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REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Optical fibre cables –
Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods

IEC 60794-1-23:2019-10 RLV(en)

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Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60794-1-23 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

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

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

a) addition of a new test method G9: Bleeding and evaporation (formerly known as method E15 in IEC 60794-1-21:2015);

b) addition of a new test method G10A: Stripping force stability of cabled optical fibres (formerly known as method E5A in IEC 60794-1-21:2015);

c) addition of a new test method G10B: Strippability of optical fibre ribbons (formerly known as method E5B in IEC 60794-1-21:2015);

d) addition of a new test method G10C: Strippability of buffered optical fibres (formerly known as method E5C in IEC 60794-1-21:2015);

e) addition of a new test method G11A: Tensile strength and elongation of buffer tubes (included in IEC 60811-501);

f) addition of a new test method G11B: Elongation of buffer tubes at low temperature (included in IEC 60811-505);

g) clarification of the sample preparation procedure in method G5: Ribbon tear (separability);

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

CDV	Report on voting
86A/1912/CDV	86A/1945/RVC

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

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

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

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

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

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OPTICAL FIBRE CABLES

Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods

1 Scope ~~and object~~

This part of IEC 60794 describes test procedures to be used in establishing uniform requirements for the geometrical, material, mechanical, environmental properties of optical fibre cable elements.

This document 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 part of IEC 60794 is to define test procedures to be used in establishing uniform requirements for the geometrical, material, mechanical, environmental properties of optical fibre cable elements.~~

Throughout the document, the wording "optical cable" ~~may~~ can 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.~~

NOTE The environmental testing of optical fibre ribbon would be valuable for some applications. Useful information about suitable test methods can be found in the optical fibre standards IEC 60793-1-50, IEC 60793-1-51, IEC 60793-1-52, and IEC 60793-1-53.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60794-1-31:2018, *Optical fibre cables – Part 1-31: Generic specification – Optical cable elements – Optical fibre ribbon*

IEC 60793-1-32:2018, *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 measurement methods*

~~IEC 60794-3:2001, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*~~

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

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

4 General requirements

IEC 60794-1-2 is the reference guide to test methods of all types. It shall be considered for general requirements and definitions.

5 Method G1: Bend test for optical cable elements

5.1 Object

The purpose of this test is to characterize cable elements for splicing purposes by determining the attenuation increase of an optical cable element (fibre, ribbon, core tube, breakout unit, etc.) ~~element~~ when bent within a splice closure or similar device.

5.2 Sample

The length of the sample of optical cable element shall be sufficient to carry out the testing specified.

5.3 Apparatus

The apparatus consists of

a) a mandrel having a smooth surface with diameter as stated in the detail specification, and

b) an attenuation measuring apparatus for the determination of attenuation change (~~see~~ according to the test methods of IEC 60793-1-40 and IEC 60793-1-46).

5.4 Procedure

The element to be tested shall be ~~loosely~~ wound on the mandrel at minimal tension; the number of turns shall be stated in the detail specification.

In order to measure the attenuation increase caused by bending, allowance should be made for the intrinsic attenuation of the fibre.

5.5 Requirements

Any increase in attenuation shall comply with the limits shown in the detail specification.

5.6 Details to be specified

The detail specification shall include the following:

a) optical test wavelength;

b) diameter of the mandrel;

c) number of turns;

d) apparatus and attenuation measuring technique;

e) temperature at which the evaluation shall be performed if different from room temperature.

6 Method G2: Ribbon dimensions and geometry – Visual method

6.1 Object

The purpose of this test is to determine the geometry of an optical fibre ribbon as defined by the parameters of width, height and fibre alignment, for the purpose of type testing to assume proper manufacturing process control. This test is not necessarily suitable for final product inspection and, unless otherwise specified, shall not be used for that purpose.

6.2 Sample

The number of samples to be tested shall be specified in the detail specification. The selected samples shall be statistically independent and representative of the ribbon population tested.

6.3 Apparatus

The apparatus consists of a microscope or profile projector with appropriate magnification.

6.4 Procedure

6.4.1 General

Either of the two ~~following~~ procedure~~s~~ methods described in 6.4.2 and 6.4.3 may be used.

For the specified number of samples, all dimensions shall be measured as average as well as maximum and minimum values.

~~NOTE~~ Care should be taken that the preparation of the sample does not change the structure of the fibre ribbon and represents an undisturbed image of the fibre cladding and ribbon cross-section.

6.4.2 Method 1

The sample is prepared by cutting it perpendicular to the axis of the ribbon and placing it in a curable resin or in a tool which holds the ribbon. If necessary, the sample shall be ground and polished to prepare a smooth perpendicular end face. The prepared sample is secured with its end face perpendicular to the optical path and measured by means of a microscope or profile projector.

6.4.3 Method 2

Place the ribbon in a ribbon fibre holder and remove 20 mm to 25 mm of the fibre coating and matrix material with the ribbon hot sheath stripping tool and wipe the stripped portion of the fibres clean with an alcohol-moistened pad. Adjust the position of the ribbon in the ribbon fibre holder and cleave the fibres at a distance of 250 μm to 500 μm from the stripped edge of the ribbon. Cut and polish the other end of the ribbon, and illuminate it with a collimated light source. Align and measure the cleaved end of the ribbon under microscope.

~~NOTE Care should be taken that the preparation of the sample does not change the structure of the fibre ribbon and represents an undisturbed image of the fibre cladding and ribbon cross-section.~~

6.5 Requirements

Unless otherwise specified in the detail specification, the width, height and fibre alignment shall be in accordance with ~~IEC 60794-3:2001, Table 1~~ IEC 60794-1-31:2018.

6.6 Details to be specified

The detail specification shall include the following:

a) permissible maximum and minimum values;

b) limits for average values;

c) number of samples tested.

6.7 Definitions of ribbon dimensions and geometry

6.7.1 General

The following definitions apply to a fibre ribbon cross-section as shown in Figure 1. The figure illustrates an example for a 4-fibre ribbon, where a is the diameter of a coloured fibre.

NOTE In consideration of the precision of fibre geometric attributes and the relatively larger precision of ribbon geometry requirements, it is acceptable for glass core/glass cladding fibres to use the edge of the cladding for the measurements of 6.7.3 and 6.7.4 in lieu of the fibre centres. In this case, the measurements ~~shall~~ can be made on the same side of all fibres (e.g. top or bottom, left or right side).

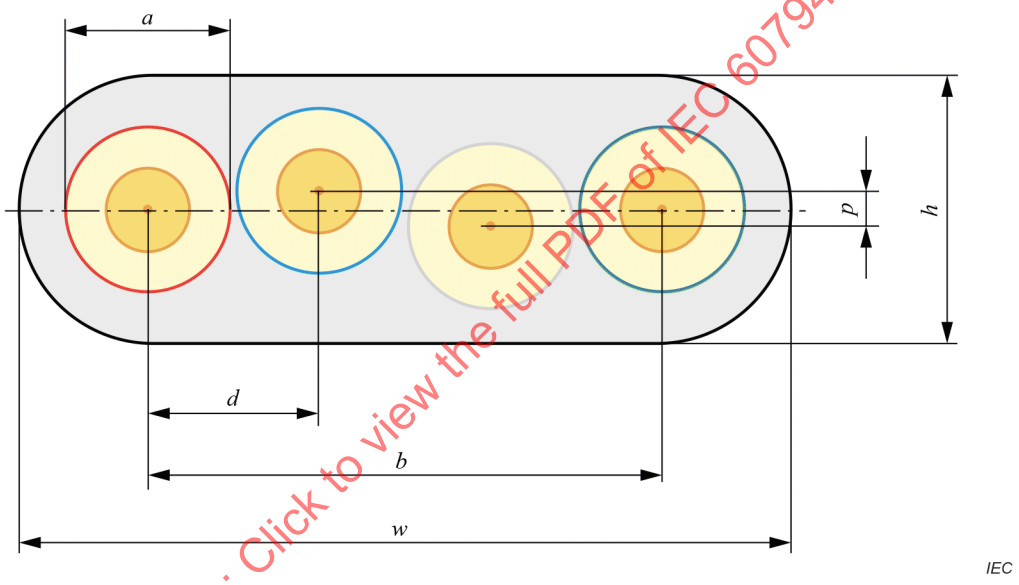


Figure 1 – Cross-sectional drawing illustrating fibre ribbon geometry

6.7.2 Width and height

The width w and height h of the ribbon are the dimensions of the minimum rectangular area enclosing the ribbon cross-section.

6.7.3 Basis line

The basis line is ~~given~~ that line in the cross-section of an optical fibre ribbon ~~as the straight line~~ crossing the fibre centres of the first fibre (fibre 1) and the last fibre (fibre n) of the fibre ribbon, as shown in Figure 1 as dotted line. This line is used as the reference plane for the fibre alignment measurements.

6.7.4 Fibre alignment

6.7.4.1 Horizontal fibre separation

The horizontal separation of fibres is the distance of the orthogonal projection of two fibre centres on the basis line in the fibre ribbon cross-section.

Two horizontal separation parameters can be distinguished:

a) centre-centre distance d between adjacent fibres;

b) centre-centre distance b between the extreme fibres.

6.7.4.2 Planarity

The planarity p of the fibre ribbon structure is the sum of the maximum positive and absolute value of the maximum negative vertical separation of the fibres.

The vertical separation of the fibres is the orthogonal distance from the fibre centre to the basis line. The vertical separation is positive for fibres "above" the basis line and negative for fibres "below" the basis line.

7 Method G3: Ribbon dimensions – Aperture gauge

7.1 Object

The purpose of this test is to verify the functional performance of a ribbon. In order to ensure functional performance, the dimensions of edge bonded ribbons may be controlled and verified for final inspection purposes with an aperture gauge. The intent is to verify that the end portion of a ribbon can be inserted into and would be reasonably aligned to the guide slots of commercial stripping tools. ~~This method is under consideration for encapsulated ribbons.~~

7.2 Sample

Unless otherwise specified in the detail specification, five representative ribbon samples, each with a minimum length of 50 mm, shall be taken from the ribbon to be tested.

7.3 Apparatus

An aperture gauge, as shown in Figure 2~~, having an aperture based on the dimensions shown in IEC 60794-3:2001, Table 1, may~~ shall be used to assess the overall dimensions of a ribbon. The values for ribbon width (w) and ribbon height (h) of Figure 2 shall be the nominal ribbon dimensions as established using method G2 in an appropriate quality assessment scheme.

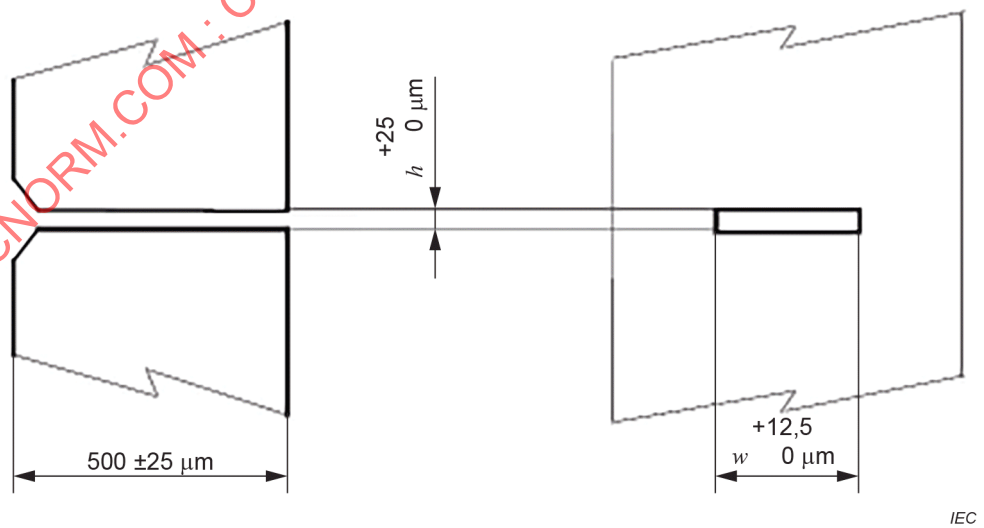


Figure 2 – Aperture gauge

7.4 Procedure

The ribbon sample to be tested is held in the middle, and a 10 mm end portion is inserted through the aperture gauge.

7.5 Requirement

It ~~must~~ shall be possible for the 10 mm ribbon end portion to be freely inserted through the aperture gauge without mechanical damage to the sample.

7.6 Details to be specified

The detail specification shall include the following:

a) dimensions of the aperture gauge;

b) number of samples to be tested.

8 Method G4: Ribbon dimensions – Dial gauge (~~Test deleted~~ obsoleted method)

9 Method G5: Ribbon tear (separability)

9.1 Object

The purpose of this test is to assure sufficient tear resistance for ribbons where the fibres are not required to be separable, or to assure sufficient separability of the fibres for ribbons where the fibres are required to be separated. The intention of this test is to be able to tear by hand without damage.

9.2 Sample

~~For an n fibre ribbon, n/2 specimens, each with a minimum length of 100 mm, are taken from lengths of approximately 1 m each from the fibre ribbon.~~

~~The fibres to be tested are separated with a knife or other suitable method on a suitable length for clamping (see Figure 3) for x samples (x, typically 3 to 5, to be specified in the detail specification). One fibre is separated from the other fibres in the ribbon. For x more samples, two fibres are separated from the other fibres in the ribbon, etc. up to n/2 fibres.~~

A number of samples of fibre ribbon, as specified in the detail specification, typically 3 to 5, shall be selected from the ribbon or ribbons to be tested. The length of each sample shall be sufficient to provide the number of test specimens as detailed below.

For an n fibre ribbon, n/2 specimens are taken from each of the samples above. Each specimen shall be 100 mm minimum length, consistent with Figure 3.

Prepare the n/2 specimens involving increasing numbers of fibres to be separated as a ribbon unit. That is, a specimen for fibre 1; a specimen for fibres 1 to 2; a specimen for fibres 1 to 3; etc.

The fibres to be tested are separated with a knife or other suitable method on a suitable length for clamping, per Figure 3.

For the first sample, the preparation of the test sequence shall be to separate one fibre from the other fibres in the ribbon in the first specimen. Then, separate a unit of two fibres from the next specimen. Then, units of three, four, etc. fibres are separated in the other specimens, up to a unit of n/2 fibres in the last specimen.

Do the same preparation for all the other samples.

NOTE If n is an odd number, replace n/2 with (n-1)/2 in the above description.

Dimensions in millimetres

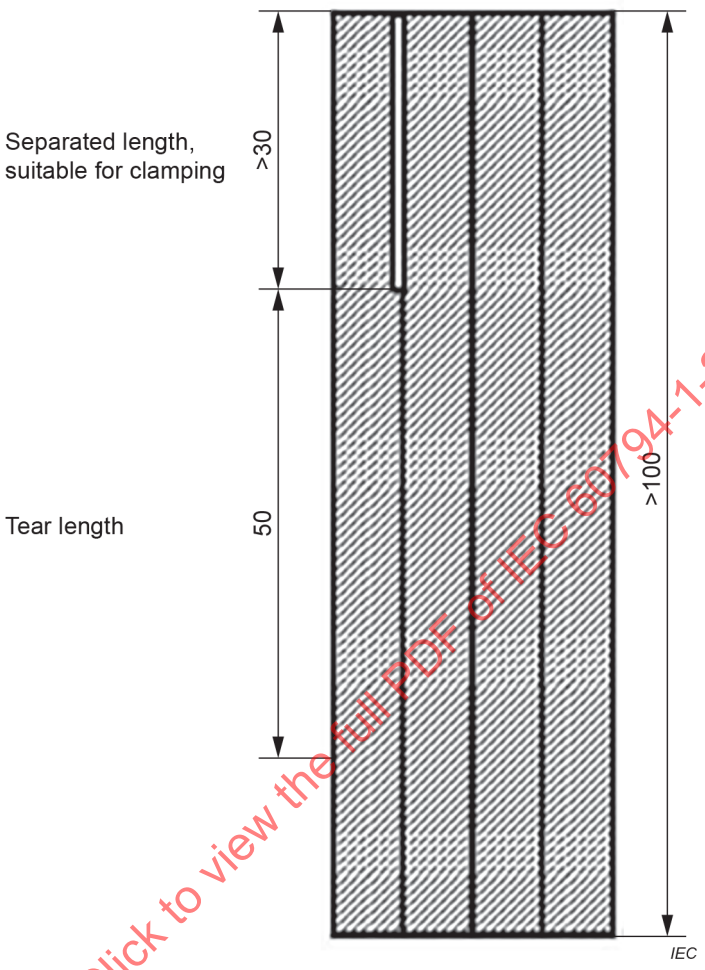


Figure 3 – Sample preparation for ribbon separability test

9.3 Apparatus

The apparatus consists of

a) a tensile strength measuring apparatus with suitable clamping devices and suitable force recording functions, and

b) a microscope with at least 100 × magnification.

9.4 Procedure

The specimen is inserted into the strength measuring apparatus, as shown in Figure 4. The fibres to be tested are torn at a speed of approximately 100 mm/min to 500 mm/min. The force to tear the fibres on a minimum length of 50 mm is continuously recorded.

In the case where fibres are required to be separated, the primary coating of the separated fibre(s) shall be visually inspected by means of a microscope.

The procedure is repeated for the specimens involving separation of fibre 1, fibres 1 to 2, fibres 1 to 3, etc. up through fibres 1 to n/2.

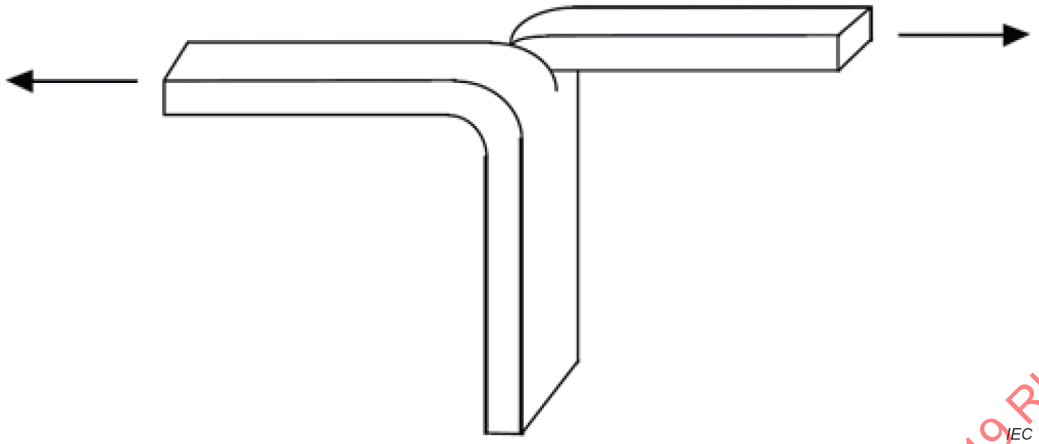


Figure 4 – Separability procedure

9.5 Requirements

The primary requirement is to be able to make the tear without fibre damage (coating damage or fibre breakage). For ribbons where the fibres are required to be separated, the coloured primary coating of the separated fibre(s) shall be effectively free from ribbon matrix residues.

Any colour coding of fibres shall remain sufficiently intact within any 25 mm segment to enable individual fibres to be distinguished from each other.

The minimum or maximum and mean tear forces shall be as specified in the detail specification.

9.6 Details to be specified

The detail specification shall include the following:

a) minimum and mean tear force, in N, when fibres are not required to be separated;

b) maximum and mean tear force, in N, as required by the detail specification, when fibres are required to be separated;

c) number of samples;

d) type of ribbon (separable or non-separable).

10 Method G6: Ribbon torsion

10.1 Object

The purpose of this test is to verify the mechanical and functional integrity of the fibre ribbon structure. The test determines the capability of the ribbon to withstand torsion without delamination~~, whilst maintaining the fibre separability where required~~.

10.2 Sample

Unless otherwise specified in the detail specification, five representative samples, each with a minimum length of 120 mm, are obtained from the ribbon to be tested.

10.3 Apparatus

The testing apparatus, an example of which is in Figure 5, consists of two vertically positioned clamps to hold the sample while it is twisted under a minimum tension of 1 N. The minimum length to be tested is 100 mm.

Dimensions in millimetres

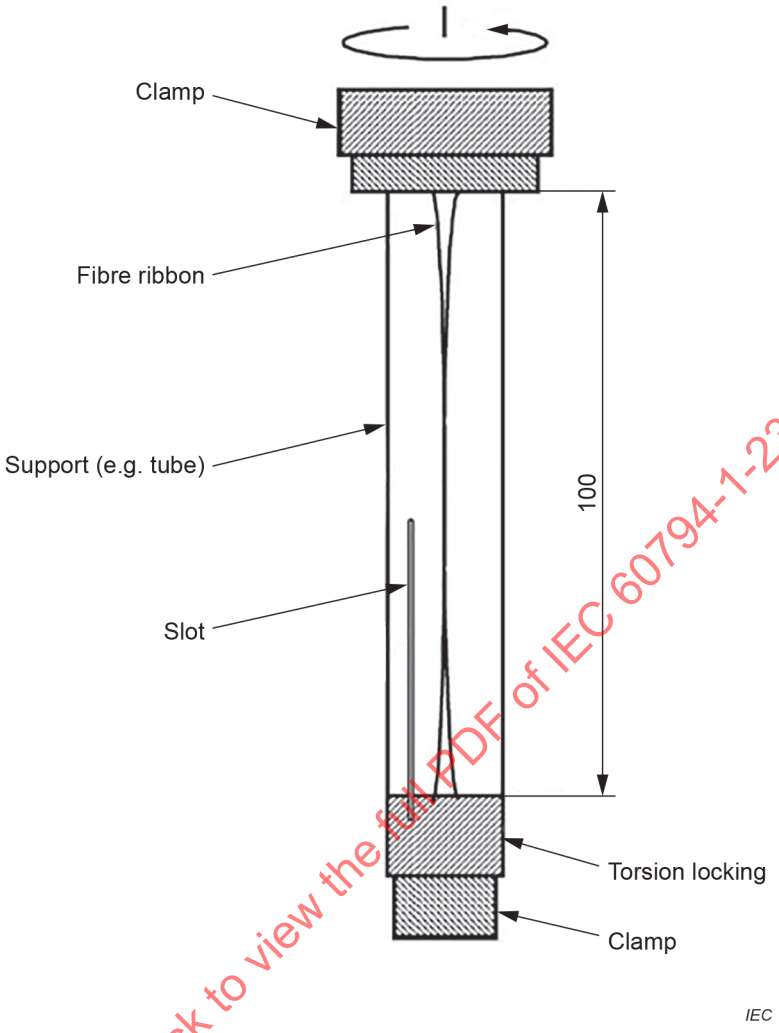


Figure 5 – Torsion test

10.4 Procedure

The sample is securely fixed in the apparatus and twisted in increments of 180° ± 5° within a time of 2 s. The minimum dwell time after each twist increment is 5 s. The incremental twisting is continued to the value(s) agreed upon between the ~~manufacturer~~ customer and ~~user~~ supplier, as defined in the detail specification, or until delamination occurs.

10.5 Requirements

The ribbon shall withstand the number of 180° turns ~~until delamination occurs, as given~~ stated in the detail specification until delamination occurs.

10.6 Details to be specified

The detail specification shall include the following:

a) number of samples;

b) number of turns.

11 Method G7: Tube kinking

11.1 Object

The purpose of this test is to determine the ability of tubes containing optical fibres to withstand mechanical stresses encountered during cable installation and splicing. The test is carried out on tubes taken from an optical cable.

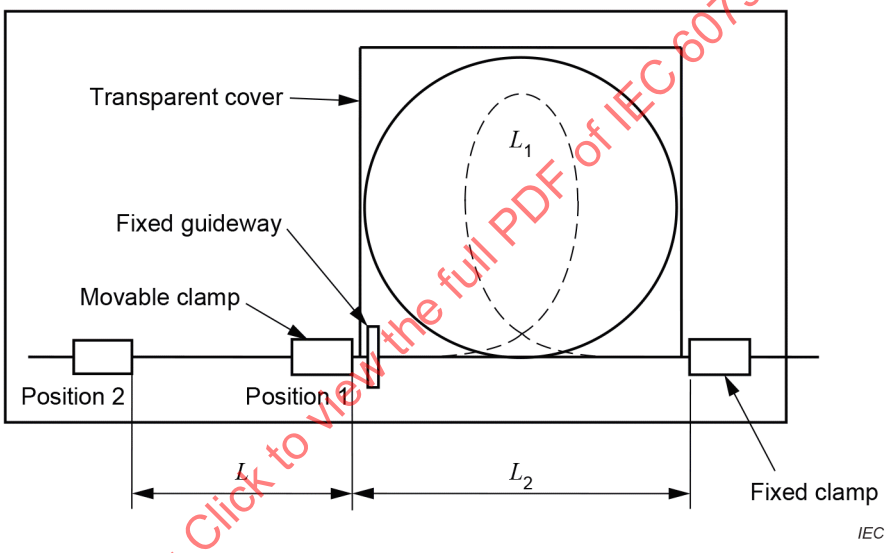
11.2 Sample

Tube containing fibres, with a length of at least L_1 + 50 mm, shall be taken from an optical fibre cable.

Five (5) samples shall be tested, unless otherwise specified.

11.3 Apparatus

The apparatus consists of a testing device as shown in Figure 6.



Key

L_1 length of tube under test

L_2 distance between the tube clamping point of the movable clamp and the tube clamping point of the fixed clamp at the start of the test

L moving distance (the length of which determines the reduction of the ellipse dimension)

~~The dimensions of the apparatus are given in Table 1.~~

~~NOTE 1~~ The minimum diameter of the loop is not fixed by a curvature in the test equipment, but only controlled by the fixed length L_1 of the specimen and the moving length L.

~~NOTE 2~~ The fixed guideway ensures a defined position of the sample. A transparent cover allows the sample to be kept in the same plane and observed whilst being tested. The distance between the two covers shall be typically three times the tube diameter. Too great a distance will allow the tube to move sideways during the test and does not ensure that the test is severe enough.

Figure 6 – Tube kinking test

Examples of test apparatus dimensions for tube kinking are shown in Table 1.

Table 1 – Examples of test apparatus dimensions for tube kinking

Nominal tube diameter mm	L_1 mm	L_2 mm
≤ 3,1	350	100
≤ 6,1	650	200
≤ 10,1	1 050	300

11.4 Procedure

The test shall be carried out at standard atmospheric conditions.

The sample shall be marked with a length L_1 and mounted in the test device as shown in Figure 6, with the movable and fixed clamps separated by a distance L_2.

The moveable clamp shall be moved between positions 1 and 2 over a distance L and returned to position 1 at a speed approximately 10 mm/s. This movement is one cycle. During the last cycle, the sample shall remain in position 2 for 60 s.

The values of test parameters L, L_1, L_2 and the number of cycles (five, unless stated otherwise) should simulate the service deployment conditions. They shall be agreed between ~~user~~ customer and ~~manufacturer~~ supplier.

NOTE 1 Whilst the loop tends to form an ellipse rather than a perfect circle during the test, it is possible to simplify the understanding of the test parameters considerably by assuming that a circle is formed. Based on this assumption, then

$$L = L_1 - (L_2 + \pi \times D) \quad (1)$$

where

D is the tube loop diameter (mm).

NOTE 2 As a mechanical test, a typical minimum value for the tube loop diameter is 60 mm, since this aligns with the minimum specified bend diameter for most classes of fibre and also represents a minimum practical value of coiled tube loops within a joint or other connectivity plant.

NOTE 3 Using D = 60 mm, then L can be calculated (for tubes ≤ 3,1 mm) from Formula (1), which also yields the value of 60 mm. Since the loop does form an ellipse, which makes the effective loop diameter in one plane much more severe, it is ~~recommended~~ possible that 60 mm is taken as the maximum length specified for the moving length, L. Lower values ~~may~~ can be specified.

NOTE 4 If this test is used to simulate installation of a tube within a joint, then the value for D ~~may~~ can be replaced by the available width within a joint.

11.5 Requirements

During the test, no kinking of the sample shall be visible.

11.6 Details to be specified

The detail specification shall include the following:

a) number of cycles (five, unless otherwise specified);

b) lengths L, L_1, L_2 (use L = 60 mm, ~~L_1 = 350 mm, L_2 = 100 mm~~ L_1 and L_2 according to Table 1, unless otherwise specified~~, for tubes ≤ 3,1 mm~~)

c) test temperature.

12 Method G8: Ribbon residual twist test

12.1 Object

The ribbon residual twist test, or flatness test, evaluates the degree of permanent twist in a cabled optical fibre ribbon.

12.2 Sample

Ribbon samples shall be taken from a preconditioned (aged) test cable.

The samples shall be of a length sufficient to include the gauge length of 50 cm and additional length on each end to facilitate attachment of clamps and the test weight.

12.3 Apparatus

The apparatus shall be constructed to have the following characteristics.

– The ribbon shall hang vertically, clamped at the top, with the bottom end free to rotate and translate as necessary.
– A mass shall be attached to the bottom end of the ribbon sample, with the gauge length situated between the top clamp and the bottom mass.
– The bottom mass shall be arranged so that it does not impart any twisting or side loading of the ribbon.
– The gauge length shall be 50 cm ± 5 cm, unless otherwise specified.
– The mass shall be 100 g ± 5 g, unless otherwise specified.
– A method shall be provided to measure the axial rotation of the lower end of the ribbon gauge length with respect to the upper end.

12.4 Procedure

Perform the following steps, unless otherwise specified.

1) Precondition the ribbon at 85 °C ± 2 °C, uncontrolled relative humidity, for 30 days in its cable.
2) Mount one end of the ribbon in the top clamp.
3) Attach the bottom mass.
4) Allow the ribbon to rotate. When the rotation settles out and the ribbon becomes still, measure the angular rotation of the bottom end of the gauge length with respect to the upper end of the gauge length.
5) Calculate the residual twist of the sample according to Formula (2):

~~Residual twist = (final angle, top to bottom) / (measured gauge length)~~

$$T = \frac{\theta}{L} \tag{2}$$

where

T is residual twist, °/cm;

θ is final angle from top to bottom, °;

L is measured gauge length, cm.

12.5 Requirements

The ~~buffered fibres~~ calculated residual twist of optical fibre ribbon shall not exceed the maximum residual twist requirements of the detail specification. In most cases, a maximum residual twist of 8°/cm is adequate.

12.6 Details to be specified

The detail specification shall include the following:

a) the preconditioning conditions, if different from those stated above;
b) the ribbon gauge length, if different from that stated above;
c) the tension mass, if different from that stated above.

13 Method G9: Bleeding and evaporation

13.1 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.

NOTE This method is known as method E15 in IEC 60794-1-21:2015.

13.2 Sample

Filling compound material intended to be used in contact with optical fibres shall be prepared with sufficient amount to perform the test.

13.3 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, and
c) the test set-up (see Figure 7), consisting of the following:
   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;

      NOTE 1 Alternatively, the cone can consist of stainless steel (60 mesh, opening 0,25 mm) and the solder width can be more than 1 mm, provided it is proved that the results are not significantly different from the first one.

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

      NOTE 2 The cover is not needed when measuring the evaporation.

   3) a desiccator.

Dimensions in millimetres

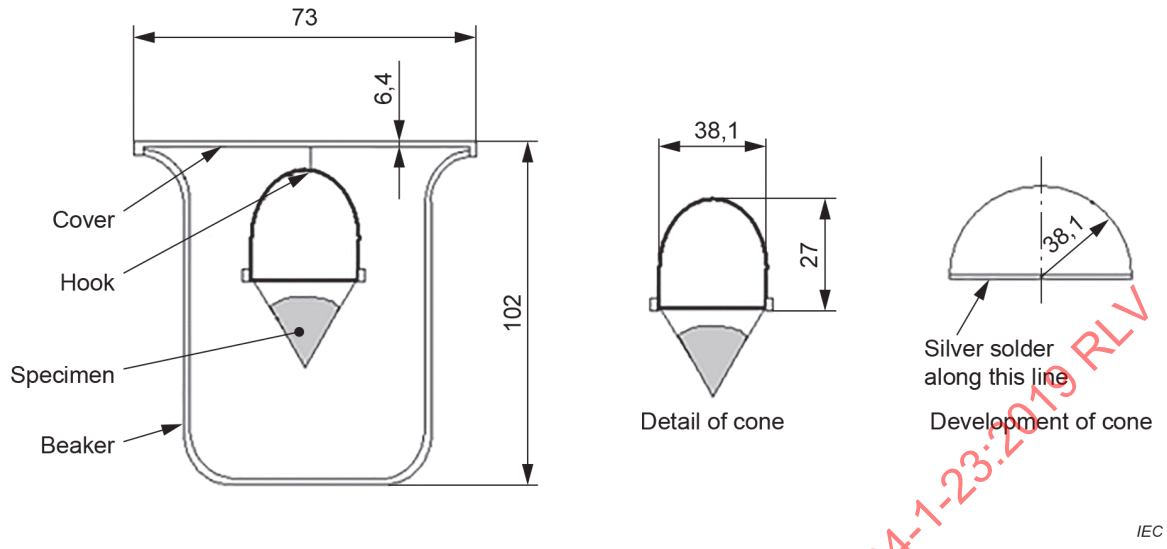


Figure 7 – Bleeding and evaporation test set-up

13.4 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 according to Formulae (3) and (4) and report the average of the duplicate results.

Calculations:

$$B = \frac{M_5 - M_1}{M_3 - M_2} \times 100 \quad (3)$$

$$E = \frac{M_3 - M_4}{M_3 - M_2} \times 100 \quad (4)$$

where

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

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

13.5 Requirements

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

13.6 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 13.3, c), 1);
d) number of samples to be tested.

14 Method G10A: Stripping force stability of cabled optical fibres

14.1 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.

NOTE This method is known as method E5A in IEC 60794-1-21:2015.

14.2 Sample

14.2.1 Sample length

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

14.2.2 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).

14.3 Apparatus

The apparatus consists of conditioning equipment (if necessary) and a fibre strippability apparatus (according to the strippability test method of IEC 60793-1-32:2018).

14.4 Procedure

The optical fibre strippability shall be measured on the environmentally conditioned samples using the strippability method of IEC 60793-1-32:2018, 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 60794-1-22:2017.

14.5 Requirements

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

14.6 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.

15 Method G10B: Strippability of optical fibre ribbons

15.1 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.

NOTE This method is known as method E5B in IEC 60794-1-21:2015.

15.2 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.

15.3 Apparatus

15.3.1 General

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

15.3.2 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 manufacturer's 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.

15.3.3 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.

15.4 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.

15.5 Alcohol wipe

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

15.6 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 2.

Table 2 – Condition of stripped samples

Rating	Condition of stripped sample
1	Coating and matrix materials leave no residue after one or two alcohol wipes
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.

15.7 Requirements

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

No fibres shall break.

15.8 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.

16 Method G10C: Strippability of buffered optical fibres

16.1 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, where the buffer is designed to be removable while leaving the fibre coating intact.

NOTE This method is known as method E5C in IEC 60794-1-21:2015.

16.2 Sample

Samples of buffered fibre to be tested shall comply with the requirements of method G10A.

16.3 Apparatus

The apparatus shall comply with the requirements of method G10A.

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.

16.4 Procedure

Follow the procedure of method G10A.

If comparison of unaged and aged samples is specified, perform the procedure as follows, following the intent of method G10A.

– Set aside unaged control samples for later test.
– Age the buffered fibre in the cable or in a representative environment in the lab (in filling compound, or the like, as appropriate) as specified in the detail specification. Ageing according to method F9 of IEC 60794-1-22:2017 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 G10A.

16.5 Requirements

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

16.6 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.

17 Method G11A: Tensile strength and elongation of buffer tubes and micro tubes at break

17.1 Object

These tests are to determine the tensile strength and elongation at break of the buffer tubes of the cable and micro tubes in the condition as manufactured (i.e. without any ageing treatment) and, when required, after one or more accelerated ageing treatment(s), which are prescribed in the relevant cable standard.

When the ageing treatment is to be carried out on prepared test pieces (in accordance with IEC 60811-401), the test pieces for the ageing treatment shall be from positions adjacent to the test pieces used for the test without ageing and the tensile tests on the aged and unaged test pieces shall be made in immediate succession.

NOTE 1 This method is included in IEC 60811-501.

Where further increased test reliability is necessary, it is recommended that the tests on aged and unaged test pieces are performed by the same person using the same testing method and the same apparatus, in the same laboratory.

NOTE 2 In 17.2 to 17.5, descriptions for buffer tube also include micro tube.

17.2 Sample

17.2.1 General

One sample of each buffer tube to be tested shall be taken of sufficient size to provide a minimum of five test pieces each for the tensile tests without ageing and the tensile tests after each of the required ageing treatments, bearing in mind that a 100 mm length is needed for the preparation of each test piece.

Any sample that shows signs of mechanical damage shall not be used for the test.

17.2.2 Preparation and conditioning of test pieces

a) Conditioning of test pieces

1) Elevated temperature conditioning

NOTE 1 Elevated temperature conditioning is not an ageing treatment. It is used as a means of ensuring stable and consistent test pieces when required. It is used a) when called for in the relevant cable standard, or b) if there is a doubt or disagreement about a result and the test needs to be repeated. In either case, the conditioning applies only to the test piece as taken from the cable before any subsequent treatment (ageing, compatibility test, oil immersion, etc.).

Where conditioning at elevated temperature is used, such conditioning shall be carried out as follows:

– for dumb-bells:

i) after the removal of the buffer tube from the cable but before the cutting of strips;

ii) after grinding (or cutting) to obtain parallel surfaces.

Where grinding (or cutting) is not needed, the conditioning shall be performed at the point in the test protocol according to i);

– for tubular test pieces: after removal of the fibre, and any filling compound, but before applying the reference marks, if any, for measurement of the extension.

Where the relevant cable standard calls for conditioning at elevated temperature, it shall be for the time and temperature given in that standard. Where, in case of doubt, the test has to be repeated, the conditioning shall be 24 h at 70 °C ± 2 °C, or a lower temperature corresponding to the maximum operating temperature of the cable.

2) Room temperature conditioning

Before determination of the cross-sectional area, all test pieces shall be protected from direct sunlight and maintained for at least 3 h at a temperature of 23 °C ± 5 °C.

b) Dumb-bell test pieces

Dumb-bell test pieces shall be used whenever possible. They shall be prepared from samples of buffer tube, cut open in the direction of the axis.

Each sample of buffer tube shall be cut into strips of an appropriate length. The strips shall be marked to identify the sample from which they are cut and their positions relative to each other in the original sample.

The strips of buffer tube shall be ground or cut, so as to obtain two parallel smooth surfaces between the reference marks mentioned below, care being taken to avoid undue heating. An example of a cutting machine is given in 17.3. For polyethylene (PE) and polypropylene (PP) buffer tube, cutting only, not grinding, shall be employed. After cutting or grinding, including any removal of burrs, the thickness of the strips shall not be less than 0,8 mm and not more than 2,0 mm. If it is not possible to prepare dumb-bell test pieces that comply with the minimum thickness of 0,8 mm, then tubular test pieces shall be used. If tubular test pieces cannot be prepared, then dumb-bells thinner than 0,8 mm may be used, but the rate of separation shall be 25 mm/min.

The test report should also include the fact that non-compliant dumb-bells were used and that the result is indicative.

For certain tests, a minimum thickness may be required, for instance for the ozone resistance test (IEC 60811-403) and the mineral oil immersion test (IEC 60811-404).

A dumb-bell test piece, in accordance with Figure 8, shall then be punched from each prepared strip of buffer tube, or if possible, two dumb-bell test pieces shall be punched side by side.

In order to improve the reliability of the results, the following is recommended:

– the punch should be very sharp to minimize imperfections in the test piece;

– a cardboard or other suitable support should be placed between the strip and the base plate; this support shall be marked during punching, but not completely cut through by the punch;

– burrs on the sides of the test piece should be avoided.

For materials where punching results in burrs, the following method may be used:

1) each end of the punch shall have a groove approximately 2,5 mm wide and 2,5 mm high (see Figure 10);

2) the cut dumb-bell test pieces shall remain attached at both ends with the strip previously prepared according to the requirements of 17.2.2 b) (see Figure 11);

3) with the machine given in 17.3, an additional 0,10 mm to 0,15 mm thickness can be cut away to remove possible burrs resulting from the dumb-bell punch; when this operation is completed, the dumb-bell test pieces shall be cut through at their ends in order to remove them from the strip.

When the diameter of the core is too small to allow the dumb-bell to be cut in accordance with Figure 8, then a smaller dumb bell test piece in accordance with Figure 9 shall be punched from each prepared strip.

The central 20 mm for the larger dumb-bells or 10 mm for the smaller dumb-bells shall be marked on each test piece, immediately before the tensile test.

NOTE 2 Where a contact extensometer is used, the pre set grips at the required spacing are deemed to constitute a mark.

Dumb-bell test pieces with incomplete ends are permitted, provided that the breaking point occurs between the reference marks.

c) Tubular test pieces

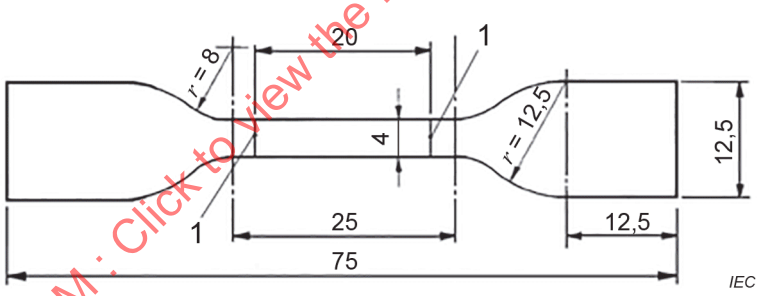
Tubular test pieces shall be used only when the dimensions of the buffer tube are such that it is not possible to prepare dumb-bell test pieces.

The samples of buffer tube shall be cut into pieces approximately 100 mm long and the fibre and any filling compound removed, care being taken not to damage the buffer tube. The tubes shall be marked to identify the sample from which they were prepared and their relative positions in the sample.

The central 20 mm shall be marked immediately before the tensile test.

NOTE 3 Where a contact extensometer is used, the pre set grips at the required spacing are deemed to constitute a mark.

Dimension in millimeters

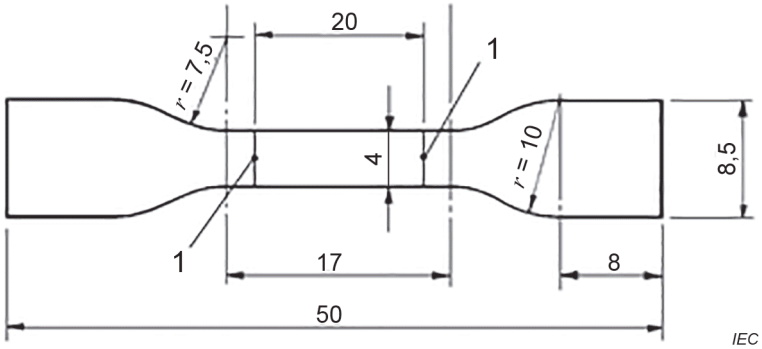


Key

1 reference marks

Figure 8 – Dumb-bell test piece

Dimensions in millimeters



Key

1 reference marks

Figure 9 – Small dumb-bell test piece

Dimensions in millimeters

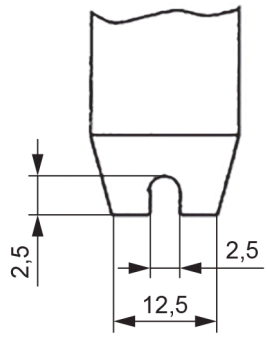


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Figure 10 – Punch end showing groove

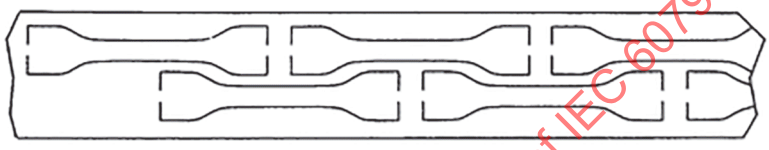

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Figure 11 – Test pieces cut by grooved punch

17.2.3 Determination of cross-sectional area

a) Dumb-bell test piece

The cross-sectional area of each test piece is the product of the common width and the measured individual minimum thickness which shall be determined as follows.

For the width:

– the common width is the minimum width of three, randomly selected test pieces;

– if there is doubt about the uniformity of the width, this shall be measured at three positions on the top and the bottom side of the three test pieces. The mean of the top and bottom side measurements shall be calculated for each position. The common width shall be the minimum of the nine mean values determined on the three test pieces;

– in the case of further doubt, the width is measured on each individual test piece.

For the thickness:

– the thickness of each test piece is the minimum of three thickness measurements carried out in the area to be stretched.

The measurements shall be carried out by an optical instrument or by a dial gauge giving a contact pressure not exceeding 0,07 N/mm^2.

The instrument shall be capable of measuring the thickness with an error of not more than 0,01 mm and the width with an error of not more than 0,04 mm.

In case of doubt, where technically possible, an optical instrument shall be used. Alternatively, a dial gauge with a maximum contact pressure of 0,02 N/mm^2 may be used.

An appropriate curved foot of the dial gauge should be used if the central part of the dumb-bell is still curved.

b) Tubular test piece

In the middle of the sample being used to prepare the test pieces, a piece shall be taken to determine the cross-sectional area, A, in square millimetres, of the test piece, using one of the following methods. In case of doubt, the methods 2) and 3) shall be used.

1) From the dimensions, using the formula:

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

where

δ is the mean value of the thickness of the buffer tube, in millimetres, rounded off to two decimal places;

D is the mean value of the outer diameter of the test piece, in millimetres, rounded off to two decimal places.

2) From the density, the mass and the length, using the formula:

$$A = \frac{1000\, m}{d \times l}$$

where

m is the mass of the test piece, in grams, to three decimal places;

d is the density, in grams per cubic centimetre, to three decimal places;

l is the length, in millimetres, to one decimal place.

3) From the volume and the length, the volume being determined by means of immersion in, for example ethyl alcohol, using the formula:

$$A = \frac{V}{l}$$

where

V is the volume, in cubic millimetres, to two decimal places;

l is the length, in millimetres, to one decimal place.

Care shall be taken to avoid air bubbles in or on the surface of the test piece during immersion.

c) Sequence of determination of cross-sectional area and ageing

For test pieces which are to be aged, the cross-sectional area shall be determined before ageing treatment.

17.2.4 Ageing treatment

Each required ageing treatment shall be carried out on a minimum of five test pieces (see 17.2.1) in accordance with IEC 60811-401, under the conditions specified in the relevant cable standard.

17.3 Apparatus

A calibrated tensile test machine shall be used.

For the tubular test pieces, in order to avoid damage on samples because of clamping and to get stable results, using the following in the clamping section is recommended:

– rigid inserts whose diameters are similar to the inner diameter of the buffer tube;

– close-to-tube diameter shape clamps.

NOTE 1 As buffer tubes have a kind of rigid behavior, their structures are susceptible to be fractured at the clamping section when using plain clamps with the result of breakage in the clamping section which will get inconsistent values from mechanical evaluations.

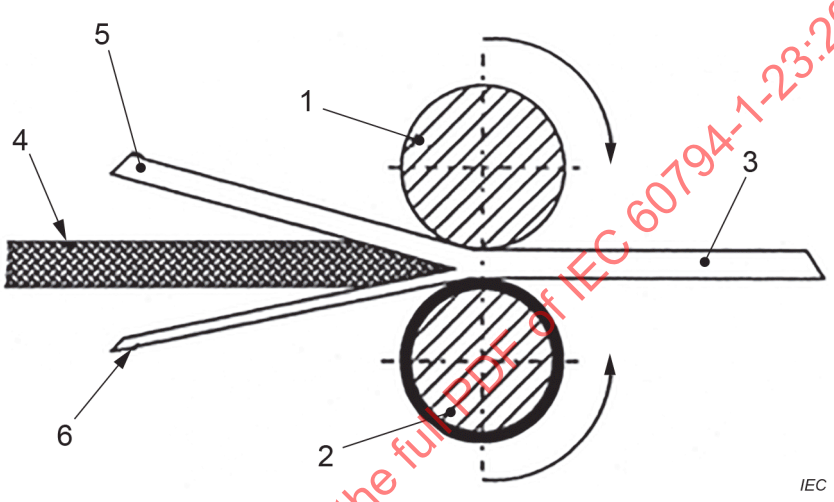
An example of a cutting machine is given in Figure 12.

Two rolls, one made of steel and partly grooved (1), and the other, in rubber-tyred steel (2), drive the strip (3) against a highly sharpened fixed, or moving blade (4) (surgical scalpel quality).

The strip is longitudinally cut into two parts: part (5) from which the test piece is cut, and part (6), which is rejected.

The thickness of part (6) can be limited to 0,1 mm if necessary. For this purpose, consideration should be given to the behaviour of the material prepared and the preservation of the blade sharpness.

When the strip (3) has marks of tearing or scratching, which may induce a premature break, it is recommended that part (6) be cut and rejected from both sides.



Key

1	steel roll, partly grooved	4	blade, fixed or moving
2	steel roll, rubber-tyred	5	part of strip used for test piece
3	strip	6	rejected part of strip

Figure 12 – Machine for preparing test pieces

17.4 Procedure

The test procedure shall be as follows:

a) Test temperature

The test shall be carried out at a temperature of 23 °C ± 5 °C.

b) Distance between the grips and rate of separation

The grips of the tensile testing machine may be either of a self-tightening type or not. The total length between the grips shall be about:

– 34 mm for dumb-bells as illustrated in Figure 9;

– 50 mm for dumb-bells as illustrated in Figure 8;

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

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

The rate of separation, except for PE and PP buffer tubes, shall be 250 mm/min ± 50 mm/min and, in case of doubt, 25 mm/min ± 5 mm/min.

For PE and PP, or buffer tubes containing these materials, the rate of separation shall be 25 mm/min ± 5 mm/min, but for routine tests, separation rates up to 250 mm/min ± 50 mm/min are permitted.

c) Measurements

The maximum tensile force during the test shall be measured and recorded and the distance between the two reference marks at breaking point shall be measured on the same test piece.

An unsatisfactory result due to any test piece breaking due to damage in the grips shall be ignored. In this event, at least four valid results shall be obtained in order to calculate the tensile strength and elongation at break; otherwise, the test shall be repeated.

17.5 Requirements

The buffer tubes shall meet the tensile strength and elongation requirements of the detail specification. Details to be specified.

The detail specification shall include the following:

a) buffer tube preconditioning, if any;

b) dimensions of the dumb-bell test piece or tubular test piece;

c) number of samples to be tested.

18 Method G11B: Elongation of buffer tubes and micro tubes at low temperature

18.1 Object

These tests are to determine the elongation of the buffer tubes and micro tubes at low temperature.

NOTE1 This method is included in IEC 60811-505.

NOTE 2 In 18.2 to 18.6, descriptions for buffer tube also include micro tube.

18.2 Sample

18.2.1 General

Each buffer tube to be tested shall be represented by two samples of suitable length.

18.2.2 Preparation of test pieces

After all covering has been removed, the buffer tube shall be cut open in the direction of the axis, after which the fibre and any filling compound, if any, shall be removed.

The test is intended for buffer tubes circular cross-section having an external diameter greater than 12,5 mm and for sector-shaped cores large enough to prepare dumb-bells described in 17.2.2. Where it is not possible to prepare dumb-bells, the tubular test pieces described in 17.2.2 are suitable for testing the performance of cores of smaller diameter.

The buffer tube need not be ground or cut if the inner and outer surfaces are smooth, and its mean specified thickness does not exceed 2,0 mm. Samples having a thickness exceeding this limit, or samples having imprints or ridges on the inner side, shall be ground or cut to obtain two parallel and smooth surfaces, and a thickness which does not exceed 2,0 mm. The minimum thickness after grinding or cutting shall be 0,8 mm but if the original thickness of the buffer tube does not allow it, then 0,6 mm shall be permitted as the minimum thickness. Grinding and cutting shall be carefully carried out to avoid undue heating and mechanical stresses in the buffer tube.

All strips shall be conditioned at 23 °C ± 5 °C for at least 3 h.

After this preparation, two dumb-bells from each sample in accordance with Figure 8, or if necessary Figure 9, shall be punched in the direction of the axis of each sample; if possible, two dumb-bells shall be punched side by side.

If an apparatus is used which allows the direct measurement of the distance between the marker lines during the test, the dumb-bells shall be marked in accordance with 17.2.2.

18.3 Apparatus

The test may be carried out on a machine provided with a cooling device or on a machine installed in a cooling chamber.

Using a liquid as the refrigerant, the conditioning time shall be not less than 10 min at the specified test temperature.

When cooling in air, the conditioning time for cooling the apparatus and test piece together shall be at least 4 h. If the apparatus has been pre-cooled, this period may be reduced to 2 h, and if the apparatus and test piece have been pre-cooled, the conditioning time after the test piece has been fixed in the apparatus shall be not less than 1 h.

If a liquid mixture is used for cooling, it shall not impair the buffer tube.

18.4 Procedure

The grips of the tensile apparatus shall be of a non-self-tightening type. In both pre-cooled grips, the dumb-bell shall be clamped over the same length.

The free length between the grips shall be about 30 mm for both types of dumb-bells if the direct measurement of the distance between the marker lines is to be made during the test.

If the displacement of the grips is to be measured, the free length between the grips shall be 30 mm ± 0,5 mm for the dumb-bell in accordance with Figure 8, and 22 mm ± 0,5 mm for the dumb-bell in accordance with Figure 9.

The speed of separation of the grips of the tensile machine shall be 25 mm/min ± 5 mm/min.

The test temperature shall be as specified in the relevant cable standard.

The elongation shall be determined by measuring the distance between the marker lines, if possible, or between the grips at the moment of the rupture.

For calculating the elongation, the increase of the distance between the marker lines shall be related to the initial distance of 20 mm (or 10 mm if the dumb-bell in accordance with Figure 9 is used), and expressed as a percentage of this distance.

If the alternative method of measuring the distance between the grips is used, the increase of this distance shall be related to the original distance, being 30 mm for the dumb-bell in accordance with Figure 8, and 22 mm for the dumb-bell in accordance with Figure 9. When this method is used, the test piece shall be examined before being removed from the apparatus; if the test piece has partly slipped out of the grips, the result shall be ignored. At least three valid results are required for calculating the elongation, otherwise the test shall be repeated.

Unless otherwise specified, none of the valid results shall be less than 50 %. In case of dispute, the method employing marker lines shall be used.

18.5 Requirements

The buffer tube shall meet the elongation requirements of the detail specification.

18.6 Details to be specified

The detail specification shall include the following:

a) buffer tube preconditioning, if any;
b) test temperature;
c) dimensions of the dumb-bell test piece or tubular test piece;
d) number of samples to be tested.

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IEC 60793-1-53:2014, *Optical fibres – Part 1-53: Measurement methods and test procedures – Water immersion tests*

IEC 60794-1-21:2015, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods*

IEC 60794-1-22:2017, *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental tests methods*

IEC 60811-403, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked compounds*

IEC 60811-404, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 404: Miscellaneous tests - Mineral oil immersion tests for sheaths*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

IEC 60794-1-23

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INTERNATIONAL STANDARD

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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OPTICAL FIBRE CABLES

Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60794-1-23 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

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

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

a) addition of a new test method G9: Bleeding and evaporation (formerly known as method E15 in IEC 60794-1-21:2015);
b) addition of a new test method G10A: Stripping force stability of cabled optical fibres (formerly known as method E5A in IEC 60794-1-21:2015);
c) addition of a new test method G10B: Strippability of optical fibre ribbons (formerly known as method E5B in IEC 60794-1-21:2015);
d) addition of a new test method G10C: Strippability of buffered optical fibres (formerly known as method E5C in IEC 60794-1-21:2015);

e) addition of a new test method G11A: Tensile strength and elongation of buffer tubes (included in IEC 60811-501);

f) addition of a new test method G11B: Elongation of buffer tubes at low temperature (included in IEC 60811-505);

g) clarification of the sample preparation procedure in method G5: Ribbon tear (separability);

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

CDV	Report on voting
86A/1912/CDV	86A/1945/RVC

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

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

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

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

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

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

OPTICAL FIBRE CABLES

Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods

1 Scope

This part of IEC 60794 describes test procedures to be used in establishing uniform requirements for the geometrical, material, mechanical, environmental properties of optical fibre cable elements.

This document 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.

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

NOTE The environmental testing of optical fibre ribbon would be valuable for some applications. Useful information about suitable test methods can be found in the optical fibre standards IEC 60793-1-50, IEC 60793-1-51, IEC 60793-1-52, and IEC 60793-1-53.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60794-1-31:2018, *Optical fibre cables – Part 1-31: Generic specification – Optical cable elements – Optical fibre ribbon*

IEC 60793-1-32:2018, *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*

IEC 60793-1-40, *Optical fibres – Part 1-40: Attenuation measurement methods*

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

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

4 General requirements

IEC 60794-1-2 is the reference guide to test methods of all types. It shall be considered for general requirements and definitions.

5 Method G1: Bend test for optical cable elements

5.1 Object

The purpose of this test is to characterize cable elements for splicing purposes by determining the attenuation increase of an optical cable element (fibre, ribbon, core tube, breakout unit, etc.) when bent within a splice closure or similar device.

5.2 Sample

The length of the sample of optical cable element shall be sufficient to carry out the testing specified.

5.3 Apparatus

The apparatus consists of

a) a mandrel having a smooth surface with diameter as stated in the detail specification, and

b) an attenuation measuring apparatus for the determination of attenuation change (according to the test methods of IEC 60793-1-40 and IEC 60793-1-46).

5.4 Procedure

The element to be tested shall be wound on the mandrel at minimal tension; the number of turns shall be stated in the detail specification.

In order to measure the attenuation increase caused by bending, allowance should be made for the intrinsic attenuation of the fibre.

5.5 Requirements

Any increase in attenuation shall comply with the limits shown in the detail specification.

5.6 Details to be specified

The detail specification shall include the following:

a) optical test wavelength;

b) diameter of the mandrel;

c) number of turns;

d) apparatus and attenuation measuring technique;

e) temperature at which the evaluation shall be performed if different from room temperature.

6 Method G2: Ribbon dimensions and geometry – Visual method

6.1 Object

The purpose of this test is to determine the geometry of an optical fibre ribbon as defined by the parameters of width, height and fibre alignment, for the purpose of type testing to assume proper manufacturing process control. This test is not necessarily suitable for final product inspection and, unless otherwise specified, shall not be used for that purpose.

6.2 Sample

The number of samples to be tested shall be specified in the detail specification. The selected samples shall be statistically independent and representative of the ribbon population tested.

6.3 Apparatus

The apparatus consists of a microscope or profile projector with appropriate magnification.

6.4 Procedure

6.4.1 General

Either of the two procedure methods described in 6.4.2 and 6.4.3 may be used.

For the specified number of samples, all dimensions shall be measured as average as well as maximum and minimum values.

Care should be taken that the preparation of the sample does not change the structure of the fibre ribbon and represents an undisturbed image of the fibre cladding and ribbon cross-section.

6.4.2 Method 1

The sample is prepared by cutting it perpendicular to the axis of the ribbon and placing it in a curable resin or in a tool which holds the ribbon. If necessary, the sample shall be ground and polished to prepare a smooth perpendicular end face. The prepared sample is secured with its end face perpendicular to the optical path and measured by means of a microscope or profile projector.

6.4.3 Method 2

Place the ribbon in a ribbon fibre holder and remove 20 mm to 25 mm of the fibre coating and matrix material with the ribbon hot sheath stripping tool and wipe the stripped portion of the fibres clean with an alcohol-moistened pad. Adjust the position of the ribbon in the ribbon fibre holder and cleave the fibres at a distance of 250 μm to 500 μm from the stripped edge of the ribbon. Cut and polish the other end of the ribbon, and illuminate it with a collimated light source. Align and measure the cleaved end of the ribbon under microscope.

6.5 Requirements

Unless otherwise specified in the detail specification, the width, height and fibre alignment shall be in accordance with IEC 60794-1-31:2018.

6.6 Details to be specified

The detail specification shall include the following:

a) permissible maximum and minimum values;

b) limits for average values;

c) number of samples tested.

6.7 Definitions of ribbon dimensions and geometry

6.7.1 General

The following definitions apply to a fibre ribbon cross-section as shown in Figure 1. The figure illustrates an example for a 4-fibre ribbon, where a is the diameter of a coloured fibre.

NOTE In consideration of the precision of fibre geometric attributes and the relatively larger precision of ribbon geometry requirements, it is acceptable for glass core/glass cladding fibres to use the edge of the cladding for the measurements of 6.7.3 and 6.7.4 in lieu of the fibre centres. In this case, the measurements can be made on the same side of all fibres (e.g. top or bottom, left or right side).

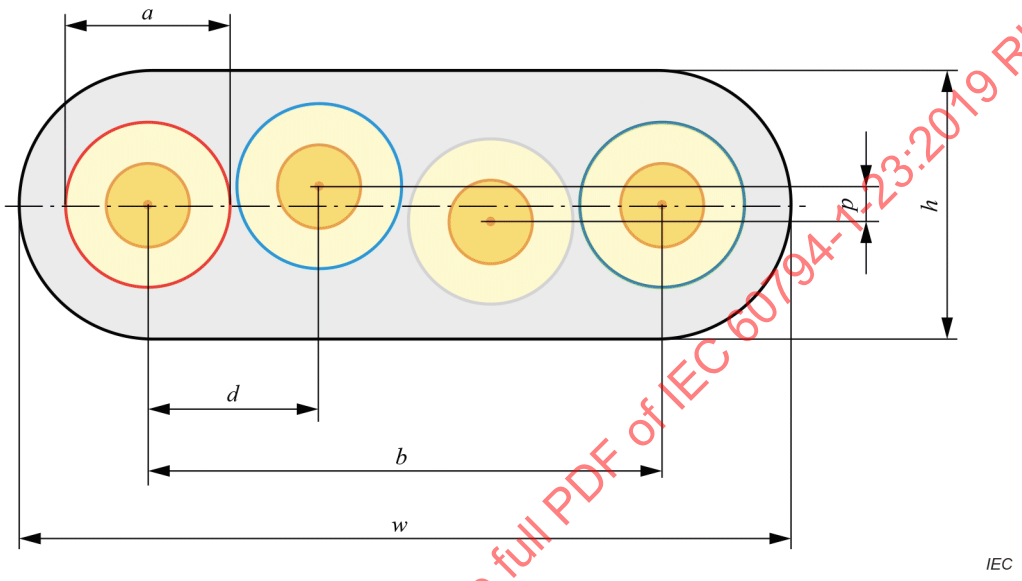


Figure 1 – Cross-sectional drawing illustrating fibre ribbon geometry

6.7.2 Width and height

The width w and height h of the ribbon are the dimensions of the minimum rectangular area enclosing the ribbon cross-section.

6.7.3 Basis line

The basis line is that line in the cross-section of an optical fibre ribbon crossing the fibre centres of the first fibre (fibre 1) and the last fibre (fibre n) of the fibre ribbon, as shown in Figure 1 as dotted line. This line is used as the reference plane for the fibre alignment measurements.

6.7.4 Fibre alignment

6.7.4.1 Horizontal fibre separation

The horizontal separation of fibres is the distance of the orthogonal projection of two fibre centres on the basis line in the fibre ribbon cross-section.

Two horizontal separation parameters can be distinguished:

a) centre-centre distance d between adjacent fibres;

b) centre-centre distance b between the extreme fibres.

6.7.4.2 Planarity

The planarity p of the fibre ribbon structure is the sum of the maximum positive and absolute value of the maximum negative vertical separation of the fibres.

The vertical separation of the fibres is the orthogonal distance from the fibre centre to the basis line. The vertical separation is positive for fibres "above" the basis line and negative for fibres "below" the basis line.

7 Method G3: Ribbon dimensions – Aperture gauge

7.1 Object

The purpose of this test is to verify the functional performance of a ribbon. In order to ensure functional performance, the dimensions of edge bonded ribbons may be controlled and verified for final inspection purposes with an aperture gauge. The intent is to verify that the end portion of a ribbon can be inserted into and would be reasonably aligned to the guide slots of commercial stripping tools.

7.2 Sample

Unless otherwise specified in the detail specification, five representative ribbon samples, each with a minimum length of 50 mm, shall be taken from the ribbon to be tested.

7.3 Apparatus

An aperture gauge, as shown in Figure 2 shall be used to assess the overall dimensions of a ribbon. The values for ribbon width (w) and ribbon height (h) of Figure 2 shall be the nominal ribbon dimensions as established using method G2 in an appropriate quality assessment scheme.

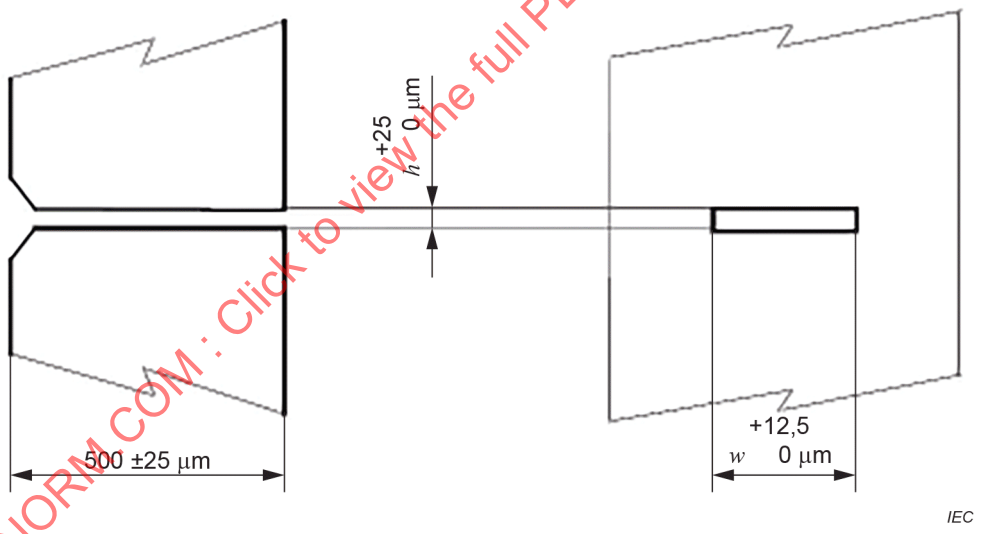


Figure 2 – Aperture gauge

7.4 Procedure

The ribbon sample to be tested is held in the middle, and a 10 mm end portion is inserted through the aperture gauge.

7.5 Requirement

It shall be possible for the 10 mm ribbon end portion to be freely inserted through the aperture gauge without mechanical damage to the sample.

7.6 Details to be specified

The detail specification shall include the following:

a) dimensions of the aperture gauge;

b) number of samples to be tested.

8 Method G4: Ribbon dimensions – Dial gauge (obsoleted method)

9 Method G5: Ribbon tear (separability)

9.1 Object

The purpose of this test is to assure sufficient tear resistance for ribbons where the fibres are not required to be separable, or to assure sufficient separability of the fibres for ribbons where the fibres are required to be separated. The intention of this test is to be able to tear by hand without damage.

9.2 Sample

A number of samples of fibre ribbon, as specified in the detail specification, typically 3 to 5, shall be selected from the ribbon or ribbons to be tested. The length of each sample shall be sufficient to provide the number of test specimens as detailed below.

For an n fibre ribbon, n/2 specimens are taken from each of the samples above. Each specimen shall be 100 mm minimum length, consistent with Figure 3.

Prepare the n/2 specimens involving increasing numbers of fibres to be separated as a ribbon unit. That is, a specimen for fibre 1; a specimen for fibres 1 to 2; a specimen for fibres 1 to 3; etc.

The fibres to be tested are separated with a knife or other suitable method on a suitable length for clamping, per Figure 3.

For the first sample, the preparation of the test sequence shall be to separate one fibre from the other fibres in the ribbon in the first specimen. Then, separate a unit of two fibres from the next specimen. Then, units of three, four, etc. fibres are separated in the other specimens, up to a unit of n/2 fibres in the last specimen.

Do the same preparation for all the other samples.

NOTE If n is an odd number, replace n/2 with (n-1)/2 in the above description.

Dimensions in millimetres

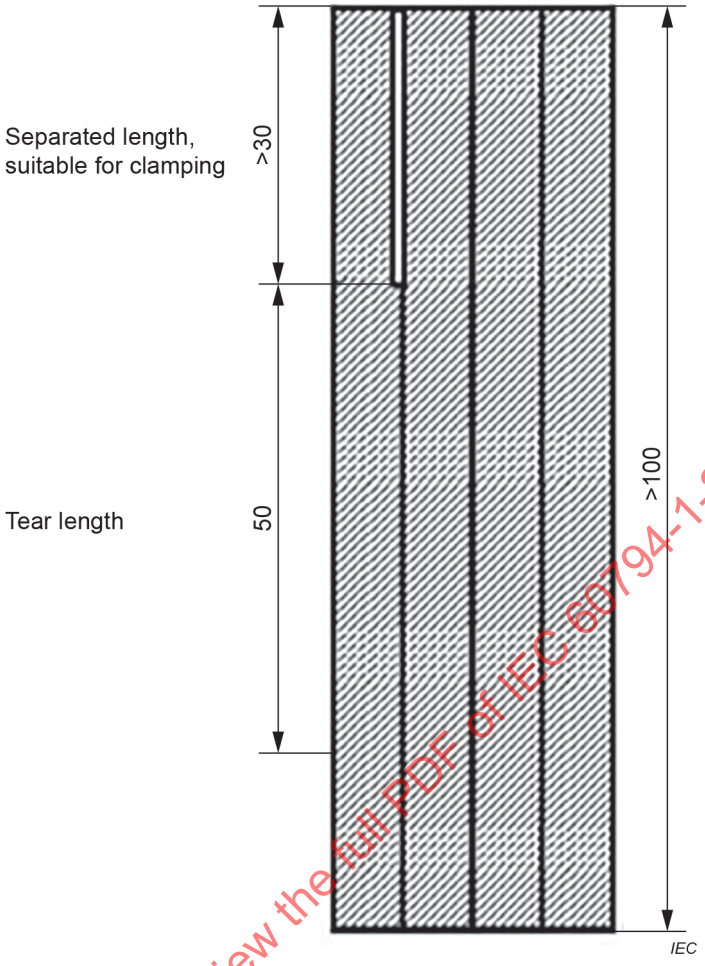


Figure 3 – Sample preparation for ribbon separability test

9.3 Apparatus

The apparatus consists of

a) a tensile strength measuring apparatus with suitable clamping devices and suitable force recording functions, and

b) a microscope with at least 100 × magnification.

9.4 Procedure

The specimen is inserted into the strength measuring apparatus, as shown in Figure 4. The fibres to be tested are torn at a speed of approximately 100 mm/min to 500 mm/min. The force to tear the fibres on a minimum length of 50 mm is continuously recorded.

In the case where fibres are required to be separated, the primary coating of the separated fibre(s) shall be visually inspected by means of a microscope.

The procedure is repeated for the specimens involving separation of fibre 1, fibres 1 to 2, fibres 1 to 3, etc. up through fibres 1 to $n/2$.

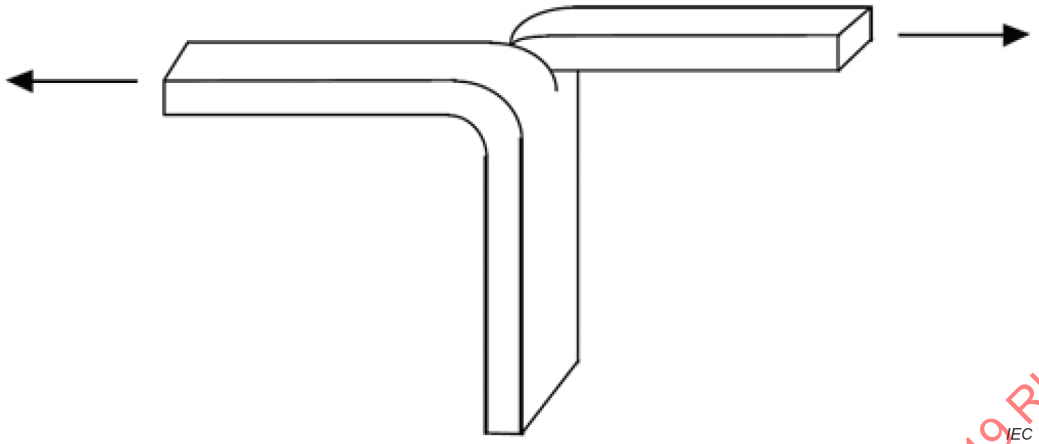


Figure 4 – Separability procedure

9.5 Requirements

The primary requirement is to be able to make the tear without fibre damage (coating damage or fibre breakage). For ribbons where the fibres are required to be separated, the coloured primary coating of the separated fibre(s) shall be effectively free from ribbon matrix residues.

Any colour coding of fibres shall remain sufficiently intact within any 25 mm segment to enable individual fibres to be distinguished from each other.

The minimum or maximum and mean tear forces shall be as specified in the detail specification.

9.6 Details to be specified

The detail specification shall include the following:

a) minimum and mean tear force, in N, when fibres are not required to be separated;

b) maximum and mean tear force, in N, as required by the detail specification, when fibres are required to be separated;

c) number of samples;

d) type of ribbon (separable or non-separable).

10 Method G6: Ribbon torsion

10.1 Object

The purpose of this test is to verify the mechanical and functional integrity of the fibre ribbon structure. The test determines the capability of the ribbon to withstand torsion without delamination.

10.2 Sample

Unless otherwise specified in the detail specification, five representative samples, each with a minimum length of 120 mm, are obtained from the ribbon to be tested.

10.3 Apparatus

The testing apparatus, an example of which is in Figure 5, consists of two vertically positioned clamps to hold the sample while it is twisted under a minimum tension of 1 N. The minimum length to be tested is 100 mm.

Dimensions in millimetres

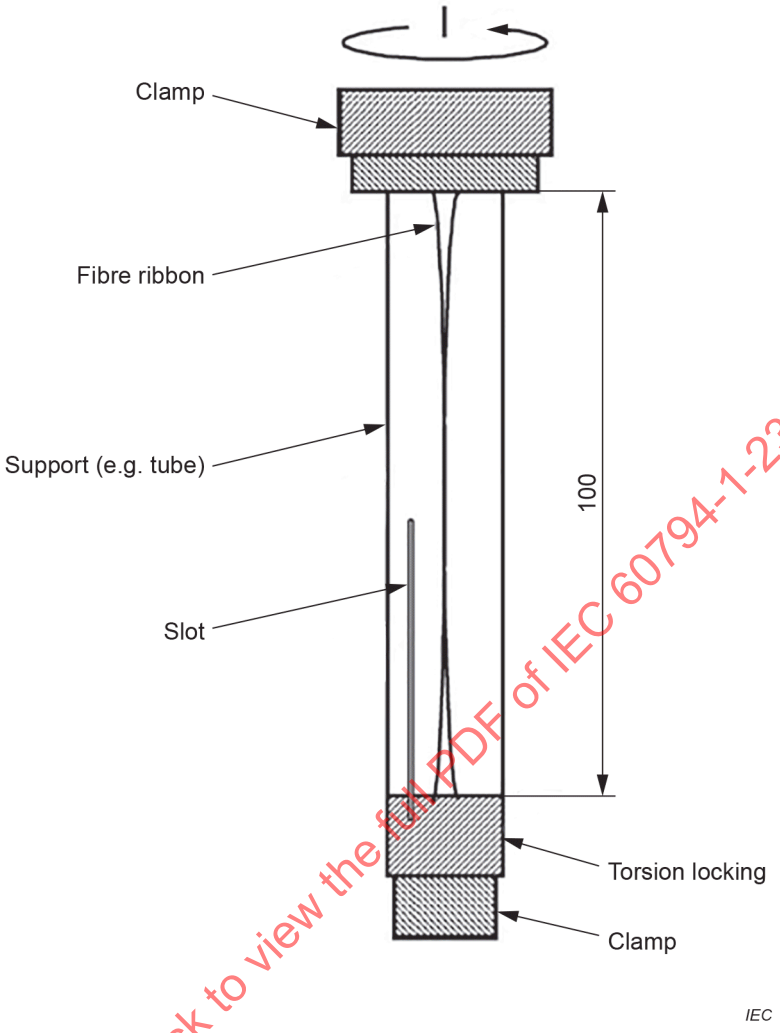


Figure 5 – Torsion test

10.4 Procedure

The sample is securely fixed in the apparatus and twisted in increments of 180° ± 5° within a time of 2 s. The minimum dwell time after each twist increment is 5 s. The incremental twisting is continued to the value(s) agreed upon between the customer and supplier, as defined in the detail specification, or until delamination occurs.

10.5 Requirements

The ribbon shall withstand the number of 180° turns stated in the detail specification until delamination occurs.

10.6 Details to be specified

The detail specification shall include the following:

a) number of samples;

b) number of turns.

11 Method G7: Tube kinking

11.1 Object

The purpose of this test is to determine the ability of tubes containing optical fibres to withstand mechanical stresses encountered during cable installation and splicing. The test is carried out on tubes taken from an optical cable.

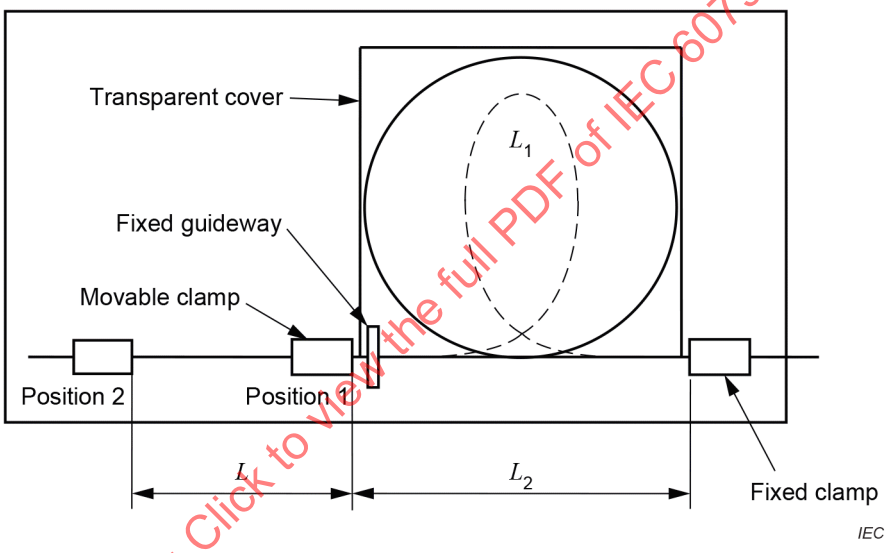
11.2 Sample

Tube containing fibres, with a length of at least L_1 + 50 mm, shall be taken from an optical fibre cable.

Five (5) samples shall be tested, unless otherwise specified.

11.3 Apparatus

The apparatus consists of a testing device as shown in Figure 6.



Key

L_1 length of tube under test

L_2 distance between the tube clamping point of the movable clamp and the tube clamping point of the fixed clamp at the start of the test

L moving distance (the length of which determines the reduction of the ellipse dimension)

The minimum diameter of the loop is not fixed by a curvature in the test equipment, but only controlled by the fixed length L_1 of the specimen and the moving length L.

The fixed guideway ensures a defined position of the sample. A transparent cover allows the sample to be kept in the same plane and observed whilst being tested. The distance between the two covers shall be typically three times the tube diameter. Too great a distance will allow the tube to move sideways during the test and does not ensure that the test is severe enough.

Figure 6 – Tube kinking test

Examples of test apparatus dimensions for tube kinking are shown in Table 1.

Table 1 – Examples of test apparatus dimensions for tube kinking

Nominal tube diameter mm	L_1 mm	L_2 mm
≤ 3,1	350	100
≤ 6,1	650	200
≤ 10,1	1 050	300

11.4 Procedure

The test shall be carried out at standard atmospheric conditions.

The sample shall be marked with a length L_1 and mounted in the test device as shown in Figure 6, with the movable and fixed clamps separated by a distance L_2.

The moveable clamp shall be moved between positions 1 and 2 over a distance L and returned to position 1 at a speed approximately 10 mm/s. This movement is one cycle. During the last cycle, the sample shall remain in position 2 for 60 s.

The values of test parameters L, L_1, L_2 and the number of cycles (five, unless stated otherwise) should simulate the service deployment conditions. They shall be agreed between customer and supplier.

NOTE 1 Whilst the loop tends to form an ellipse rather than a perfect circle during the test, it is possible to simplify the understanding of the test parameters considerably by assuming that a circle is formed. Based on this assumption, then

$$L = L_1 - (L_2 + \pi \times D) \quad (1)$$

where

D is the tube loop diameter (mm).

NOTE 2 As a mechanical test, a typical minimum value for the tube loop diameter is 60 mm, since this aligns with the minimum specified bend diameter for most classes of fibre and also represents a minimum practical value of coiled tube loops within a joint or other connectivity plant.

NOTE 3 Using D = 60 mm, then L can be calculated (for tubes ≤ 3,1 mm) from Formula (1), which also yields the value of 60 mm. Since the loop does form an ellipse, which makes the effective loop diameter in one plane much more severe, it is possible that 60 mm is taken as the maximum length specified for the moving length, L. Lower values can be specified.

NOTE 4 If this test is used to simulate installation of a tube within a joint, then the value for D can be replaced by the available width within a joint.

11.5 Requirements

During the test, no kinking of the sample shall be visible.

11.6 Details to be specified

The detail specification shall include the following:

a) number of cycles (five, unless otherwise specified);

b) lengths L, L_1, L_2 (use L = 60 mm, L_1 and L_2 according to Table 1, unless otherwise specified);

c) test temperature.

12 Method G8: Ribbon residual twist test

12.1 Object

The ribbon residual twist test, or flatness test, evaluates the degree of permanent twist in a cabled optical fibre ribbon.

12.2 Sample

Ribbon samples shall be taken from a preconditioned (aged) test cable.

The samples shall be of a length sufficient to include the gauge length of 50 cm and additional length on each end to facilitate attachment of clamps and the test weight.

12.3 Apparatus

The apparatus shall be constructed to have the following characteristics.

– The ribbon shall hang vertically, clamped at the top, with the bottom end free to rotate and translate as necessary.

– A mass shall be attached to the bottom end of the ribbon sample, with the gauge length situated between the top clamp and the bottom mass.

– The bottom mass shall be arranged so that it does not impart any twisting or side loading of the ribbon.

– The gauge length shall be 50 cm ± 5 cm, unless otherwise specified.

– The mass shall be 100 g ± 5 g, unless otherwise specified.

– A method shall be provided to measure the axial rotation of the lower end of the ribbon gauge length with respect to the upper end.

12.4 Procedure

Perform the following steps, unless otherwise specified.

1) Precondition the ribbon at 85 °C ± 2 °C, uncontrolled relative humidity, for 30 days in its cable.
2) Mount one end of the ribbon in the top clamp.
3) Attach the bottom mass.
4) Allow the ribbon to rotate. When the rotation settles out and the ribbon becomes still, measure the angular rotation of the bottom end of the gauge length with respect to the upper end of the gauge length.
5) Calculate the residual twist of the sample according to Formula (2):

$$T = \frac{\theta}{L} \tag{2}$$

where

T is residual twist, °/cm;

θ is final angle from top to bottom, °;

L is measured gauge length, cm.

12.5 Requirements

The calculated residual twist of optical fibre ribbon shall not exceed the maximum residual twist requirements of the detail specification. In most cases, a maximum residual twist of 8°/cm is adequate.

12.6 Details to be specified

The detail specification shall include the following:

a) the preconditioning conditions, if different from those stated above;
b) the ribbon gauge length, if different from that stated above;
c) the tension mass, if different from that stated above.

13 Method G9: Bleeding and evaporation

13.1 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.

NOTE This method is known as method E15 in IEC 60794-1-21:2015.

13.2 Sample

Filling compound material intended to be used in contact with optical fibres shall be prepared with sufficient amount to perform the test.

13.3 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, and
c) the test set-up (see Figure 7), consisting of the following:
   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;

      NOTE 1 Alternatively, the cone can consist of stainless steel (60 mesh, opening 0,25 mm) and the solder width can be more than 1 mm, provided it is proved that the results are not significantly different from the first one.

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

      NOTE 2 The cover is not needed when measuring the evaporation.

   3) a desiccator.

Dimensions in millimetres

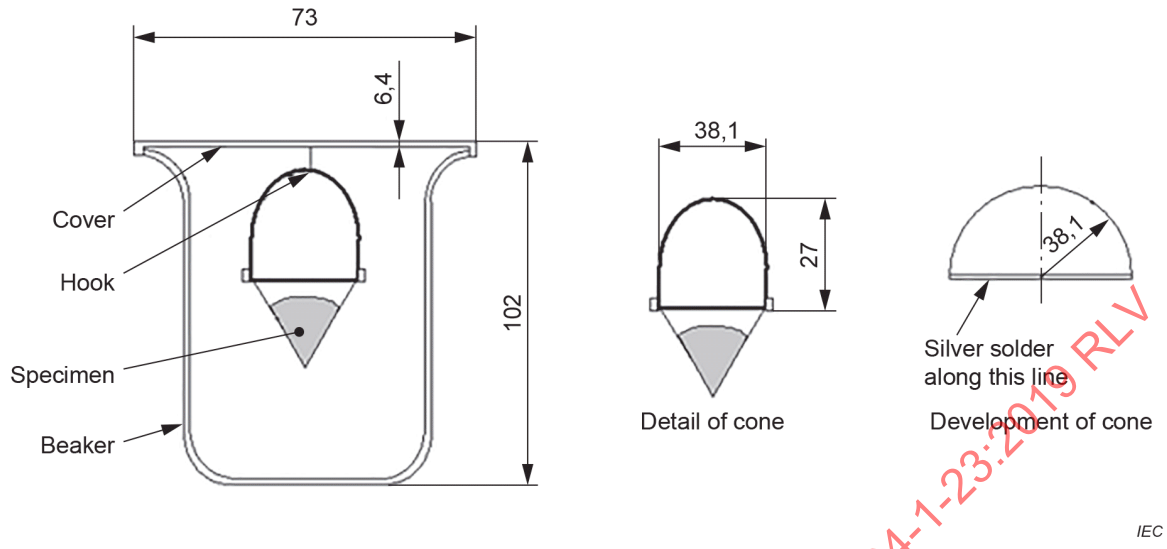


Figure 7 – Bleeding and evaporation test set-up

13.4 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 according to Formulae (3) and (4) and report the average of the duplicate results.

Calculations:

$$B = \frac{M_5 - M_1}{M_3 - M_2} \times 100 \quad (3)$$

$$E = \frac{M_3 - M_4}{M_3 - M_2} \times 100 \quad (4)$$

where

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

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

13.5 Requirements

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

13.6 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 13.3, c), 1);
d) number of samples to be tested.

14 Method G10A: Stripping force stability of cabled optical fibres

14.1 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.

NOTE This method is known as method E5A in IEC 60794-1-21:2015.

14.2 Sample

14.2.1 Sample length

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

14.2.2 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).

14.3 Apparatus

The apparatus consists of conditioning equipment (if necessary) and a fibre strippability apparatus (according to the strippability test method of IEC 60793-1-32:2018).

14.4 Procedure

The optical fibre strippability shall be measured on the environmentally conditioned samples using the strippability method of IEC 60793-1-32:2018, 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 60794-1-22:2017.

14.5 Requirements

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

14.6 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.

15 Method G10B: Strippability of optical fibre ribbons

15.1 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.

NOTE This method is known as method E5B in IEC 60794-1-21:2015.

15.2 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.

15.3 Apparatus

15.3.1 General

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

15.3.2 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 manufacturer's 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.

15.3.3 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.

15.4 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.

15.5 Alcohol wipe

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

15.6 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 2.

Table 2 – Condition of stripped samples

Rating	Condition of stripped sample
1	Coating and matrix materials leave no residue after one or two alcohol wipes
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.

15.7 Requirements

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

No fibres shall break.

15.8 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.

16 Method G10C: Strippability of buffered optical fibres

16.1 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, where the buffer is designed to be removable while leaving the fibre coating intact.

NOTE This method is known as method E5C in IEC 60794-1-21:2015.

16.2 Sample

Samples of buffered fibre to be tested shall comply with the requirements of method G10A.

16.3 Apparatus

The apparatus shall comply with the requirements of method G10A.

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.

16.4 Procedure

Follow the procedure of method G10A.

If comparison of unaged and aged samples is specified, perform the procedure as follows, following the intent of method G10A.

– Set aside unaged control samples for later test.
– Age the buffered fibre in the cable or in a representative environment in the lab (in filling compound, or the like, as appropriate) as specified in the detail specification. Ageing according to method F9 of IEC 60794-1-22:2017 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 G10A.

16.5 Requirements

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

16.6 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.

17 Method G11A: Tensile strength and elongation of buffer tubes and micro tubes at break

17.1 Object

These tests are to determine the tensile strength and elongation at break of the buffer tubes of the cable and micro tubes in the condition as manufactured (i.e. without any ageing treatment) and, when required, after one or more accelerated ageing treatment(s), which are prescribed in the relevant cable standard.

When the ageing treatment is to be carried out on prepared test pieces (in accordance with IEC 60811-401), the test pieces for the ageing treatment shall be from positions adjacent to the test pieces used for the test without ageing and the tensile tests on the aged and unaged test pieces shall be made in immediate succession.

NOTE 1 This method is included in IEC 60811-501.

Where further increased test reliability is necessary, it is recommended that the tests on aged and unaged test pieces are performed by the same person using the same testing method and the same apparatus, in the same laboratory.

NOTE 2 In 17.2 to 17.5, descriptions for buffer tube also include micro tube.

17.2 Sample

17.2.1 General

One sample of each buffer tube to be tested shall be taken of sufficient size to provide a minimum of five test pieces each for the tensile tests without ageing and the tensile tests after each of the required ageing treatments, bearing in mind that a 100 mm length is needed for the preparation of each test piece.

Any sample that shows signs of mechanical damage shall not be used for the test.

17.2.2 Preparation and conditioning of test pieces

a) Conditioning of test pieces

1) Elevated temperature conditioning

NOTE 1 Elevated temperature conditioning is not an ageing treatment. It is used as a means of ensuring stable and consistent test pieces when required. It is used a) when called for in the relevant cable standard, or b) if there is a doubt or disagreement about a result and the test needs to be repeated. In either case, the conditioning applies only to the test piece as taken from the cable before any subsequent treatment (ageing, compatibility test, oil immersion, etc.).

Where conditioning at elevated temperature is used, such conditioning shall be carried out as follows:

– for dumb-bells:

i) after the removal of the buffer tube from the cable but before the cutting of strips;

ii) after grinding (or cutting) to obtain parallel surfaces.

Where grinding (or cutting) is not needed, the conditioning shall be performed at the point in the test protocol according to i);

– for tubular test pieces: after removal of the fibre, and any filling compound, but before applying the reference marks, if any, for measurement of the extension.

Where the relevant cable standard calls for conditioning at elevated temperature, it shall be for the time and temperature given in that standard. Where, in case of doubt, the test has to be repeated, the conditioning shall be 24 h at 70 °C ± 2 °C, or a lower temperature corresponding to the maximum operating temperature of the cable.

2) Room temperature conditioning

Before determination of the cross-sectional area, all test pieces shall be protected from direct sunlight and maintained for at least 3 h at a temperature of 23 °C ± 5 °C.

b) Dumb-bell test pieces

Dumb-bell test pieces shall be used whenever possible. They shall be prepared from samples of buffer tube, cut open in the direction of the axis.

Each sample of buffer tube shall be cut into strips of an appropriate length. The strips shall be marked to identify the sample from which they are cut and their positions relative to each other in the original sample.

The strips of buffer tube shall be ground or cut, so as to obtain two parallel smooth surfaces between the reference marks mentioned below, care being taken to avoid undue heating. An example of a cutting machine is given in 17.3. For polyethylene (PE) and polypropylene (PP) buffer tube, cutting only, not grinding, shall be employed. After cutting or grinding, including any removal of burrs, the thickness of the strips shall not be less than 0,8 mm and not more than 2,0 mm. If it is not possible to prepare dumb-bell test pieces that comply with the minimum thickness of 0,8 mm, then tubular test pieces shall be used. If tubular test pieces cannot be prepared, then dumb-bells thinner than 0,8 mm may be used, but the rate of separation shall be 25 mm/min.

The test report should also include the fact that non-compliant dumb-bells were used and that the result is indicative.

For certain tests, a minimum thickness may be required, for instance for the ozone resistance test (IEC 60811-403) and the mineral oil immersion test (IEC 60811-404).

A dumb-bell test piece, in accordance with Figure 8, shall then be punched from each prepared strip of buffer tube, or if possible, two dumb-bell test pieces shall be punched side by side.

In order to improve the reliability of the results, the following is recommended:

– the punch should be very sharp to minimize imperfections in the test piece;

– a cardboard or other suitable support should be placed between the strip and the base plate; this support shall be marked during punching, but not completely cut through by the punch;

– burrs on the sides of the test piece should be avoided.

For materials where punching results in burrs, the following method may be used:

1) each end of the punch shall have a groove approximately 2,5 mm wide and 2,5 mm high (see Figure 10);

2) the cut dumb-bell test pieces shall remain attached at both ends with the strip previously prepared according to the requirements of 17.2.2 b) (see Figure 11);

3) with the machine given in 17.3, an additional 0,10 mm to 0,15 mm thickness can be cut away to remove possible burrs resulting from the dumb-bell punch; when this operation is completed, the dumb-bell test pieces shall be cut through at their ends in order to remove them from the strip.

When the diameter of the core is too small to allow the dumb-bell to be cut in accordance with Figure 8, then a smaller dumb bell test piece in accordance with Figure 9 shall be punched from each prepared strip.

The central 20 mm for the larger dumb-bells or 10 mm for the smaller dumb-bells shall be marked on each test piece, immediately before the tensile test.

NOTE 2 Where a contact extensometer is used, the pre set grips at the required spacing are deemed to constitute a mark.

Dumb-bell test pieces with incomplete ends are permitted, provided that the breaking point occurs between the reference marks.

c) Tubular test pieces

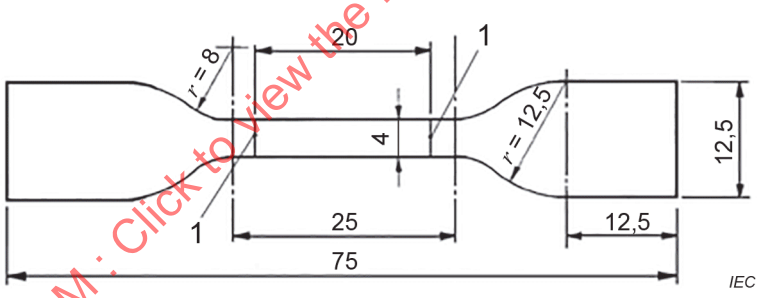
Tubular test pieces shall be used only when the dimensions of the buffer tube are such that it is not possible to prepare dumb-bell test pieces.

The samples of buffer tube shall be cut into pieces approximately 100 mm long and the fibre and any filling compound removed, care being taken not to damage the buffer tube. The tubes shall be marked to identify the sample from which they were prepared and their relative positions in the sample.

The central 20 mm shall be marked immediately before the tensile test.

NOTE 3 Where a contact extensometer is used, the pre set grips at the required spacing are deemed to constitute a mark.

Dimension in millimeters

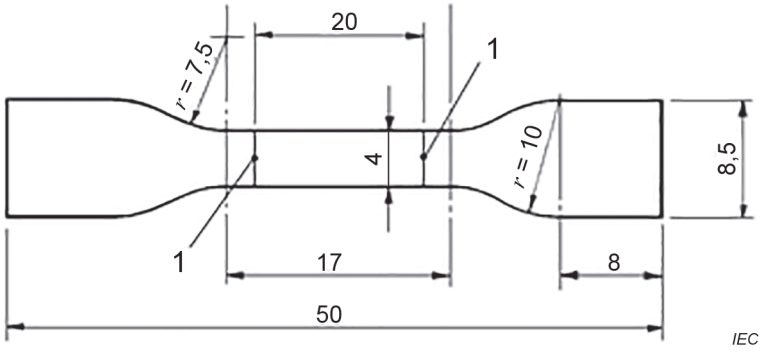


Key

1 reference marks

Figure 8 – Dumb-bell test piece

Dimensions in millimeters



Key

1 reference marks

Figure 9 – Small dumb-bell test piece

Dimensions in millimeters

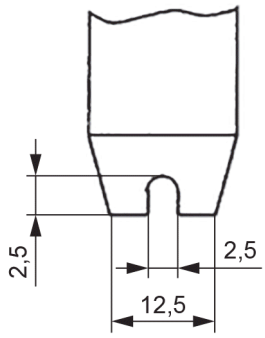


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Figure 10 – Punch end showing groove

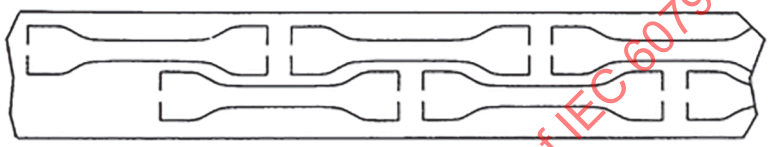

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Figure 11 – Test pieces cut by grooved punch

17.2.3 Determination of cross-sectional area

a) Dumb-bell test piece

The cross-sectional area of each test piece is the product of the common width and the measured individual minimum thickness which shall be determined as follows.

For the width:

– the common width is the minimum width of three, randomly selected test pieces;

– if there is doubt about the uniformity of the width, this shall be measured at three positions on the top and the bottom side of the three test pieces. The mean of the top and bottom side measurements shall be calculated for each position. The common width shall be the minimum of the nine mean values determined on the three test pieces;

– in the case of further doubt, the width is measured on each individual test piece.

For the thickness:

– the thickness of each test piece is the minimum of three thickness measurements carried out in the area to be stretched.

The measurements shall be carried out by an optical instrument or by a dial gauge giving a contact pressure not exceeding 0,07 N/mm^2.

The instrument shall be capable of measuring the thickness with an error of not more than 0,01 mm and the width with an error of not more than 0,04 mm.

In case of doubt, where technically possible, an optical instrument shall be used. Alternatively, a dial gauge with a maximum contact pressure of 0,02 N/mm^2 may be used.

An appropriate curved foot of the dial gauge should be used if the central part of the dumb-bell is still curved.

b) Tubular test piece

In the middle of the sample being used to prepare the test pieces, a piece shall be taken to determine the cross-sectional area, A, in square millimetres, of the test piece, using one of the following methods. In case of doubt, the methods 2) and 3) shall be used.

1) From the dimensions, using the formula:

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

where

δ is the mean value of the thickness of the buffer tube, in millimetres, rounded off to two decimal places;

D is the mean value of the outer diameter of the test piece, in millimetres, rounded off to two decimal places.

2) From the density, the mass and the length, using the formula:

$$A = \frac{1000\, m}{d \times l}$$

where

m is the mass of the test piece, in grams, to three decimal places;

d is the density, in grams per cubic centimetre, to three decimal places;

l is the length, in millimetres, to one decimal place.

3) From the volume and the length, the volume being determined by means of immersion in, for example ethyl alcohol, using the formula:

$$A = \frac{V}{l}$$

where

V is the volume, in cubic millimetres, to two decimal places;

l is the length, in millimetres, to one decimal place.

Care shall be taken to avoid air bubbles in or on the surface of the test piece during immersion.

c) Sequence of determination of cross-sectional area and ageing

For test pieces which are to be aged, the cross-sectional area shall be determined before ageing treatment.

17.2.4 Ageing treatment

Each required ageing treatment shall be carried out on a minimum of five test pieces (see 17.2.1) in accordance with IEC 60811-401, under the conditions specified in the relevant cable standard.

17.3 Apparatus

A calibrated tensile test machine shall be used.

For the tubular test pieces, in order to avoid damage on samples because of clamping and to get stable results, using the following in the clamping section is recommended:

– rigid inserts whose diameters are similar to the inner diameter of the buffer tube;

– close-to-tube diameter shape clamps.

NOTE 1 As buffer tubes have a kind of rigid behavior, their structures are susceptible to be fractured at the clamping section when using plain clamps with the result of breakage in the clamping section which will get inconsistent values from mechanical evaluations.

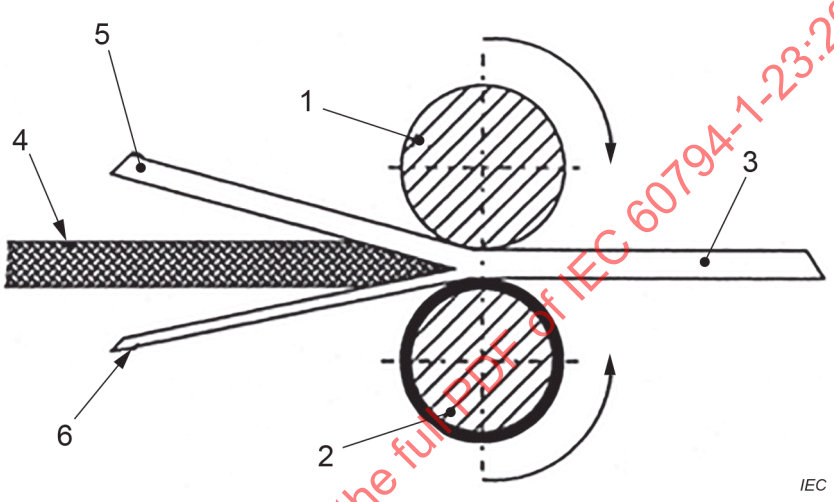
An example of a cutting machine is given in Figure 12.

Two rolls, one made of steel and partly grooved (1), and the other, in rubber-tyred steel (2), drive the strip (3) against a highly sharpened fixed, or moving blade (4) (surgical scalpel quality).

The strip is longitudinally cut into two parts: part (5) from which the test piece is cut, and part (6), which is rejected.

The thickness of part (6) can be limited to 0,1 mm if necessary. For this purpose, consideration should be given to the behaviour of the material prepared and the preservation of the blade sharpness.

When the strip (3) has marks of tearing or scratching, which may induce a premature break, it is recommended that part (6) be cut and rejected from both sides.



Key

1	steel roll, partly grooved	4	blade, fixed or moving
2	steel roll, rubber-tyred	5	part of strip used for test piece
3	strip	6	rejected part of strip

Figure 12 – Machine for preparing test pieces

17.4 Procedure

The test procedure shall be as follows:

a) Test temperature

The test shall be carried out at a temperature of 23 °C ± 5 °C.

b) Distance between the grips and rate of separation

The grips of the tensile testing machine may be either of a self-tightening type or not. The total length between the grips shall be about:

– 34 mm for dumb-bells as illustrated in Figure 9;

– 50 mm for dumb-bells as illustrated in Figure 8;

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

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

The rate of separation, except for PE and PP buffer tubes, shall be 250 mm/min ± 50 mm/min and, in case of doubt, 25 mm/min ± 5 mm/min.

For PE and PP, or buffer tubes containing these materials, the rate of separation shall be 25 mm/min ± 5 mm/min, but for routine tests, separation rates up to 250 mm/min ± 50 mm/min are permitted.

c) Measurements

The maximum tensile force during the test shall be measured and recorded and the distance between the two reference marks at breaking point shall be measured on the same test piece.

An unsatisfactory result due to any test piece breaking due to damage in the grips shall be ignored. In this event, at least four valid results shall be obtained in order to calculate the tensile strength and elongation at break; otherwise, the test shall be repeated.

17.5 Requirements

The buffer tubes shall meet the tensile strength and elongation requirements of the detail specification. Details to be specified.

The detail specification shall include the following:

a) buffer tube preconditioning, if any;

b) dimensions of the dumb-bell test piece or tubular test piece;

c) number of samples to be tested.

18 Method G11B: Elongation of buffer tubes and micro tubes at low temperature

18.1 Object

These tests are to determine the elongation of the buffer tubes and micro tubes at low temperature.

NOTE1 This method is included in IEC 60811-505.

NOTE 2 In 18.2 to 18.6, descriptions for buffer tube also include micro tube.

18.2 Sample

18.2.1 General

Each buffer tube to be tested shall be represented by two samples of suitable length.

18.2.2 Preparation of test pieces

After all covering has been removed, the buffer tube shall be cut open in the direction of the axis, after which the fibre and any filling compound, if any, shall be removed.

The test is intended for buffer tubes circular cross-section having an external diameter greater than 12,5 mm and for sector-shaped cores large enough to prepare dumb-bells described in 17.2.2. Where it is not possible to prepare dumb-bells, the tubular test pieces described in 17.2.2 are suitable for testing the performance of cores of smaller diameter.

The buffer tube need not be ground or cut if the inner and outer surfaces are smooth, and its mean specified thickness does not exceed 2,0 mm. Samples having a thickness exceeding this limit, or samples having imprints or ridges on the inner side, shall be ground or cut to obtain two parallel and smooth surfaces, and a thickness which does not exceed 2,0 mm. The minimum thickness after grinding or cutting shall be 0,8 mm but if the original thickness of the buffer tube does not allow it, then 0,6 mm shall be permitted as the minimum thickness. Grinding and cutting shall be carefully carried out to avoid undue heating and mechanical stresses in the buffer tube.

All strips shall be conditioned at 23 °C ± 5 °C for at least 3 h.

After this preparation, two dumb-bells from each sample in accordance with Figure 8, or if necessary Figure 9, shall be punched in the direction of the axis of each sample; if possible, two dumb-bells shall be punched side by side.

If an apparatus is used which allows the direct measurement of the distance between the marker lines during the test, the dumb-bells shall be marked in accordance with 17.2.2.

18.3 Apparatus

The test may be carried out on a machine provided with a cooling device or on a machine installed in a cooling chamber.

Using a liquid as the refrigerant, the conditioning time shall be not less than 10 min at the specified test temperature.

When cooling in air, the conditioning time for cooling the apparatus and test piece together shall be at least 4 h. If the apparatus has been pre-cooled, this period may be reduced to 2 h, and if the apparatus and test piece have been pre-cooled, the conditioning time after the test piece has been fixed in the apparatus shall be not less than 1 h.

If a liquid mixture is used for cooling, it shall not impair the buffer tube.

18.4 Procedure

The grips of the tensile apparatus shall be of a non-self-tightening type. In both pre-cooled grips, the dumb-bell shall be clamped over the same length.

The free length between the grips shall be about 30 mm for both types of dumb-bells if the direct measurement of the distance between the marker lines is to be made during the test.

If the displacement of the grips is to be measured, the free length between the grips shall be 30 mm ± 0,5 mm for the dumb-bell in accordance with Figure 8, and 22 mm ± 0,5 mm for the dumb-bell in accordance with Figure 9.

The speed of separation of the grips of the tensile machine shall be 25 mm/min ± 5 mm/min.

The test temperature shall be as specified in the relevant cable standard.

The elongation shall be determined by measuring the distance between the marker lines, if possible, or between the grips at the moment of the rupture.

For calculating the elongation, the increase of the distance between the marker lines shall be related to the initial distance of 20 mm (or 10 mm if the dumb-bell in accordance with Figure 9 is used), and expressed as a percentage of this distance.

If the alternative method of measuring the distance between the grips is used, the increase of this distance shall be related to the original distance, being 30 mm for the dumb-bell in accordance with Figure 8, and 22 mm for the dumb-bell in accordance with Figure 9. When this method is used, the test piece shall be examined before being removed from the apparatus; if the test piece has partly slipped out of the grips, the result shall be ignored. At least three valid results are required for calculating the elongation, otherwise the test shall be repeated.

Unless otherwise specified, none of the valid results shall be less than 50 %. In case of dispute, the method employing marker lines shall be used.

18.5 Requirements

The buffer tube shall meet the elongation requirements of the detail specification.

18.6 Details to be specified

The detail specification shall include the following:

a) buffer tube preconditioning, if any;
b) test temperature;
c) dimensions of the dumb-bell test piece or tubular test piece;
d) number of samples to be tested.

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CÂBLES À FIBRES OPTIQUES

Partie 1-23: Spécification générique – Procédures fondamentales d'essai des câbles optiques – Méthodes d'essai des éléments de câbles

AVANT-PROPOS

1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
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La Norme internationale IEC 60794-1-23 a été établie par le sous-comité 86A: Fibres et câbles, du comité d'études 86 de l'IEC: Fibres optiques.

Cette deuxième édition annule et remplace la première édition parue en 2012. Elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout d'une nouvelle méthode d'essai G9: dégorgement et évaporation (précédemment connue en tant que méthode E15 dans l'IEC 60794-1-21:2015);

b) ajout d'une nouvelle méthode d'essai G10A: stabilité de la force de dénudage des fibres optiques câblées (précédemment connue en tant que méthode E5A dans l'IEC 60794-1-21:2015);

c) ajout d'une nouvelle méthode d'essai G10B: dénudabilité des rubans de fibres optiques (précédemment connue en tant que méthode E5B dans l'IEC 60794-1-21:2015);

d) ajout d'une nouvelle méthode d'essai G10C: dénudabilité des fibres optiques à revêtement protecteur (précédemment connue en tant que méthode E5C dans l'IEC 60794-1-21:2015);

e) ajout d'une nouvelle méthode d'essai G11A: résistance à la traction et allongement des tubes de protection (inclus à l'IEC 60811-501);

f) ajout d'une nouvelle méthode d'essai G11B: allongement des tubes de protection à basse température (inclus à l'IEC 60811-505);

g) clarification de la procédure de préparation des échantillons dans la méthode G5: déchirement des rubans (séparabilité).

Le texte de cette Norme internationale est issu des documents suivants:

CDV	Rapport de vote
86A/1912/CDV	86A/1945/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60794, publiées sous le titre général *Câbles à fibres optiques*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

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CÂBLES À FIBRES OPTIQUES

Partie 1-23: Spécification générique – Procédures fondamentales d'essai des câbles optiques – Méthodes d'essai des éléments de câbles

1 Domaine d'application

La présente partie de l'IEC 60794 décrit les procédures d'essai à utiliser pour l'établissement d'exigences uniformes pour les propriétés géométriques, matérielles, mécaniques et environnementales des éléments de câble à fibres optiques.

Le présent document s'applique aux câbles à fibres optiques destinés à être utilisés avec des équipements de télécommunication et des dispositifs utilisant des techniques analogues, ainsi qu'aux câbles constitués de fibres optiques d'une part et de conducteurs électriques d'autre part.

Dans le présent document, le terme "câble optique" peut également englober les unités de fibres optiques, les unités de fibres en microconduit, etc.

NOTE L'essai environnemental du ruban de fibres optiques serait précieux pour certaines applications. Des informations utiles au sujet des méthodes d'essai appropriées sont disponibles dans les normes sur les fibres optiques IEC 60793-1-50, IEC 60793-1-51, IEC 60793-1-52 et IEC 60793-1-53.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60794-1-2, *Câbles à fibres optiques – Partie 1-2: Spécification générique – Procédures fondamentales d'essais des câbles optiques – Lignes directrices générales*

IEC 60794-1-31:2018, *Câbles à fibres optiques – Partie 1-31: Spécification générique – Eléments de câbles optiques – Rubans de fibres optiques*

IEC 60793-1-32:2018, *Fibres optiques – Partie 1-32: Méthodes de mesure et procédures d'essai – Dénudabilité du revêtement*

IEC 60793-1-40, *Fibres optiques – Partie 1-40: Méthodes de mesurage de l'affaiblissement*

IEC 60793-1-46, *Fibres optiques – Partie 1-46: Méthodes de mesure et procédures d'essai – Contrôle des variations du facteur de transmission optique*

IEC 60811-401, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 401: Essais divers – Méthodes de vieillissement thermique – Vieillissement en étuve à air*

3 Termes et définitions

Aucun terme n'est défini dans le présent document.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

4 Exigences générales

L'IEC 60794-1-2 est le guide de référence des méthodes d'essai de tous types. Il doit être pris en considération pour les exigences générales et les définitions.

5 Méthode G1: essai de courbure pour les éléments de câble optique

5.1 Objet

L'objet de cet essai est de caractériser les éléments de câble pour les besoins de l'épissurage en déterminant l'augmentation de l'affaiblissement d'un élément de câble optique (fibre, ruban, cœur, unité de jonction, etc.) lorsqu'il est plié dans un boîtier à épissure ou un dispositif similaire.

5.2 Echantillon

La longueur de l'échantillon d'élément de câble optique doit être suffisante pour effectuer l'essai spécifié.

5.3 Appareillage

L'appareillage se compose

a) d'un mandrin dont la surface est lisse avec un diamètre tel qu'indiqué dans la spécification particulière; et

b) d'un appareillage de mesure de l'affaiblissement pour déterminer la variation de l'affaiblissement (conformément aux méthodes d'essai de l'IEC 60793-1-40 et de l'IEC 60793-1-46).

5.4 Procédure

L'élément à soumettre à essai doit être enroulé sur le mandrin avec une tension minimale; le nombre de tours doit être indiqué dans la spécification particulière.

Afin de mesurer l'augmentation de l'affaiblissement provoquée par le pliage, il convient de prévoir l'affaiblissement intrinsèque de la fibre.

5.5 Exigences

Toute augmentation de l'affaiblissement doit être conforme aux limites indiquées dans la spécification particulière.

5.6 Détails à spécifier

La spécification particulière doit indiquer les éléments suivants:

a) la longueur d'onde de l'essai optique;

b) le diamètre du mandrin;

c) le nombre de tours;

d) l'appareillage et la technique de mesurage de l'affaiblissement;

e) la température à laquelle l'évaluation doit être effectuée si elle est différente de la température ambiante.

6 Méthode G2: dimensions et géométrie du ruban – Méthode visuelle

6.1 Objet

L'objet de cet essai est de déterminer la géométrie d'un ruban de fibres optiques telle que définie par les paramètres de largeur, hauteur et alignement des fibres, pour les besoins de l'essai de type pour un contrôle approprié du processus de fabrication. Cet essai ne convient pas nécessairement à l'inspection finale des produits et, sauf indication contraire, ne doit pas être utilisé à cette fin.

6.2 Echantillon

Le nombre d'échantillons à soumettre à essai doit être indiqué dans la spécification particulière. Les échantillons sélectionnés doivent être statistiquement indépendants et représentatifs de la population de rubans soumis à essai.

6.3 Appareillage

L'appareillage se compose d'un microscope ou d'un comparateur optique avec un grossissement approprié.

6.4 Procédure

6.4.1 Généralités

L'une des deux méthodes de procédure décrites en 6.4.2 et 6.4.3 peut être utilisée.

Pour le nombre d'échantillons spécifié, toutes les dimensions doivent être mesurées en tant que valeurs moyenne ainsi que maximale et minimale.

Il convient de s'assurer que la préparation de l'échantillon ne modifie pas la structure du ruban de fibres et représente une image intacte de la gaine des fibres et de la section transversale du ruban.

6.4.2 Méthode 1

L'échantillon est préparé en le coupant perpendiculairement à l'axe du ruban et en le plaçant dans une résine durcissable ou dans un outil qui maintient le ruban. Si nécessaire, l'échantillon doit être meulé et poli pour préparer une face terminale perpendiculaire lisse. L'échantillon préparé est fixé avec sa face terminale perpendiculaire au trajet optique et mesuré à l'aide d'un microscope ou d'un comparateur optique.

6.4.3 Méthode 2

Placer le ruban dans un support de fibres en ruban et dénuder 20 mm à 25 mm de revêtement et de matériau matriciel des fibres avec l'outil de dénudage à chaud des gaines de ruban et nettoyer la partie dénudée des fibres en l'essuyant avec un tampon imbibé d'alcool. Ajuster la position du ruban dans le support de fibres en ruban et scinder les fibres à une distance de 250 μm à 500 μm à partir de l'extrémité dénudée du ruban. Couper et polir l'autre extrémité du ruban et l'éclairer avec une source lumineuse collimatée. Aligner et mesurer l'extrémité scindée du ruban au microscope.

6.5 Exigences

Sauf indication contraire dans la spécification particulière, la largeur, la hauteur et l'alignement de la fibre doivent être conformes à l'IEC 60794-1-31:2018.

6.6 Détails à spécifier

La spécification particulière doit indiquer les éléments suivants:

a) les valeurs maximale et minimale autorisées;

b) les limites des valeurs moyennes;

c) le nombre d'échantillons soumis à essai.

6.7 Définitions des dimensions et de la géométrie du ruban

6.7.1 Généralités

Les définitions suivantes s'appliquent à une section transversale de ruban de fibres comme représenté à la Figure 1. La figure représente un exemple pour un ruban à 4 fibres, où a est le diamètre d'une fibre colorée.

NOTE Etant donné la précision des attributs géométriques des fibres et la précision relativement plus grande des exigences de géométrie du ruban, il est acceptable d'utiliser, pour les fibres à cœur en verre/revêtement en verre, le bord du revêtement pour les mesurages de 6.7.3 et 6.7.4 au lieu du centre des fibres. Dans ce cas, les mesurages peuvent être effectués du même côté de toutes les fibres (par exemple au-dessus ou au-dessous, du côté gauche ou droit).

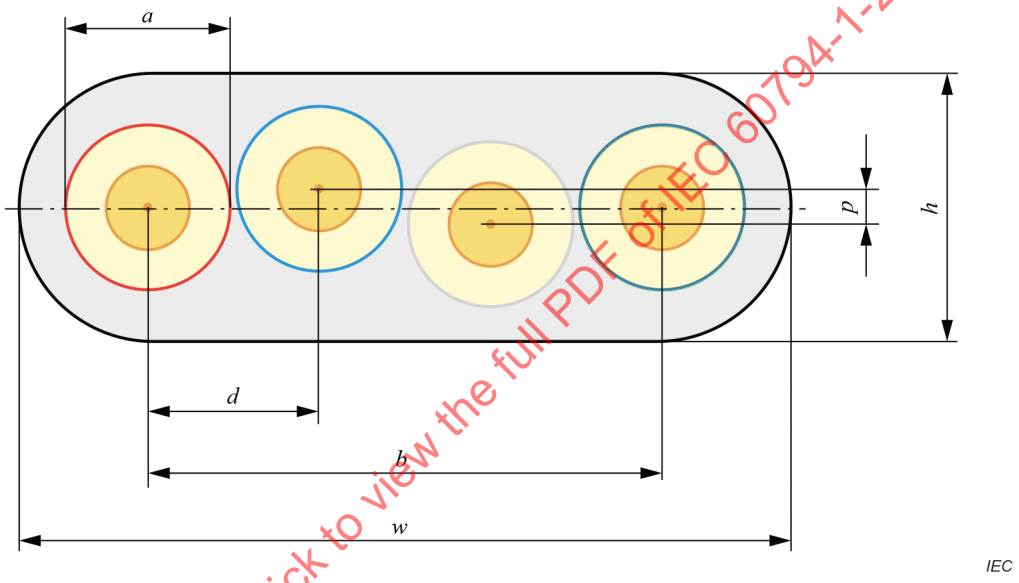


Figure 1 – Schéma de la section transversale représentant la géométrie du ruban de fibres

6.7.2 Largeur et hauteur

La largeur w et la hauteur h du ruban sont les dimensions de la surface rectangulaire minimale circonscrivant la section transversale du ruban.

6.7.3 Ligne de base

La ligne de base est la ligne de la section transversale d'un ruban de fibres optiques traversant le centre de fibre de la première fibre (fibre 1) et celui de la dernière fibre (fibre n) du ruban de fibres, comme indiqué en pointillés à la Figure 1. Cette ligne est utilisée comme plan de référence pour les mesurages d'alignement des fibres.

6.7.4 Alignement des fibres

6.7.4.1 Séparation horizontale des fibres

La séparation horizontale des fibres est la distance de la projection orthogonale de deux centres de fibres sur la ligne de base dans la section transversale du ruban de fibres.

Deux paramètres de séparation horizontale peuvent être distingués:

a) la distance de centre à centre d entre fibres adjacentes;

b) la distance de centre à centre b entre les fibres extrêmes.

6.7.4.2 Planarité

La planarité p de la structure du ruban de fibres est la somme de la valeur positive maximale et de la valeur absolue de la valeur négative maximale de la séparation verticale des fibres.

La séparation verticale des fibres est la distance orthogonale du centre des fibres à la ligne de base. La séparation verticale est positive pour les fibres situées "au-dessus" de la ligne de base et négative pour les fibres "au-dessous" de la ligne de base.

7 Méthode G3: dimensions du ruban – Gabarit d'ouverture

7.1 Objet

L'objet de cet essai est de vérifier la performance fonctionnelle d'un ruban. Afin d'assurer la performance fonctionnelle, les dimensions des rubans liés par les bords peuvent être contrôlées et vérifiées avec un gabarit d'ouverture pour les besoins de l'inspection finale. L'objectif est de vérifier que l'extrémité d'un ruban peut être insérée et serait convenablement alignée avec les fentes de guidage des outils de dénudage du commerce.

7.2 Echantillon

Sauf indication contraire dans la spécification particulière, cinq échantillons de ruban représentatifs, chacun d'une longueur minimale de 50 mm, doivent être prélevés sur le ruban soumis à essai.

7.3 Appareillage

Un gabarit d'ouverture, comme représenté à la Figure 2, doit être utilisé pour évaluer les dimensions globales d'un ruban. Les valeurs pour la largeur du ruban (w) et la hauteur du ruban (h) de la Figure 2 doivent être les dimensions nominales du ruban telles qu'établies en utilisant la méthode G2 dans un programme approprié d'évaluation de la qualité.

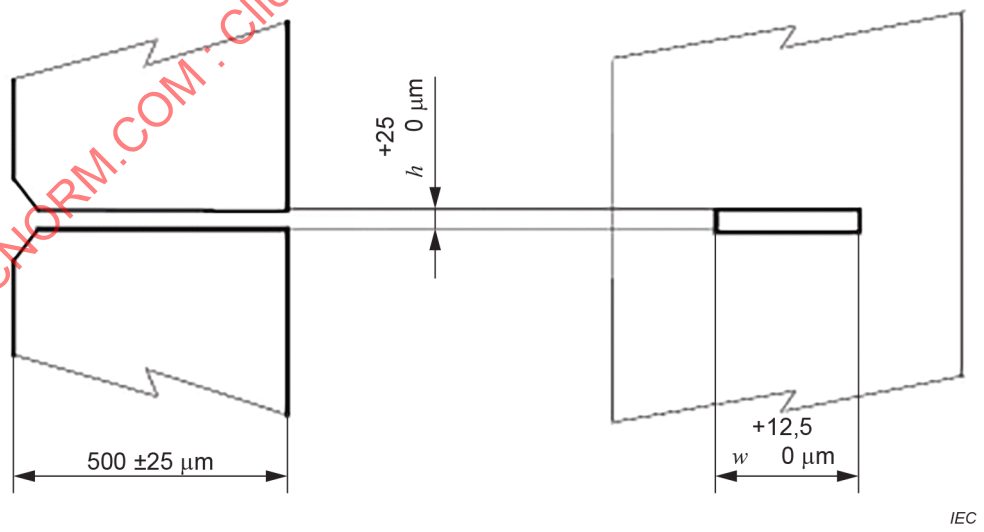


Figure 2 – Gabarit d'ouverture

7.4 Procédure

L'échantillon de ruban soumis à essai est maintenu au milieu, et une extrémité de 10 mm est insérée dans le gabarit d'ouverture.

7.5 Exigence

Il doit être possible d'insérer librement l'extrémité de 10 mm du ruban dans le gabarit d'ouverture sans dommage mécanique de l'échantillon.

7.6 Détails à spécifier

La spécification particulière doit indiquer les éléments suivants:

a) les dimensions du gabarit d'ouverture;

b) le nombre d'échantillons soumis à essai.

8 Méthode G4: dimensions du ruban – Comparateur à cadran (méthode obsolète)

9 Méthode G5: déchirement des rubans (séparabilité)

9.1 Objet

L'objet de cet essai est d'assurer une résistance suffisante au déchirement pour les rubans dont les fibres n'ont pas à être séparables, ou pour assurer la séparabilité suffisante des fibres pour les rubans dont les fibres doivent être séparées. L'objectif de cet essai est de permettre le déchirement à la main sans dommage.

9.2 Echantillon

Un certain nombre d'échantillons de rubans de fibres, tel que défini dans la spécification particulière, en général entre 3 et 5, doit être prélevé sur le ruban ou les rubans soumis à essai. La longueur de chaque échantillon doit être suffisante pour donner le nombre d'éprouvettes tel qu'indiqué ci-dessous.

Pour un ruban à n fibres, n/2 éprouvettes sont prises sur les échantillons ci-dessus. Chaque éprouvette doit avoir une longueur minimale de 100 mm, conformément à la Figure 3.

Préparer les n/2 éprouvettes impliquant la séparation d'un nombre croissant de fibres comme unité de ruban. C'est-à-dire une éprouvette pour la fibre 1; une éprouvette pour les fibres 1 à 2; une éprouvette pour les fibres 1 à 3; etc.

Les fibres soumises à essai sont séparées à l'aide d'un couteau ou par une autre méthode appropriée sur une longueur permettant la fixation, conformément à la Figure 3.

Pour le premier échantillon, la préparation de la séquence d'essai doit consister en la séparation d'une fibre parmi les autres fibres du ruban dans la première éprouvette. Puis, séparer une unité de deux fibres de l'éprouvette suivante. Puis, des unités de trois, quatre, etc. fibres sont séparées dans les autres éprouvettes, jusqu'à une unité de n/2 fibres dans la dernière éprouvette.

Effectuer la même préparation pour tous les autres échantillons.

NOTE Si n est un nombre impair, remplacer n/2 par (n-1)/2 dans la description ci-dessus.

Dimensions en millimètres

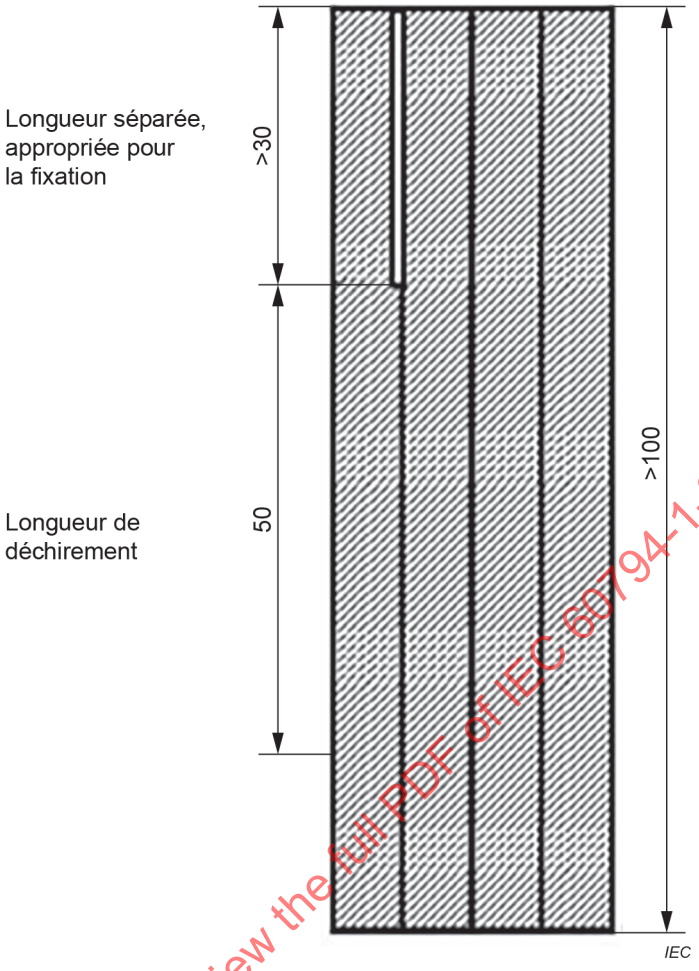


Figure 3 – Préparation des échantillons pour l'essai de séparabilité des rubans

9.3 Appareillage

L'appareillage se compose

a) d'un appareil de mesure de la résistance à la traction avec des appareils de fixation appropriés et des fonctions appropriées d'enregistrement de la force; et

b) d'un microscope d'un grossissement minimal de 100 ×.

9.4 Procédure

Insérer l'éprouvette dans l'appareil de mesure de la résistance, comme indiqué à la Figure 4. Les fibres soumises à essai sont déchirées à une vitesse d'environ 100 mm/min à 500 mm/min. La force de déchirement des fibres sur une longueur minimale de 50 mm est enregistrée en continu.

Dans le cas où il est exigé que les fibres soient séparées, le revêtement primaire de la ou des fibres séparées doit être inspecté visuellement à l'aide d'un microscope.

La procédure est répétée pour les éprouvettes impliquant la séparation de la fibre 1, des fibres 1 à 2, des fibres 1 à 3, etc. jusqu'aux fibres 1 à $n/2$.

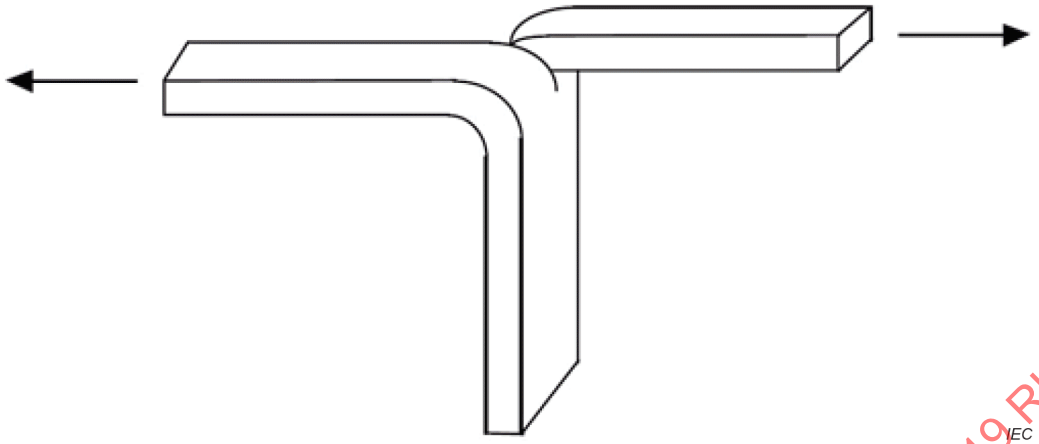


Figure 4 – Procédure de séparabilité

9.5 Exigences

L'exigence principale est de pouvoir réaliser le déchirement sans endommager la fibre (dommage du revêtement ou rupture de la fibre). Pour les rubans dont les fibres doivent être séparées, le revêtement primaire coloré de la ou des fibres séparées doit être effectivement exempt de résidus matriciels du ruban.

Le codage couleur des fibres, quel qu'il soit, doit rester suffisamment intact sur tout segment de 25 mm pour permettre de distinguer les fibres individuellement les unes des autres.

Les forces minimale ou maximale et moyenne de déchirement doivent être telles qu'indiquées dans la spécification particulière.

9.6 Détails à spécifier

La spécification particulière doit indiquer les éléments suivants:

a) les forces minimale et moyenne de déchirement, en N, lorsqu'il n'est pas exigé que les fibres soient séparées;

b) les forces maximale et moyenne de déchirement, en N, selon l'exigence de la spécification particulière, lorsqu'il est exigé que les fibres soient séparées;

c) le nombre d'échantillons;

d) le type de ruban (séparable ou non séparable).

10 Méthode G6: torsion du ruban

10.1 Objet

L'objet de cet essai est de vérifier l'intégrité mécanique et fonctionnelle de la structure du ruban de fibres. L'essai détermine la capacité du ruban à supporter la torsion sans délaminage.

10.2 Echantillon

Sauf indication contraire dans la spécification particulière, cinq échantillons représentatifs, chacun d'une longueur minimale de 120 mm, sont réalisés à partir du ruban soumis à essai.

10.3 Appareillage

L'appareillage d'essai, dont un exemple est représenté à la Figure 5, consiste en deux fixations en position verticale maintenant l'échantillon pendant sa torsion sous une tension minimale de 1 N. La longueur minimale soumise à essai est de 100 mm.

Dimensions en millimètres

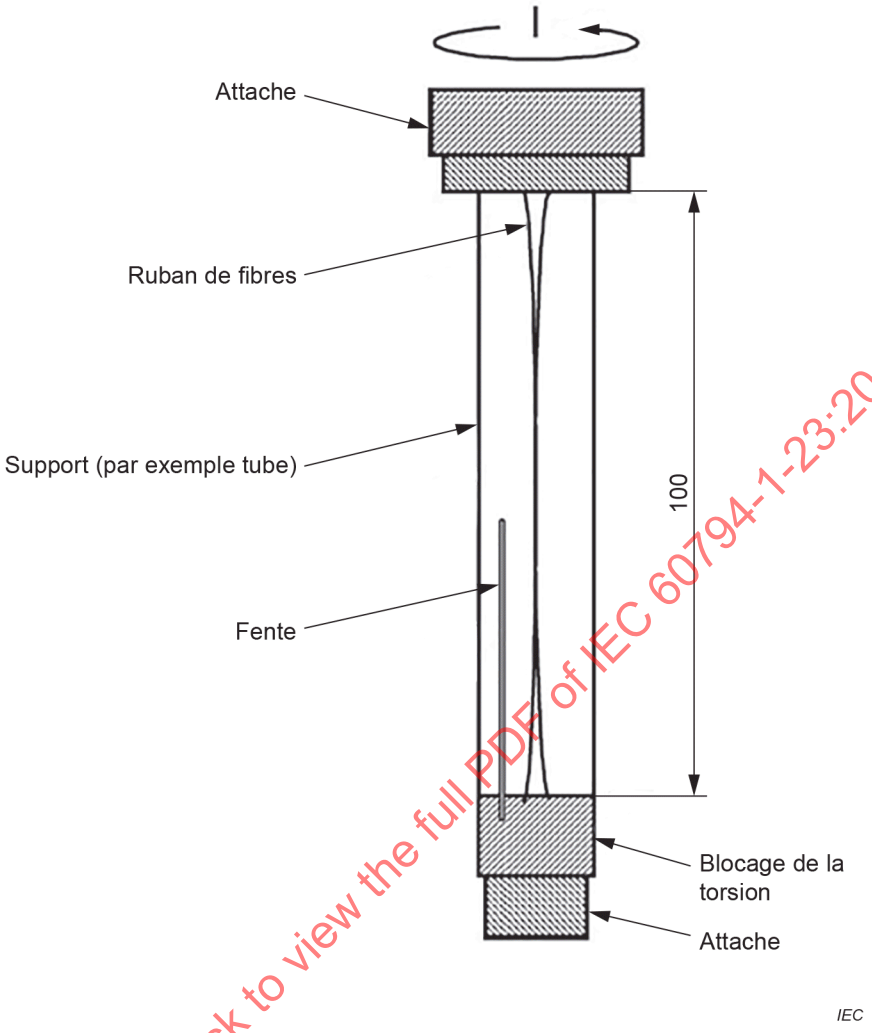


Figure 5 – Essai de torsion

10.4 Procédure

L'échantillon est fixé fermement dans l'appareillage et subit une torsion par incréments de 180° ± 5° dans un délai de 2 s. Le temps minimal de palier après chaque incrément de torsion est de 5 s. La torsion incrémentielle est poursuivie jusqu'à la ou les valeurs convenues entre le client et le fournisseur, comme cela est défini dans la spécification particulière, ou jusqu'au délaminage.

10.5 Exigences

Le ruban doit supporter le nombre de tours à 180° stipulé dans la spécification particulière jusqu'à ce que le délaminage se produise.

10.6 Détails à spécifier

La spécification particulière doit indiquer les éléments suivants:

a) le nombre d'échantillons,

b) le nombre de tours.

11 Méthode G7: déformation du tube

11.1 Objet

L'objet de cet essai est de déterminer la capacité des tubes contenant des fibres optiques à supporter les contraintes mécaniques rencontrées pendant l'installation et l'épissurage des câbles. L'essai est effectué sur des tubes prélevés sur un câble optique.

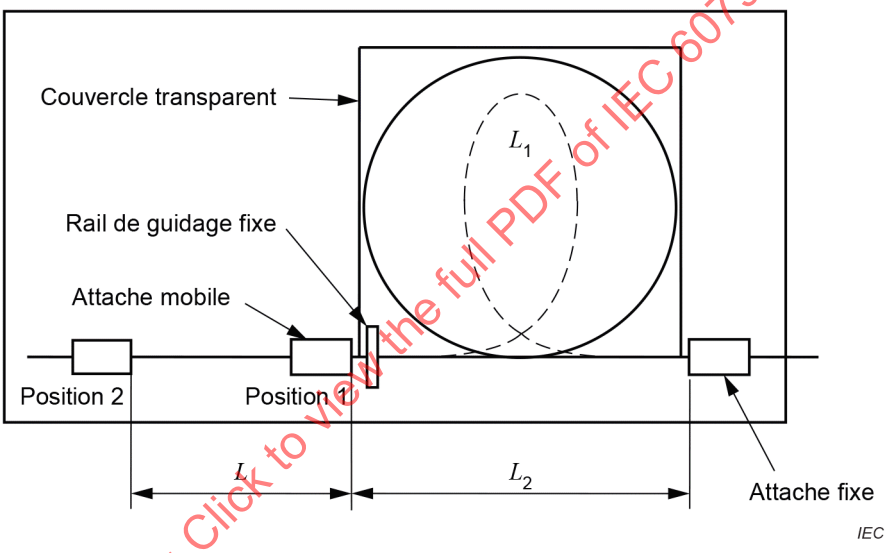
11.2 Echantillon

Un tube contenant des fibres, d'une longueur d'au moins L_1 + 50 mm, doit être prélevé sur un câble à fibres optiques.

Cinq (5) échantillons doivent être soumis à essai, sauf indication contraire.

11.3 Appareillage

L'appareillage se compose d'un dispositif d'essai tel que représenté à la Figure 6.



Légende

L_1 longueur de tube en essai

L_2 distance entre le point de fixation du tube de l'attache mobile et le point de fixation du tube de l'attache fixe au début de l'essai

L distance de déplacement (dont la longueur détermine la réduction de la dimension de l'ellipse)

Le diamètre minimal de la boucle n'est pas fixé par une courbure de l'équipement d'essai, mais seulement commandé par la longueur fixe L_1 de l'éprouvette et la longueur de déplacement L.

Le rail de guidage fixe assure une position définie de l'échantillon. Un couvercle transparent permet le maintien de l'échantillon dans le même plan et son observation pendant l'essai. La distance entre les deux couvercles doit généralement être égale au triple du diamètre du tube. Une distance trop grande permet au tube de se déplacer latéralement pendant l'essai et n'assure pas un essai suffisamment strict.

Figure 6 – Essai de déformation du tube

Des exemples de dimensions d'appareillage d'essai pour la déformation du tube sont donnés dans le Tableau 1.