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Optical fibres — Measurement methods — Microbending sensitivity

National foreword

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Optical fibres – Measurement methods – Microbending sensitivity

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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OPTICAL FIBRES –
MEASUREMENT METHODS –
MICROBENDING SENSITIVITY

FOREWORD

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IEC 62221, which is a technical report, 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 2001, and constitutes a technical and editorial revision.

The main changes with respect to the previous edition are listed below:

a) updates related to B6 (bend-insensitive) category single-mode fibres;
b) inclusion of a definition for microbending and general properties;
c) expansion of general considerations;

d) more details given for each method;
e) addition of an Annex A.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86A/1460/DTR	86A/1470/RVC

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

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

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

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- withdrawn,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

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

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

OPTICAL FIBRES –
MEASUREMENT METHODS –
MICROBENDING SENSITIVITY

1 Scope

IEC 62221, which is a technical report, describes four methods (A, B, C and D) for the measurement of microbending sensitivity of optical fibres.

These four methods are distinguished by the equipment being used for measurements and their applications:

- method A using an expandable drum and applies to category A1 and class B fibres;
- method B using a fixed diameter drum and applies to category A1 and class B fibres;
- method C using a plate and applied loads and applies to category A1 and class B fibres;
- method D using a "basketweave" wrap on a fixed diameter drum, and applies to category A1 and class B fibres

Methods A and B may also be used to measure the microbending sensitivity of optical fibre ribbons.

Methods A and C offer the capability to measure the microbending sensitivity over a wide range of applied linear pressure or loads. Method B may be used to determine the microbending sensitivity for a fixed linear pressure.

Methods A, B and D can also be used at different temperatures (temperature cycling) provided special low thermal expansion materials (e.g. quartz drums) are used.

The results from the four methods can only be compared qualitatively. These methods are considered characterization type tests.

It shall be understood that the microbend results from any method, could have significant variation between laboratories.

These methods do not constitute a routine test used in the general evaluation of optical fibre. This parameter is not generally specified within a detail specification.

2 Normative references

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

IEC 60793-1-1:2008, *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance*

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

IEC 60793-1-40:2001, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

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

IEC 62614, *Fibre optics – Launch condition requirements for measuring multimode attenuation*

3 General properties of microbending loss

Added loss due to microbending occurs when localized lateral forces along the length of the fibre appear. These may be caused by manufacturing and installation strains, as well as dimensional variations in the cable materials due to temperature changes. Sensitivity to microbending is a function of the difference of refractive index of the core and the cladding, and diameters of the core and cladding. Coating structure and material property may also have an influence.

The effect of microbending in single-mode fibres is increased optical loss at 1 310 nm, 1 550 nm and 1 625 nm wavelength ranges as opposed to macrobend effects in single-mode fibres that primarily is present in the longer wavelengths 1 550 nm and 1 625 nm.

In category A1 multimode fibres, microbending manifests itself in general nearly equally over a wide wavelength range (e.g. 850 nm – 1 320 nm).

To reduce microbending losses, the cable structure has to protect the optical fibres from lateral forces. Loose tube cable construction should be optimized to prevent buckling of the fibre in the tube during temperature changes leading to possible macrobending as well as microbending loss.

Cable components such as the cable sheath and the strength member are important because they also help to reduce the microbending caused by the external mechanical forces on the cable and by temperature changes.

Microbending losses may also be introduced in aerial cables subjected to excessive elongation (e.g. heavy ice loading).

4 General considerations

4.1 Launch condition for multimode fibres

Concerning multimode fibres, reference is made to the launching technique described in IEC 62614, as done for the macrobend test method.

4.2 Sample lengths

This technical report lists several methods to evaluate microbend sensitivity for optical fibres. One key difference is the sample length requirements for the different methods. Though the exact sample lengths may vary, a list with lengths that have been typically used is given here below:

Method	Length
A	300 m
B	400 m
C	2 m – 3 m
D	2,5 km

4.3 Winding tension

When using methods A, B or D, the control of the winding tension should be mentioned and carried out with a calibrated device. Added loss due to microbending is reasonably linear over a winding tension range from 1 N to 3 N, but different winding tensions could yield different normalised microbending sensitivity results. For methods A and B, careful winding is required with no crossovers in order to avoid negative influence on the correct winding force.

4.4 Relaxation time

Information about relaxation time should be given. Almost all fibres show some kind of coating relaxation effect, most probably dependant on the mechanical properties of the secondary layer of the primary coating. If no fixed relaxation time is used (time between ending the winding and starting the attenuation measurement) less repeatable results may be obtained. This relaxation time needs to be investigated by each user (depending on the particular coating system tested).

Other mechanical relaxation issues (such as humidity and temperature) have been observed such as the difference in storage temperature of the fibre spool and the winding/measurement conditions. This requires some description of the measurement conditions. Temperature cycling is an additional option in microbending testing.

4.5 Material used for fixed roughness

For methods A and B a fixed roughness material is required that is single wide with only one single seam such as wire mesh or adhesive sandpaper (e.g. a sandpaper/lapping film PSA – grade 40 μm – mineral Al_2O_3).

Reference measurements with known fibre are recommended to control quality of the measurement.

4.6 Drum materials

Any kind of material may be used for the drum used in methods B and D. The barrel shall uniform (seamless, smooth surface, constant diameter).

The drum shall be of material showing high strength with a relaxation modulus that remains in the glassy plateau region for the time duration of the test.

4.7 Drum material for temperature cycling

Methods A, B and D can be used for temperature cycling tests. This requires a low thermal expansion material (e.g. quartz drum).

The size of the drum doesn’t need fixed dimensions. It is recommended that the drum diameter be at least 200 mm to minimize macrobending effects.

5 Test procedures

5.1 Method A: expandable drum

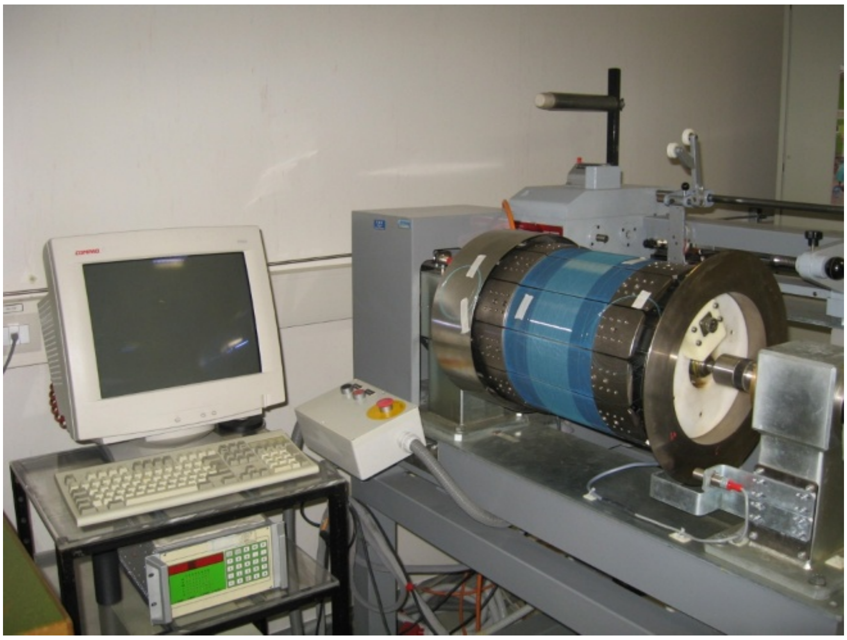
5.1.1 General

This subclause describes a technique for the measurement of the loss increase due to microbending effects induced by the application of linear pressure to category A1 and class B fibres. This method may also be used to measure the microbending sensitivity of optical fibre ribbons.

5.1.2 Apparatus

The apparatus is an expandable drum, the diameter of which can be changed continuously. In order to avoid any loss contribution due to macrobending effects a minimum drum diameter of 200 mm is recommended, see Figure 1. The curvature at any edges of the expanded segments of the drum also exceeds 200 mm diameter. The drum surface is coated with a material of fixed roughness (see subclause 4.5). The length under test should fit onto the expandable drum. The winding pitch is controlled to prevent the fibre/ribbon turns from overlapping.

While expanding the drum, the fibre elongation is measured using the phase-shift method (Method E of IEC 60793-1-22: 2001). The attenuation measurement is conducted using either the cut back technique (method A of IEC 60793-1-40: 2001), the backscatter technique (method C of IEC 60793-1-40: 2001) or by the direct transmitted power measurement technique (method A of IEC 60793-1-46: 2001).



IEC 2241/12

Figure 1 –Set-up for expandable drum method used in an optical fibre testing facility

5.1.3 Procedure

The fibre to be tested is carefully wound onto the coated drum with minimal tension (e.g. 0,4 N to 0,5 N) in one single layer avoiding any crossing or overlapping. The fibre is fixed to avoid any relative slipping. While expanding the drum the changes in attenuation coefficient and phase are recorded.

5.1.4 Calculations

The fibre elongation (ε) can be found from:

$$\varepsilon = \frac{\Delta\theta}{f \times L} \times V \quad (1)$$

where

$\Delta\theta$ is the phase shift (degrees);

f is the modulation frequency (Hz);

L is the length of the sample (km);

V is the constant depending on the photo-elastic coefficient (k), the speed of light in vacuum (c) and the group index (N_g):

$$V = \frac{k \times c}{360\, N_g} \tag{2}$$

For Category B1 fibres, V is typically 726 km/s/degree.

From this the linear pressure P can be calculated:

$$P = \frac{T}{R} = \frac{EA_\varepsilon}{R} \tag{3}$$

where

T is the tension applied to the fibre (N);

R is the radius of the expandable drum in rest condition (mm);

E is the Young's modulus of the fibre (N/mm^2);

A is the cross-sectional area of the fibre (glass part) (mm^2).

The changes in attenuation coefficient (dB/km) are plotted as a function of the linear pressure P (N/mm) or the elongation ε (%). The points obtained are interpolated by a straight line passing through the origin, the slope of which gives the microbending sensitivity (dB/km)/(N/mm) or (dB/km/%) of the tested fibre.

5.2 Method B: fixed diameter drum

5.2.1 General

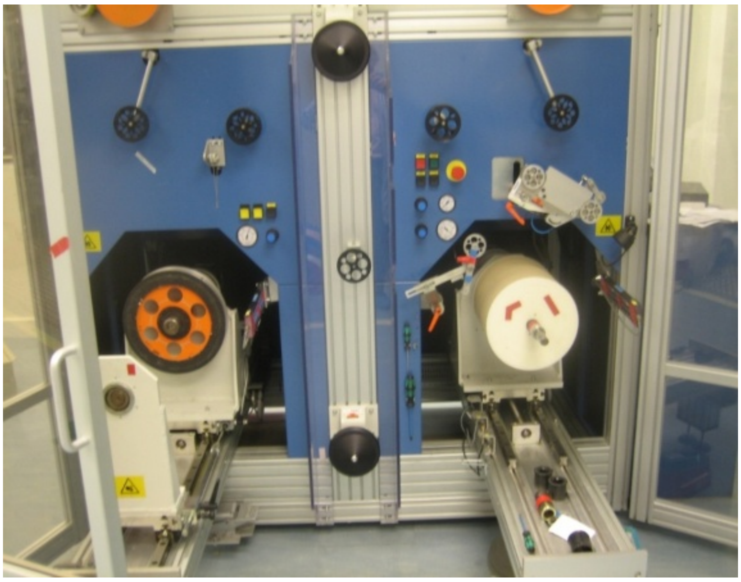
This subclause describes a procedure to measure the microbending sensitivity of category A1 and class B fibres (see Clauses A.1 and A.3). This technique gives the loss increase due to microbending effects for a fixed linear pressure applied to the fibre. This method may also be used to measure the microbending sensitivity of optical fibre ribbons (see Clause A.2).

5.2.2 Apparatus

The apparatus consists of a fixed diameter drum. In order to avoid macrobending effects the minimum drum diameter is 200 mm. When a low thermal expansion drum (e.g. quartz drum) is used the method can be used in temperature cycling as well, see Figures 3 and 7.

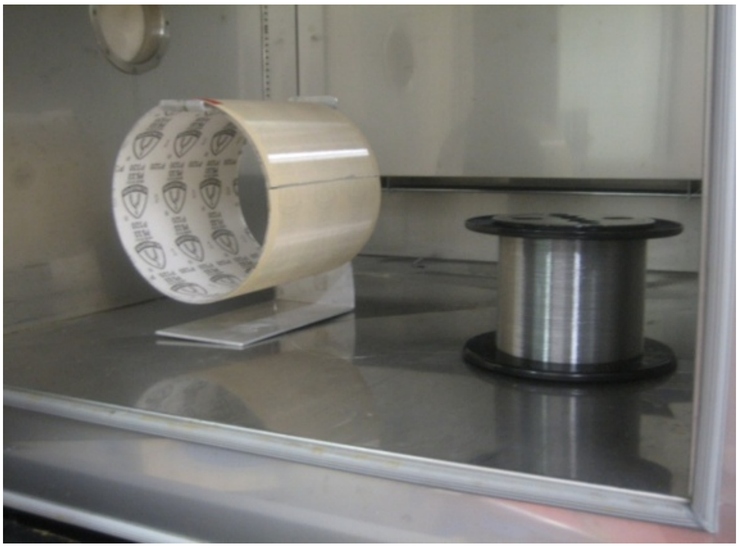
The surface of the drum is coated with a material of fixed roughness (see 4.5 and Figures 2 and 3). Alternatively, a wired mesh can be used, see Figure 4. The length under test should fit onto the drum. The attenuation measurement is performed using the cutback technique (method A of IEC 60793-1-40: 2001) or by the backscatter technique (method C of IEC 60793-1-40: 2001).

Another possibility is to use method A of IEC 60793-1-46: 2001 (monitoring of changes in optical transmittance) with taking a reference measurement after releasing the fibre package from the drum (with the fibre in loose wide coils).



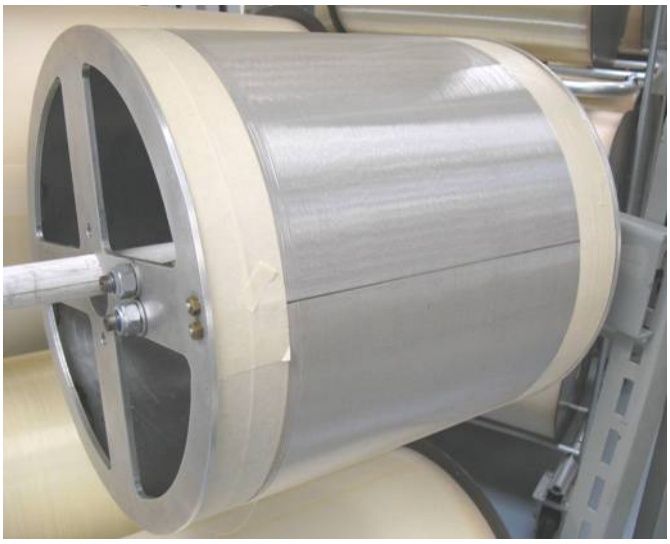
IEC 2242/12

Figure 2 – Standard winding/prooftester can be used for preparing the sample



IEC 2243/12

Figure 3 – Example of a possible set-up in temperature cycling



IEC 2244/12

Figure 4 – Alternative wire mesh set-up used in an optical fibre testing facility

5.2.3 Procedure

The sample needs to be preconditioned for a minimum of 12 h at standard atmospheric conditions as specified in IEC 60793-1-1 (temperature 23 °C ± 5 °C, relative humidity 45 % ± 25 %).

The fibre to be tested is carefully wound onto the surface of the drum in one single layer, i.e. avoiding crossovers. The winding tension has to be controlled (see 4.3). The value between 1 N and 3 N should be chosen and be kept the same for all tests for better repeatability. A lower value for a multimode fibre or a higher value for a bend-insensitive fibre might be required. Measure the attenuation coefficient of the fibre under test. Calculate the attenuation increase due to microbending by subtracting the intrinsic attenuation coefficient of the fibre. In case of power monitoring, the fibre package needs to be released from the drum and a reference measurement (with the fibre in loose wide coils) can be performed yielding directly the microbending loss.

5.2.4 Calculations

The microbending sensitivity is found from the following relationship:

$$\text{Microbending sensitivity} = \frac{\alpha R}{T} = \frac{\alpha}{P}\ [(\text{dB/km})/(\text{N/mm})] \qquad (4)$$

where

α is the attenuation increase due to the microbending sensitivity (dB/km);

P is the linear pressure (N/mm), see Equation (3);

R is the radius of the fixed drum (mm);

T is the winding tension applied to the fibre (N).

The complete procedure may be repeated using different winding forces.

5.3 Method C: plate test

5.3.1 General

This subclause describes a procedure to measure the microbending sensitivity of category A1 and class B fibres. This technique gives the loss increase due to microbending effects caused by the application of a wire mesh (under load) or sandpaper to the fibre under test

Wire mesh is recommended for this test method because the uneven surface of the sandpaper often causes fiber breakage.

A very short piece of fibre is normally tested therefore relatively small additional bending effects at the boundary of the rubber plate / wire mesh could have a large effect.

5.3.2 Apparatus

An example of microbend-inducing equipment is shown in Figure 5.

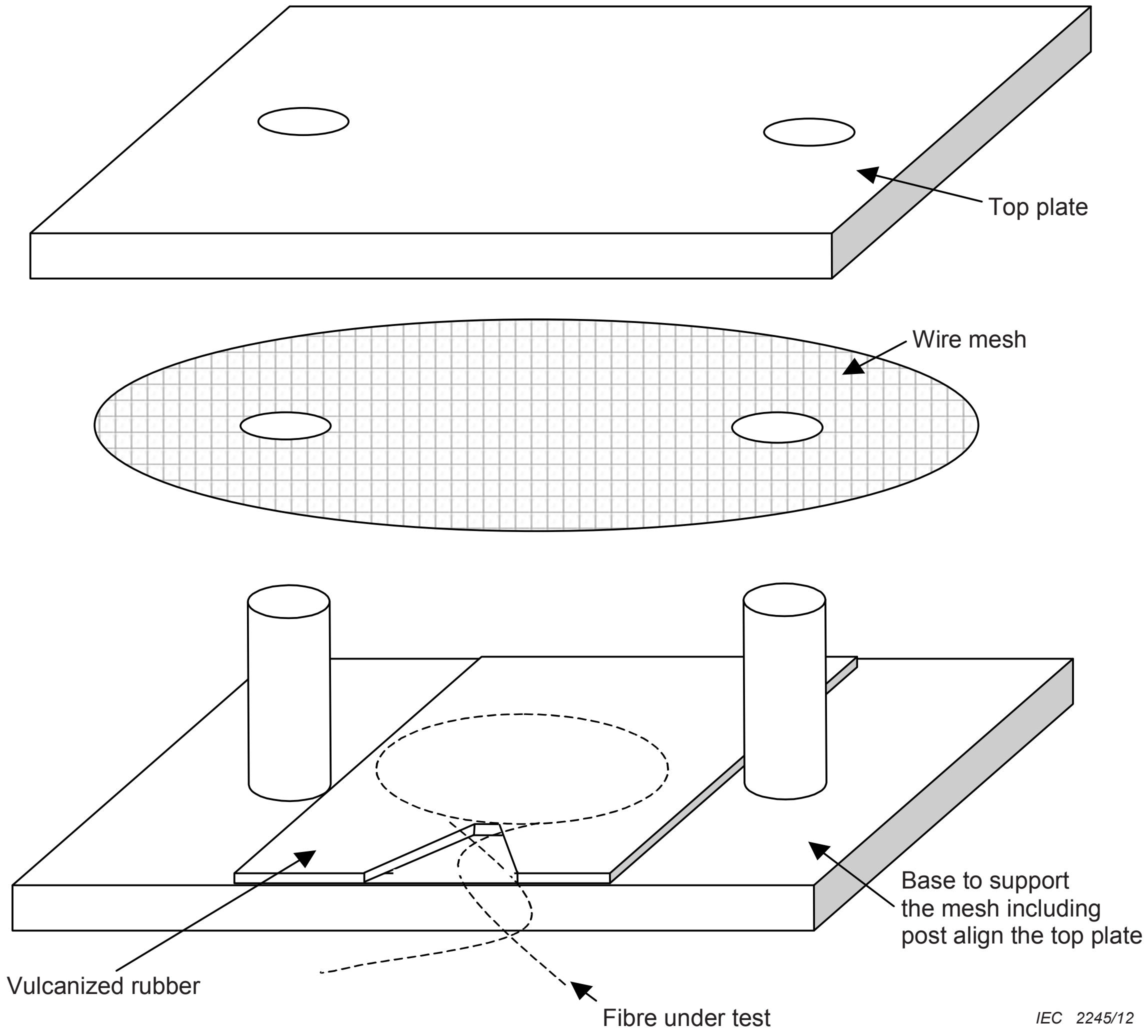


Figure 5 – Microbend-inducing equipment

An arrangement as shown in Figure 5 is used to produce the microbend losses. The metal base plate acts as a location and smooth surface for the upper layers of the equipment. Use dowels or other devices to both align the plates and allow the top plate to compress onto the lower plate.

It is critical that all the surfaces should be flat and smooth so that the load is borne only by the fibre. This can also be facilitated by reducing the surfaces to an area as small as possible whilst still covering the fibre.

A sheet of vulcanized rubber, shore A hardness of 73 to 78, is fixed securely to the upper surface of the base plate. Deploy the fibre in a single circular loop with a diameter of 98 mm by laying it onto a pre-marked circle or by the use of a temporary deployment mandrel. As can be seen in Figure 5, a section of the rubber is cut away, thus preventing fibre crossover at the point where the fibre enters and exits the test apparatus. This cut out reduces the length of fibre under test by approximately 8 mm. In order to avoid any spurious microbending effects it is important that the rubber sheet is smooth and flat.

The wire mesh is constructed from woven stainless steel wire. The mesh is plain woven with a mesh number of 70. If greater discrimination is required, then the use of a coarser mesh, e.g. mesh number 20, is appropriate. Direct comparisons cannot be made between the results obtained by using different mesh sizes, since the mesh number will affect the microbend sensitivity.

The wire mesh has holes drilled into it to enable repeated accurate location onto the dowels (or other alignment devices) in the base plate.

The top plate, of nominal mass 1 kg has two location holes which have a sliding fit with the dowels (or other alignment devices) in the base plate. A set of 1 kg weights is employed to provide the additional load required to induce additional microbending losses. Alternatively, use a controlled loading machine to achieve the required compression.

The attenuation measurement is conducted using the cut back technique (method A of IEC 60793-1-40), the backscatter technique (method C of IEC 60793-1-40) or the direct transmitted power measurement technique (method A of IEC 60793-1-46).

5.3.3 Procedure

The test is typically conducted on a 2 m to 3 m length of fibre.

Place the fibre in a loop in order to follow the circle on the rubber sheet. The fibre may be held into position by no more than 3 small (≤ 3 mm wide) pieces of tape. In order to avoid crossovers ensure that the fibre enters and exits the apparatus at the point where the rubber sheet is cut away.

Power readings are taken at each required wavelength prior to the application of the wire mesh or any load.

Gently apply the wire mesh to the fibre under test followed by the top plate (1 kg).

Take power readings at each required wavelength.

Apply further loads in 1 kg increments taking power readings between each successive loading. Wait approximately 60 s after the application of any load prior to taking power readings.

Optionally, upon completion of the test carefully remove all of the weights and the wire mesh. Take a further set of power readings. This data can be used to establish whether there is any permanent effect due to the test.

5.3.4 Calculations

The microbending sensitivity is calculated from the following:

$$\text{Microbending sensitivity} = \frac{\alpha}{P} \ [(\text{dB/km})/(\text{N/mm})] \qquad (5)$$

or

$$\text{Microbending sensitivity} = \frac{\alpha}{W} \ (\text{dB/kg}) \qquad (6)$$

where

α is the attenuation increase due to the microbending sensitivity (dB/km);

P is the linear pressure (N/mm), i.e. the load (N) applied to the fibre divided by the length (mm) of fibre beneath the mesh. This definition varies slightly from Equation (3);

W is the mass loaded onto the fibre (kg).

5.4 Method D: basketweave

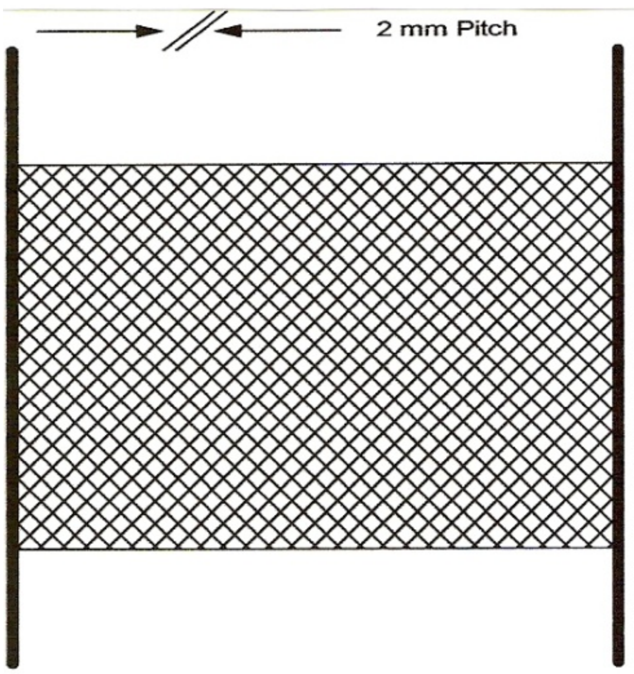
5.4.1 General

This subclause describes a procedure to measure the microbending sensitivity of category A1 and class B fibres as a function of temperature. This technique gives the attenuation loss increase over a wide temperature range.

5.4.2 Apparatus

5.4.2.1 The fixed diameter quartz drum

The apparatus consists of a fixed diameter, silica drum. The drum composition is necessary to match the expansion coefficient of the fibre. In order to minimise macrobending effects and maximise microbending effects, the recommended minimum drum diameter is 110 mm and the minimum width 200 mm, see Figure 6. These parameters have historically been used.



IEC 2246/12

Figure 6 – Quartz drum with basketwoven fibre

In Figure 7 below the picture shows a set-up used in the industry.

IEC 2247/12

Figure 7 – Basketweave example as used in an optical fibre testing facility

5.4.2.2 Temperature controlled test chamber

This test is conducted in an environmental test chamber with inside dimensions capable of accommodating the sample and allowing unrestricted air flow around the test sample. The chamber should have an operational range sufficient to cover the temperature extremes and maintain the specified temperature within ± 2 °C throughout the test duration. There should be an access port or ports through which the fibre ends may extend allowing measurements to be taken while maintaining a sufficient seal such that the specified temperatures may be maintained.

5.4.3 Procedure

5.4.3.1 Sample preparation

The fibre to be tested is carefully wound onto the glass drum with a winding tension 0,7 N ± 0,05 N and a pitch (distance between adjacent wraps of fibre) of 2 mm. The fibres in the next layer are wrapped at the opposite angle. Every second layer, the angle reverses. The crossover of the tensioned fibres from the adjacent layers creates the microbend mechanism. It is recommended that 2,5 km of fibre is tested as shorter lengths give unrepeatable results and longer lengths do not improve the measurement. To achieve accurate and repeatable results, the following wind conditions are recommended:

– winding force 0,7 N ± 0,05 N;
– take-up width ≥ 200 mm;
– take-up pitch 2,0 mm;
– tapered stack 0,5 mm/pass;
– wind speed 50 m/min to 100 m/min.

5.4.3.2 Sample preconditioning

It is recommended that the sample is preconditioned for a minimum of 12 h at standard atmospheric conditions as specified in IEC 60793-1-1 (temperature 23 °C ± 5 °C, relative humidity 45 % ± 25 %). After placing the sample in the chamber, the fibre ends extending from the chamber ports does not exceed 10 % of the fibre length inside the chamber. The fibre ends should be prepared for transmittance or attenuation measurement as recommended in measurement technique used.

The attenuation measurement is conducted using either the cut back technique (method A of IEC 60793-1-40), the backscatter technique (method C of IEC 60793-1-40) or by the direct transmitted power measurement technique (method A of IEC 60793-1-46).

5.4.3.3 Temperature cycling

Measure the attenuation as the sample is cycled to low temperatures. An example of temperature cycling (cf. Annex A) is shown in Figure 8.

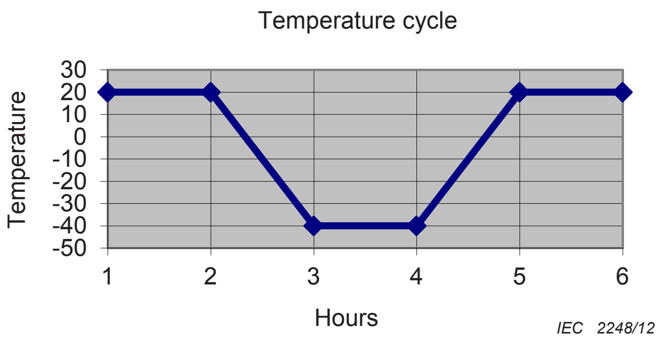


Figure 8 – Example of temperature cycle inside chamber

The measurements may be continuously monitored or are recorded at the end of each constant temperature phase. Determine the attenuation change (dB/km) between the room temperature attenuation and at each low temperature attenuation.

5.4.4 Calculations or interpretation of results

The microbend sensitivity at a given temperature shows an increase of fibre attenuation or transmittance above its inherent attenuation or transmittance determined at room temperature prior to any thermal excursions.

Data may be reported as either absolute attenuation or as a change in attenuation or transmittance from baseline.

Performance of fibre in a given cable structure can be predicted by comparing the microbend performance of the test fibre and a reference fibre. The fibre of known performance in a particular cable structure should be used as a reference. The fibre showing lower microbend sensitivity on the glass drum is predicted to perform better inside the cable.

6 Results

The following information should be reported for each test:

– date of test;
– test apparatus arrangement;
– minimum diameter of the drum;
– roughness and type of material used to cover surface (i.e drum or plate);
– fibre identification; Origin, class, and category;
– For single-mode fibres: MFD/fibre cutoff wavelength;
– For A1 multimode fibres: NA and core diameter;
– length of fibre under test;
– length of fibre subjected to load;
– environmental test conditions;

– wind test conditions;
– tested wavelengths;
– plot of measured change in attenuation coefficient as a function of the calculated linear pressure or of the elongation (For method A Only);
– microbending sensitivity [(dB/km)/(N/mm)] or (dB/km/%) or dB/kg or (dB/km)

Annex A
(informative)

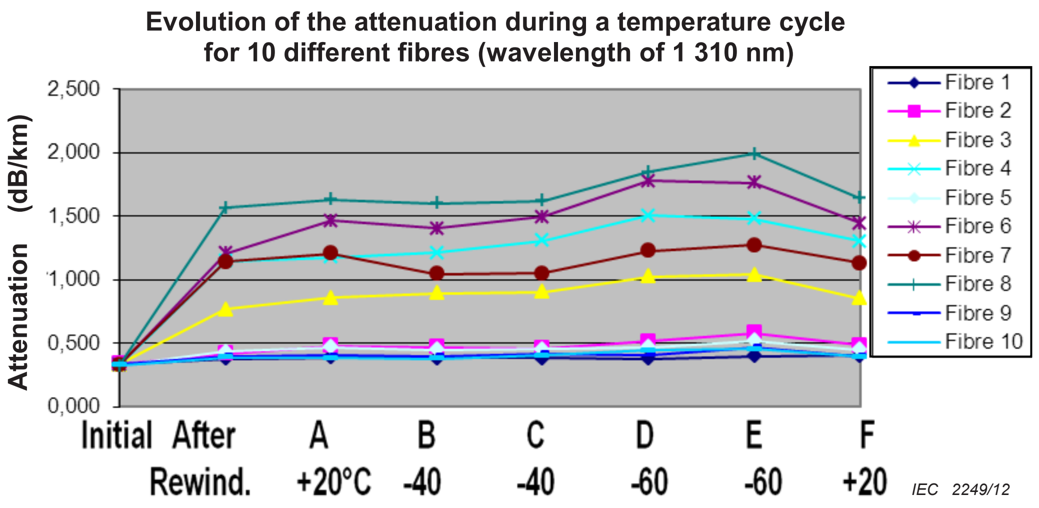
Representative results with method B

A.1 Single-mode fibres

Figures A.1, A.2 and A.3 below show some representative results achieved with this technique. Parameters have been chosen as indicated in Clause 4, see Table A.1 below.

Table A.1 – Used instrument and values for single-mode fibres

1	OTDR
2	Wavelengths: 1 310 nm, 1 550 nm and 1 625 nm
3	Pulse width/LSA: 50 ns
4	Winding tension: 1 N
5	Winding speed: 50 m/min
6	Winding pitch on sandpaper spool: 0,55 mm
7	Measured length on sandpaper: 400 m
8	Sandpaper P320 grit
9	Sandpaper spool size: quartz drum 280 mm × 280 mm
10	Temperature/humidity: 23 ± 2 °C and 50 % ± 5 % RH, see also Figure A.1
11	Change of sandpaper: reference measurements at regular times
12	Relaxation time: 2 h recommended and take readings within ± 10 min and be consistent in time for all the test fibre measurement
13	Conditioning of fibres: minimum 12 h at 50 %RH and 23°C ± 2 °C



Key

A Before the start of the cycle (+20 °C)

B Chamber at –40 °C

C Chamber at –40 °C for 30 min

D Chamber at –60 °C

E Chamber at –60 °C for 30 min

F Chamber back to +20 °C

10 min relaxation after rewinding and 1 N tension

Figure A.1 – Example of temperature cycling of 10 different unshifted single-mode fibres (wavelength 1 310 nm)

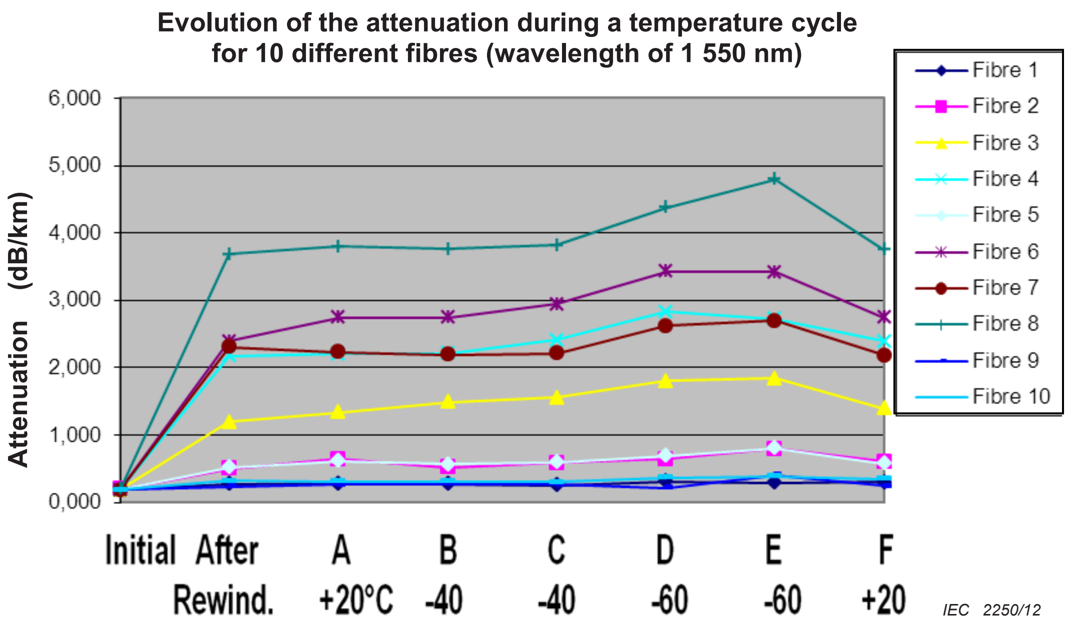


Figure A.2 – Example of temperature cycling of 10 different unshifted single-mode fibres (wavelength 1 550 nm)

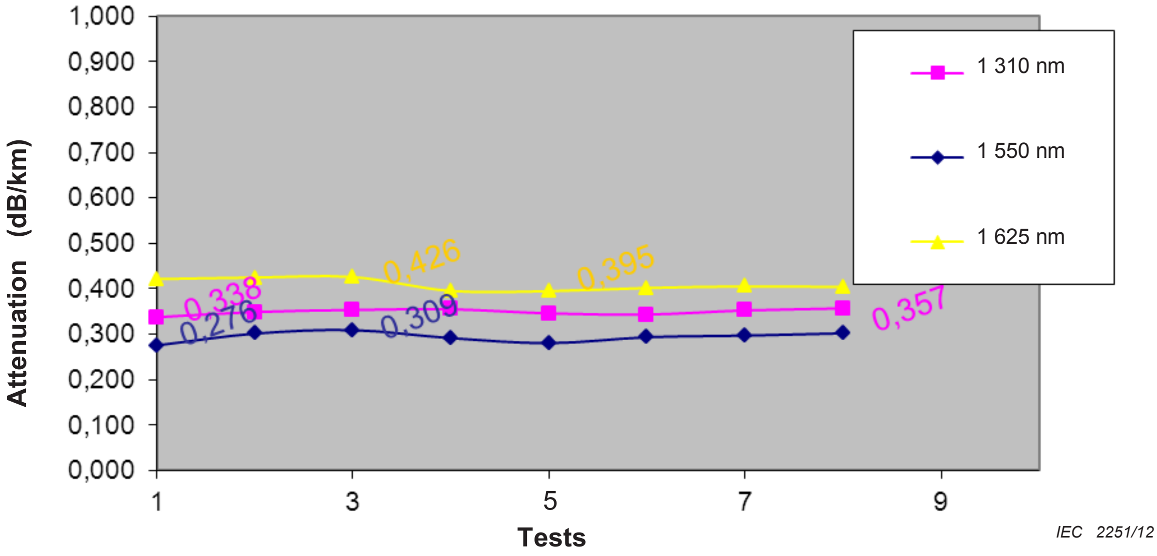


Figure A.3 – Microbending repeatability for fibre N° 1 with winding tension 1 N

A.2 Ribbons with single-mode fibres

Figures A.5 and A.6 below show the same fibres as in Clause A.1, but in the shape of four fibre ribbons. The same sand paper drum was used. Therefore the ribbons were wound as indicated in Figure A.4. Obviously the attenuation losses are different as compared with the results for the fibres. The same instruments shown in Table A.1 have been used.

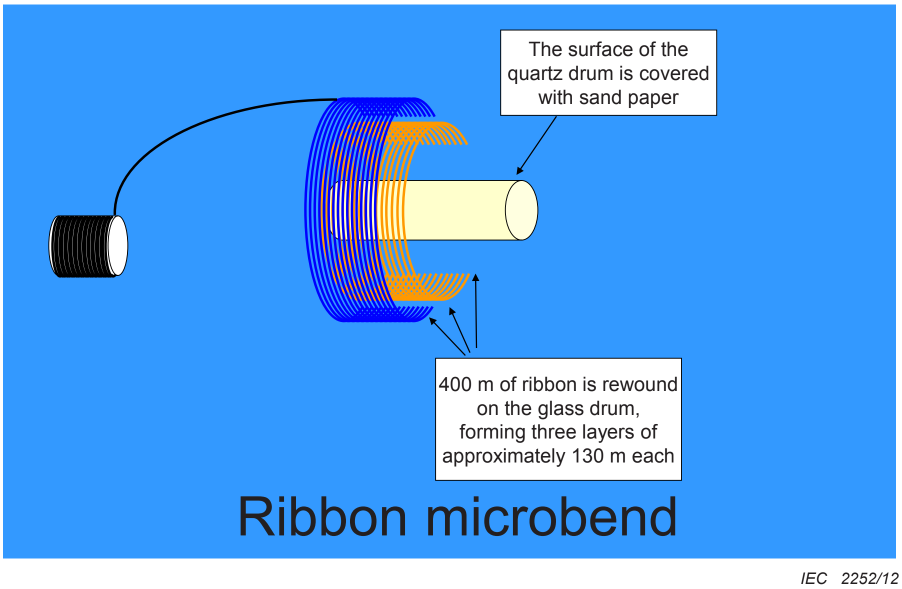


Figure A.4 – Ribbon set-up

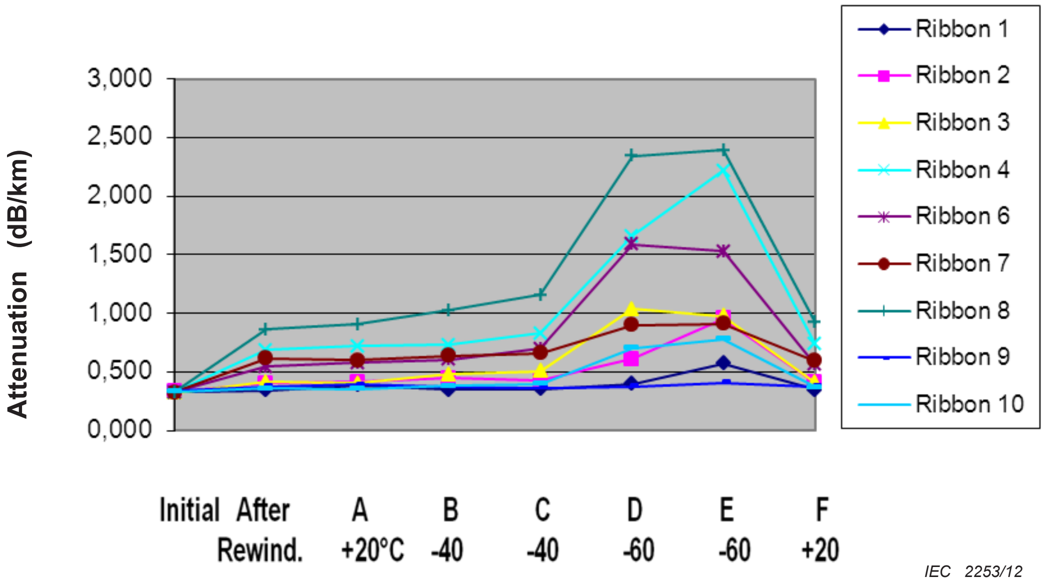


Figure A.5 – Losses at 1 310 nm for different ribbons

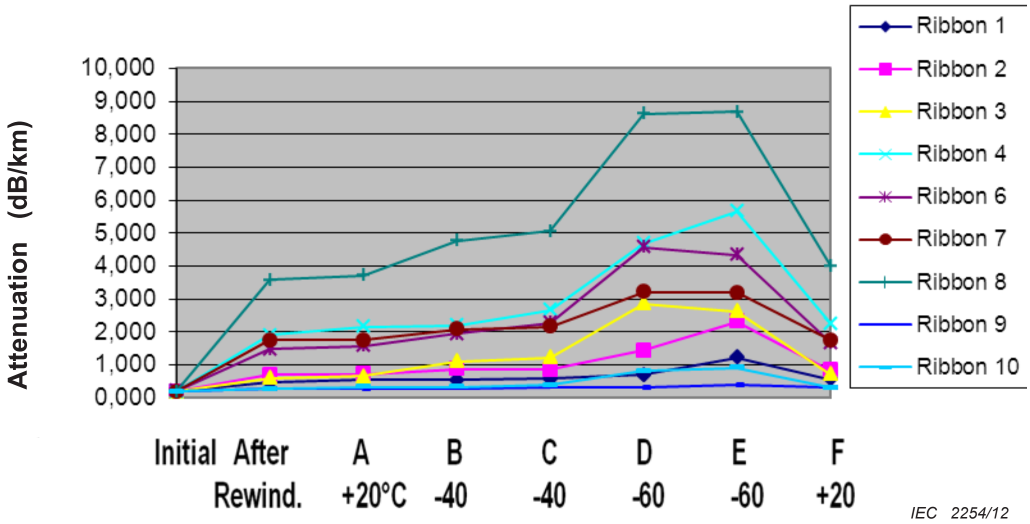


Figure A.6 – Losses at 1 625 nm for different ribbons

A.3 Multimode fibre example

To emphasize the importance of process parameters, some multimode fibre results have been included in Table A.2. Winding speed and tension have been varied with different outcome as a result.

Table A.2 – Multimode fibre test results

Microbending test multimode fibre 50 µm								
Winding speed m/min	**Winding tension** N	**Pitch** mm	**Sand-paper** no.	**Fibre no.**	**Test date**	**Length** m	**Attenuation at 1 300 nm (dB/km) pw 100 ns**	**Attenuation at 850 nm (dB/km) pw 100 ns**
100	1	0,5	P320	50µm	May-13	400	12.98	14.60
100	0,7	0,5	P320	50µm	May-13	400	12.15	13.75
50	0,25	0,5	P320	50µm	July-15	400	5.40	7.06
50	0,20	0,5	P320	50µm	July-15	400	3.92	5.94

Bibliography

IEC 60793-1-30, *Optical fibres – Part 1-30: Measurement methods and test procedures – Fibre proof test*

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