered fibre movement under compression in optical fibre cables for use in patch cords

27.1 Object

The purpose of this test is to examine the attenuation behaviour (change in attenuation) and the reaction force when a buffered fibre in a cable intended for use in patch cords moves under axial compression only.

27.2 Sample

A 5 m long cable sample shall be taken from a finished cable length. At both ends of the sample, 2 m of the cable sheath and other cable elements are removed, leaving a central 1,0 m length of cable sheath on the sample.

27.3 Apparatus

The apparatus consists of

- a device to fix one cable end without compression and a chuck to fix the buffered fibre protruding from this cable end. The chuck shall be movable towards the cable end for an adjustable distance (see Figure 31). The fixed distance between the chuck and the cable end shall be 7 mm,
- a load cell for monitoring the force on the chuck with a maximum error of ±3 %,
- attenuation monitoring equipment as described in IEC 60793-1-46.

27.4 Procedure

One end of the 1,0 m length of sheathed cable sample, including the strength member, is fixed to one side in the cable fixing device (1 in Figure 301) and the exposed buffered fibre is fixed in the fibre chuck (2 in Figure 30).

At the other end of the 1,0 m sample, the fibre and the sheath are glued together by e.g. epoxy to prevent any movement of the fibre within the cable sample. The unsheathed fibres are connected to the attenuation monitoring equipment (see Figure 31).

The chuck is moved towards the fixed cable end for 0,4 mm, or the required compression distance given in the relevant detail specification.

If multiple movements are specified, return the chuck to the starting position and perform the compression cycle again.

During the movement, any attenuation change and the reaction force are monitored. The test shall be carried out at ambient temperature.

27.5 Requirements

Attenuation change and the reaction force at the required compression distance shall not exceed the values given in the detail specification. The recommended compression distance is 0,4 mm.

27.6 Details to be specified

The detail specification shall include the following:

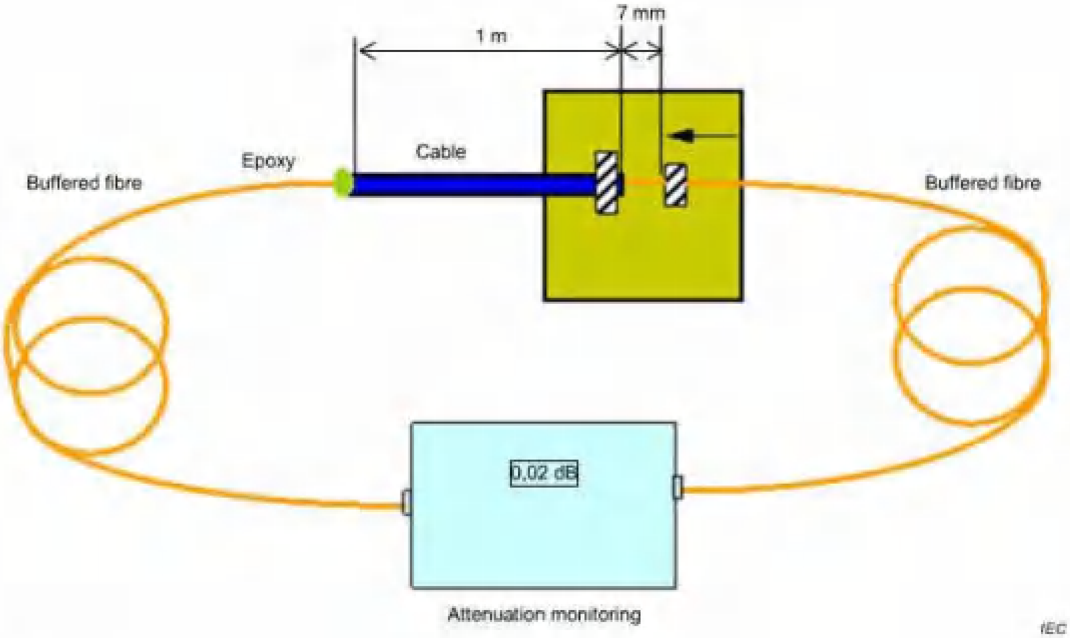
a) compression distance;

b) method of monitoring attenuation change;

c) number of movements;

d) reaction force;

e) change in attenuation.



Key

1 cable fixing

2 fibre chuck and load cell

← compression movement

Figure 31 – Test set-up for fibre movement under compression

28 Method E23: Microduct route verification test

28.1 Object

The purpose of this test is to provide a pre-installation validation of the microduct system for accepting a microduct fibre optic cable.

28.2 General

A route verification test consists of passing a test object, such as a sphere, approximately equal to the diameter of the cable in size, or 1 m of the actual cable to be installed, through the route to be populated. A successful test indicates that the intended cable path is free from obstructions.

28.3 Sample

The sample is the route into which the microduct optical cable is to be installed. Alternately, a reduced scale test apparatus may be used to prove application suitability.

28.4 Apparatus

A test object, such as a sphere, approximately equal to the diameter of the cable in size, or 1m of the actual cable to be installed, blowing installation equipment and a safe method to catch the sphere or other object at the far end of the microduct.

28.5 Procedure

Install the catcher at the far end of the microduct, launch the object into the microduct, and apply air pressure as per the detail specification.

28.6 Requirements

The object shall pass through the microduct route.

28.7 Details to be reported

The following details shall be reported:

- object dimensions;
- object material;
- microduct information (ID, OD)
  - route length,
  - location and description of significant bends, if known,
  - location of joint (if any);
- compressed air attributes
  - temperature,
  - pressure,
  - relative humidity

29 Method E24: Installation test for microduct cabling

29.1 Object

To demonstrate the feasibility of installing microduct optical cabling–micro-cable, fibre units, etc. into microduct or protected microduct.

29.2 General

This test method is designed to evaluate the blowing performance of a microduct optical cabling into a microduct or protected microduct. The test conditions approximate those in practical installations. The test is performed under ambient conditions, with temperatures above 0 °C (to avoid blocking with ice) and below +40 °C (above which temperature blowing performance has been observed to rapidly degrade).

29.3 Sample

A microduct or protected microduct, length as agreed between customer and supplier, formed according to Figure 32. Separate individual lengths may be connected by fittings.

Microduct cabling, length equal to or greater than the microduct sample.

29.4 Apparatus

The apparatus consists of

- blowing equipment as agreed between customer and supplier,
- temperature and humidity measuring equipment,
- timer,
- speed control (safety),

– pressure measuring device (safety),
– airflow meter.

29.5 Procedure

Blow air into the microduct for 10 min to condition the test route and to ensure a steady state airflow.

Prepare the leading end of the cabling as per installation instructions (e.g. by crimping a bead onto the front of a microduct fibre unit). If required by the installation method and in agreement between customer and supplier, the cabling and/or microduct may be lubricated. Most pulling lubricants are not suitable for blowing installations. Instead, lubricants are typically formulated for this specific application.

The output end of the microduct shall be suitably protected to avoid cabling exiting the microduct in an uncontrolled and unsafe manner.

Blow the microduct optical fibre cabling into the microduct test route with a specified air pressure and the safe pushing force required to maintain maximum speed. Install cabling directly from its packaging (e.g. drum, pan etc.) in a smooth fashion so as not to degrade installation performance. Record elapsed time and push force at regular intervals (typically every 100 m) during the test.

The push force may be adjusted in order to maintain the installation speed within the permitted range

Prior to any blown cable installation trial or live cable installation it is crucial that a 'crash test' is undertaken to determine the maximum push force that can be applied to the cable from the blowing head. This test involves using the blowing head to drive the cable (at the recommended cable installation speed) through a length of the mini-duct (typically 10 m). At the end of the miniduct is a tube end stop. When the cable hits the end stop the blowing head should stop the cable in a manner that does not cause any damage to the cable. This is then repeated with an increase in push force until cable damage is witnessed. The maximum push force of the cable is then taken to be the highest push force figure which resulted in the cable being undamaged when it hit the end stop. This procedure ensures that the cable will not be damaged in the event of the cable hitting a blockage in the mini-duct during the installation process [1][1].

29.6 Requirements

The following requirements shall be met:

– maximum acceptable installation time;
– minimum acceptable installation distance.

29.7 Details to be specified

The detail specification shall include the following:

– microduct ID/OD;
– leg length L (100 m, if not otherwise specified);
– total length (1 000 m, if not otherwise specified);
– bend diameter (40 times the outer diameter of the microduct, if not otherwise specified);
– requirement for lubrication (none to be used, if not otherwise specified);

[1] Numbers in square brackets refer to the Bibliography.

- blowing pressure (1,3 MPa to 1,5 MPa for microduct cable or 0,9 MPa to 1,0 MPa for microduct fibre unit, if not otherwise specified);
- installation time;
- installation speed range (5 m/min, minimum, to 60 m/min, maximum, unless otherwise specified);
- cabling to be tested.

29.8 Details to be reported

The following details shall be reported:

- microduct and cabling under test description;
- microduct cabling outer diameter, or major and minor axis for non-round cabling;
- microduct ID/OD;
- microduct surface finish (e.g. smooth or ribbed);
- protected microduct OD;
- leg length *L*;
- total route length;
- bend diameter;
- lubricant (if used);
- method(s) of lubrication (if used);
- blowing equipment (describe brand and type);
- blowing pressure;
- pushing force on microduct cabling (dependent on equipment and microduct cabling);
- temperature;
- humidity;
- installed distance;
- installation time.

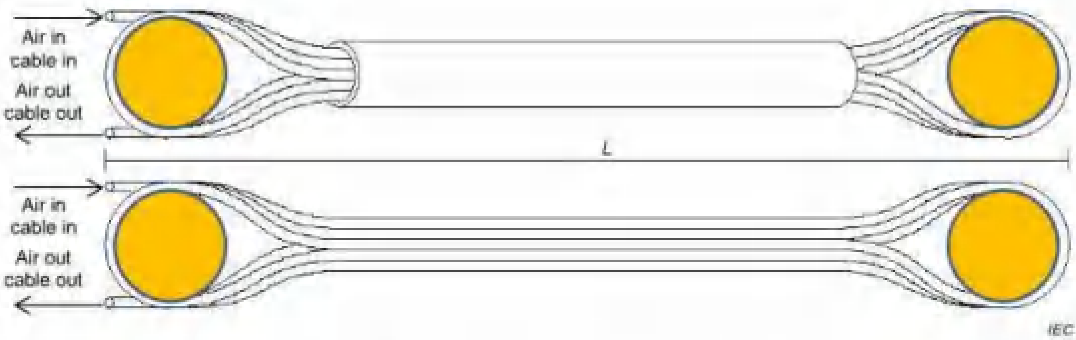


Figure 32a – Protected microduct **Figure 32b – Microduct (unprotected)**

Figure 32 – Schematic representation of test route, with leg-length *L*

30 Method E25: Rip cord functional test

30.1 Object

The object of this test is to determine the suitability of a rip-cord to facilitate the opening of an optical cable sheath without breaking. It is performed after the cable has been cooled to the minimum temperature expected for installation purposes (typical low temperatures recommended in IEC TR 62691 are 0 °C for PVC sheaths and –15 °C for polyethylene sheaths).

The test may also be carried out at the maximum installation temperature if requested (+50 °C is recommended in IEC TR 62691), though this is not normally necessary because most cable materials will have a lower modulus at high temperatures compared to lower temperatures and hence rip more easily.

30.2 Sample

The minimum length of the test sample shall be 1,5 m. Depending on the cable construction, the sample may need to be longer to ensure that the ripcord does not pull out of the test sample when pulled. The length may also be longer if more than 100 mm is required for end preparation.

30.3 Apparatus

The apparatus consists of

a) 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,
b) suitable cable preparation tools,
c) any method of holding the cable for test, such as clamping or manually securing the sample, is acceptable.

30.4 Procedure

The following steps shall be taken:

a) Prepare one end of the cable by removing all or part of sheath for a length of 100 mm to reveal the rip cord(s).
b) Make a mark on the sheath 1 m from the prepared end.
c) Place the sample into the temperature chamber. It is permitted to coil the cable to achieve this.
d) Set the temperature chamber to the test temperature (–15 °C unless otherwise agreed between the customer and the supplier).
e) Leave the sample in the chamber for at least 4 h.
f) Remove the cable from the chamber and carry out the following steps immediately.
g) Take hold of one rip cord and pull down on it until 1 m of the cable sample is ripped through and the cable core is revealed.

30.5 Requirements

The rip cord (s) shall rip through the cable sheath and shall not break for the entirety of the pull.

If the ripcord breaks prior to reaching the 1 m mark, two additional follow-up specimens may be tested from the same cable length. The cable passes if neither of the two follow-up specimens breaks prior to reaching the 1 m mark.

If the ripcord pulls out of the end of the cable without slitting the sheath, repeat the test.

30.6 Details to be specified

The relevant specification shall include the following:

– test temperature(s), if different from above.

30.7 Details to be reported

The following details shall be reported:

a) test temperature(s);
b) test gauge lengthv
c) cable construction;
d) sheath material;
e) rip-cord material;
f) number of rip-cords in the cable;
g) number of samples tested;
h) measurement results;
i) cable identification.

31 Method E26: Galloping

31.1 Object

The purpose of this test is to assess the effects of fatigue and strain on the self-supporting cable and on the optical characteristics of the fibres when exposed to typical galloping forces, such as might be experienced once installed.

31.2 Sample

The length of the fibre optic cable test sample shall allow removal of the cable coverings outside of the tensioning points to support access to the optical fibres for optical testing. The test sample shall be terminated at both ends prior to tensioning in a manner such that the optical fibres cannot move axially relative to the cable structure in the length under load. Refer to Figure 33.

The total length of optical fibre under test as a function of the fixed length (L1) shall be a minimum of 100 m. To achieve this length a number of fibres may be spliced together such that the number of concatenated fibres multiplied by the fixed length under test (L1) is at least 100 m. Splices should be made so the optical equipment can be located at the same end, but other arrangements are allowed. At least one fibre from each buffer tube, fibre bundle, or unit shall be measured for the test.

31.3 Apparatus

A basic test arrangement for conducting cable galloping testing is shown in Figure 33. The test sample is secured on each end using suitable assemblies or other fixtures to support the application of the test tensile load in the axial direction to simulate a self-supporting installation. Other assemblies are used to fix the cable in the vertical and horizontal planes, at points near the ends, to isolate the cable length subjected to galloping (fixed length). The points on each end of the test sample where the galloping length is fixed and the tensile load is applied may be combined or separate. In any case, the length exposed to galloping shall fall within a section of the test sample that is tensioned as required below, and shall not affect the application of the tensile load.

A calibrated device, such as a dynamometer, load cell, or load beam, shall be used to monitor cable tension. The tensions required are discussed in 33.4, under "Loading criteria".

The fixed length (L1) shall be at least 35 m with the suspension assembly placed at approximately one-half of the distance between the two dead-end assemblies. The suspension assembly shall be at a height such that the static sag angle of the cable to horizontal does not exceed 5 ° in the direction of the active span (L2).

An electronically controlled shaker shall be used to excite the cable in the vertical plane. The shaker assembly shall be securely fastened to the cable so that it is normal to the cable in the vertical plane, and shall not affect the application of the tensile load along the length under test. The amplitude of a mid-loop (antinode), single loop galloping, shall be monitored. The minimum galloping peak-to-peak amplitude shall be one twenty-fifth of the active span length. The test frequency shall be the single loop resonant frequency.

31.4 Procedure

The cable shall be subjected to a minimum of 100 000 galloping cycles. The test is the single loop resonant frequency for the galloping condition. The minimum peak-to-peak antinode amplitude/ loop length ratio shall be maintained at a ratio of 1/25, as measured in the active span (L2).

The optical test source output shall be split into two signals. One signal shall be connected to an optical power meter and shall act as a reference. The other signal shall be connected to a free end of the test fibre. The returning signal shall be connected to a second optical power meter. All optical connections and splices shall remain intact through the entire test duration.

Loading criteria:

The cable shall be tensioned to a value that will allow the galloping phenomenon in the test rig (one singular half-sine wave; see Figure 33). A suggested value is 5 % of maximum allowable tension (MAT) for OPGW or 50 % of maximum installation tension (MIT) for ADSS. However, the gauge length in the test rig should be taken into account, and a lower value is frequently appropriate.

Optical measurements shall be taken as follows:

a) Take an initial optical measurement of each signal.

   NOTE The difference between the two signals for the initial measurement provides a reference level. The change in this difference during the test will indicate the change in attenuation of the test fibre. The signals may be output on a strip chart recorder for a continuous hardcopy record.

b) The test sample shall then be loaded per the loading criteria above. Once the galloping have been initiated, the attenuation shall be recorded every 2 000 galloping cycles and the sample physically inspected.

c) A final optical measurement shall be taken after the completion of the 100 000 galloping test cycles, allowing for at least 2 h stabilization time.

31.5 Requirements

There shall be no visible cracks or openings on the elements of cable.

The maximum measured optical attenuation increase should not exceed the value specified in the detail specification.

31.6 Details to be specified

The detail specification shall include the following:

a) the rated maximum installation tension;

b) the maximum cable rated load (MCRL), maximum cable rated load;

c) allowable attenuation increase during the test.

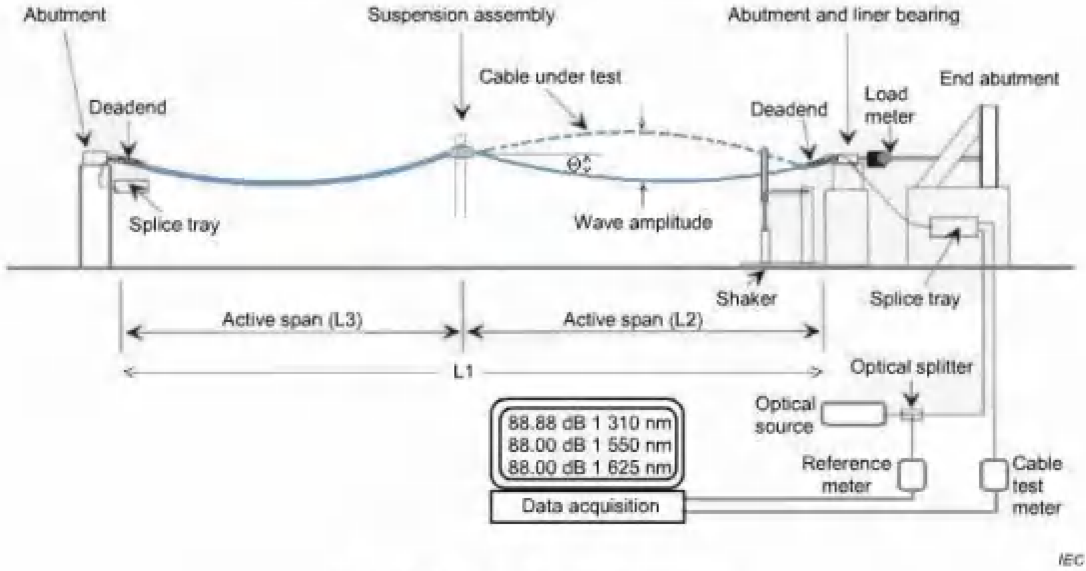


Figure 33 – Cable galloping test

Table 3 – Test values for cable galloping test schematic

Dimension	Description	Value
L1	Fixed length	≥ 30 m
L2	Active span	≥ 15 m[1]
L3	Backspan	≥ 15 m[1]
L4	Loop length	[2]
Θ	Static sag angle	≤ 1°

[1] L2 and L3 are approximately equal.

[2] Length varies as needed to obtain galloping characteristics specified based on L1 through L3.

32 Method E27: Indoor simulated installation test

32.1 General

This test is under consideration.

32.2 Object

This test is designed to simulate an installation of an indoor cable containing single-mode or multimode fibres where tight corners, stapling, and cable storage may occur. This test is aggressive, being far more severe than traditional installation practices, and is intended to demonstrate a level of robustness of the cable tested.

NOTE This test is primarily intended to evaluate the performance of cables containing bend-insensitive fibres. Indoor cables containing other fibre types are not assumed to fulfil the requirements associated with this test.

32.3 Sample

Under consideration.

32.4 Apparatus

Under consideration.

32.5 Procedure

Under consideration.

32.6 Requirements

Under consideration.

32.7 Details to be specified

Under consideration.

Under consideration

Figure 34 – Indoor simulated installation test

33 Method E28: Cable and fibre mechanical reliability test

33.1 Object

This test is designed to simulate the stress of simultaneous tension and bending. The corner wrapped cable is subjected to a load higher than the long term residual load to accelerate testing. This test is intended for small fibre-count cables. Simplex and duplex cables are the most common, but other fibre counts—perhaps 4 or 6 fibres, maximum—may be tested.

33.2 Sample

The cable samples shall be of a type as specified by the relevant specification. It shall be of sufficient length to accommodate the apparatus used, including the length under test, the length needed for the attachment method (mandrels, etc.), and any length needed for the optical test method used.

33.3 Apparatus

The test apparatus shall accommodate hanging a cable over a corner in a 90 ° bend configuration. The cable shall be tensioned by hanging a mass on the vertical tail of the sample. The diameter of the corner shall be well controlled and shall not be indented by the force of the tensioned cable. This is accomplished using a metal pin, or equivalent, at the corner. Figure 35 illustrates a typical apparatus.

The attachment method at both the anchored end of the cable and the attachment point for the tensioning mass is critical to the success of the test. The cable and fibres shall be well-coupled. The cable sheath covering shall not stretch or bunch. See Procedure, step a). A figure-8 mandrel is one method that has been demonstrated to accomplish these goals. See Figure 35.

33.4 Procedure

A continuous length of cable will hang vertically around a pin positioned to serve as a corner. A mass will hang on the cable to apply the test force:

a) The horizontal section of the cable shall be anchored such that no bunching of sheath covering material occurs and such that the fibre(s) are coupled to the balance of the cable. One possible method utilizes multiple wraps around a mandrel. The cable shall be placed on the anchor attachment shall be such that the cable bends over the pin in a 90 degree angle.

b) The corner pin shall be 3,0 mm $^{0}_{-0,05}$ mm in diameter.

c) A weight equal to 1,5 times the long term rated load shall be attached to the vertical section of cable. Load should be applied gradually to prevent sheath tearing. A figure-8 device or mandrel shall be used to couple fibre and cable components.

d) The length of test is 30 days.

33.5 Requirements

Fibre breakage or the presence of visible cracks on the outer surface of the sheath constitutes a failure.

33.6 Detail to be specified

The detail specification shall include the following:

– type of cable to be tested;
– long term rated load;
– test load if different from above;
– test time if different from above.

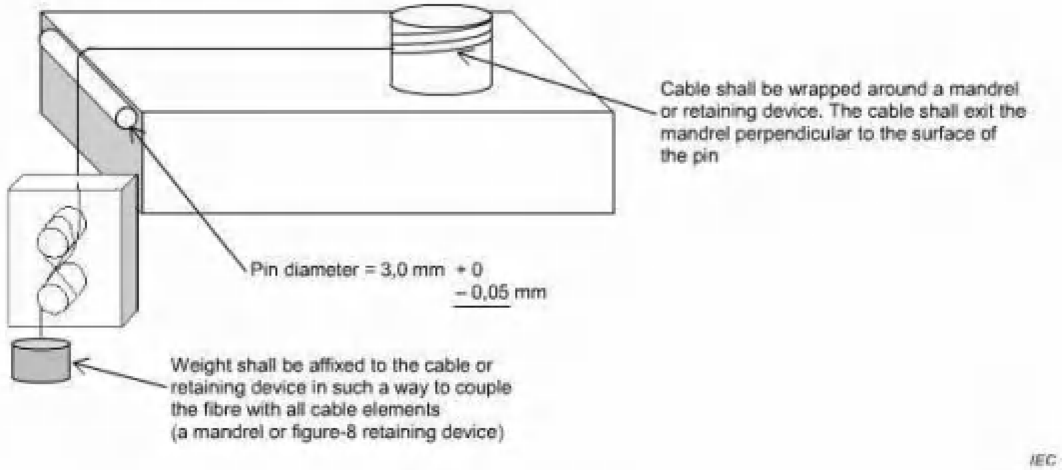


Figure not to scale.

Figure 35 – Mechanical reliability test apparatus

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[1] *Installation of Mini-Cables: factors that influence the installation performance of mini-cables*, SUTEHALL. R. et al, Proceedings of the 59th IWCS Conference. Available from http://www.iwcs.org/

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