

Generic specification for

Optical fibres

The European Standard EN 188000 : 1992 has the status of a
British Standard

Spécification générique:
Fibres optiques

Fachgrundspezifikation:
Lichtwellenleiter

Cooperating organizations

The European Committee for Electrotechnical Standardization (CENELEC), under whose supervision this European Standard was prepared, comprises the national committees of the following countries:

Austria	Italy
Belgium	Luxembourg
Denmark	Netherlands
Finland	Norway
France	Portugal
Germany	Spain
Greece	Sweden
Iceland	Switzerland
Ireland	United Kingdom

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National foreword

This British Standard has been prepared under the direction of the Electronic Components Standards Policy Committee. It is identical with EN 188000 : 1992 *Generic specification: Optical fibres*, published by the Electronic Components Committee (CECC) of the European Committee for Electrotechnical Standardization (CENELEC).

It supersedes BS 6558 : Part 1 : 1985, which is withdrawn.

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

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This European Standard was approved by the CENELEC Electronic Components Committee (CECC) on 21 August 1992. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the General Secretariat of the CECC or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CECC General Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom. The membership of the CECC is identical, with the exception of the national electrotechnical committees of Greece, Iceland and Luxembourg.

CECC

CENELEC Electronic Components Committee
Comité des Composants Electroniques du CENELEC
CENELEC-Komitee für Bauelemente der Elektronik

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Foreword

The CENELEC Electronic Components Committee (CECC) is composed of those member countries of the European Committee for Electrotechnical Standardization (CENELEC) who wish to take part in a harmonized System for electronic components of assessed quality.

The object of the System is to facilitate international trade by the harmonization of the specifications and quality assessment procedures for electronic components, and by the grant of an internationally recognized Mark, or Certificate, of Conformity. The components produced under the System are thereby acceptable in all member countries without further testing.

This European Standard was prepared by CECC WG 28, Optical fibres and optical fibre cables.

The text of the draft based on document CECC (Secretariat)3021 was submitted to the formal vote; together with the voting report, circulated as document CECC(Secretariat)3168, it was approved by CECC as EN 188000 on 21 August 1992.

The following dates were fixed:

- latest date of announcement of the EN at national level (doa) 1993-09-28
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- latest date of declaration of national standards obsolescence 1994-03-28
- latest date of withdrawal of conflicting national standards (dow) 2003-09-28

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OPTICAL FIBRES

Generic specification

SECTION ONE - GENERAL

1.1 Scope

This standard applies to primary coated or buffered optical fibres for use in telecommunication equipment and in devices employing similar techniques.

1.2 Object

To establish uniform requirements for the geometrical, optical, transmission, mechanical and environmental properties of optical fibre.

1.3 Definitions

Under consideration.

1.4 Categories of optical fibres

1.4.1 Class A — Multimode fibres

Fibre categories are based on g , the refractive index profile parameter.

The normalized index profile is expressed as :

$$\delta(x) = 1 - x^g$$

$$\text{where : } \delta(x) = \frac{n(x) - n(1)}{n(0) - n(1)}$$

and : $n(x)$ = refractive index at x

$$x = \frac{r}{a} \quad (0 \leq r \leq a)$$

a = core radius

TABLE I A
Categories of multimode fibres

Category	Material	Type	Limits
A1	Glass core/glass cladding	Graded* index fibre	$1 \leq g < 3$
A2.1	Glass core/glass cladding	Quasi step* index fibre	$3 \leq g < 10$
A2.2	Glass core/glass cladding	Step* index fibre	$10 \leq g < \infty$
A3	Glass core/plastic cladding	Step* index fibre	$10 \leq g < \infty$
A4	Plastic fibre		

* Attention is drawn to the index profile as stated in the detail specification. For some applications, g may be specified as a function of x .

The fibre category is determined on the basis of the g value which best fits the normalized refractive index profile, falling within the category defined above.

1.4.2 *Class B - single-mode fibres*

Single-mode fibres are characterized by the following parameters.

1.4.2.1 *Mode field diameter,* see clause 4.23

1.4.2.2 *Cut-off wavelength*

The cut-off wavelength is the wavelength greater than which the ratio between the total power, including launched higher order modes, and the fundamental mode power has decreased to less than a specified value, the modes being substantially uniformly excited.

Note 1. - By definition, the specified value is chosen as 0,1 dB for a substantially straight 2 m length of fibre including one single loop of radius 140 mm.

1.4.2.3 *Total dispersion*

Total dispersion is the dependence of the propagation parameter on wavelength. Where the source has a finite line width, dispersion will result in distortion.

Total dispersion can arise as a result of :

- material dispersion ;
- waveguide dispersion.
- profile dispersion polarization dispersion does not produce an appreciable effect in nominally circular fibre.

The maximum magnitude of the total dispersion coefficient and, if applicable, the wavelength of zero dispersion in a particular wavelength region shall be specified in the product specification.

1.4.2.4 *Categories of single-mode fibres*

The categories of single-mode fibres currently in use are given in the table below :

TABLE I B
Categories of glass core/glass clad single-mode fibres

Category	Material	Zero dispersion wavelength Nominal value (nm)	Operating wavelength Nominal value (nm)
B1.1	Dispersion unshifted	1 310	1 310
B1.2	Loss minimized	1 310	1 550
B2	Dispersion shifted	1 550	1 550
B3	Dispersion flattened	see note 3	1 310 and 1 550

- Notes
1. Care may be needed in splicing fibres of different types. Provisional results indicate that adequate splice loss and mechanical strength can be achieved when splicing different types within a single category.
 2. Fibre category B1.2 is not single-mode in the 1310 nm region.
 3. Category B3 single-mode fibres are characterized by a low dispersion over a large wavelength range.

1.4.3 *Other classes of fibre*

For future consideration

1.5 Optical fibre properties

The construction, dimensions and mechanical, optical, transmission, material and environmental properties of each type of optical fibre shall be as specified in the relevant detail specification.

1.6 Preparation of samples

Fibre ends shall be substantially clean, smooth and perpendicular to the fibre axis.

Note : Fibres coated by UV-curable acrylic resin can be cleaned (e.g. from cable filling compounds), without causing damage to the coating, using any cleaning agent recommended by the manufacturer of the fibres. However, the use of chlorine-based cleaning agents should be absolutely avoided, since they can attack the coating even after their use and in vapour phase.

1.7 Categories of test and measuring methods

- a) Parameter measurements.
- b) Performance measurement.
- c) Compliance tests.

SECTION TWO – MEASURING METHODS FOR DIMENSIONS

2.1 Object

The measuring methods apply to the practical measurement of the length and the cross-sectional dimensions of an optical fibre. The methods are to be used for inspection of fibres for commercial purposes.

The dimensions of the optical fibres shall be determined by subjecting samples to tests selected from table II. The tests applied, acceptance criteria and number of samples shall be as specified in the detail specification. It should be clear that this table encompasses all categories of fibres, but not all tests are applicable to any one fibre category.

TABLE II
Dimensions of optical fibres

Test method	Test	Characteristics covered by test method
101	Refracted near field	Diameter of core Diameter of cladding Non-circularities Concentricity errors
102	Near field light distribution	Diameter of core Diameter of cladding Diameter of primary coating Diameter of buffer Non-circularities Concentricity errors
103	Four concentric circles	Diameter of core Diameter of cladding Non-circularities Concentricity errors
104	Mechanical diameter measurement	Diameter of cladding Diameter of primary coating Diameter of buffer Non-circularities
105	Mechanical length measurement (under consideration)	Length of fibre
106	Delay of transmitted and/or reflected pulse	Length of fibre
303	Backscattering technique	Length of fibre

- Notes
1. - The refracted near field technique is a direct application of core definition based on the refractive index profile. This method gives the refractive index profile from which the dimensions and numerical aperture can be calculated.
 2. - With the near field light distribution the dimensions obtained are correlated to the refractive index profile, but are not strictly in accordance with the definition of core diameter.
 3. - The four concentric circles method is a compliance test normally based on near field light distribution. It is not valid for measuring the actual values of fibre dimensions.
 4. - For dimensions linked to transmission part of single-mode fibres (i.e. diameter of mode field, concentricity of mode field) make reference to Section four : Measuring methods for optical and transmission characteristics.
 5. - For practical reasons, the core diameter of single-mode fibres is not normally specified.
 6. - A definition of the core diameter of single-mode fibres is on study.

2.2 Reference surface

The reference surface will be defined in the detail specification and may be either the core, cladding, primary coating, or buffer surface.

2.3 Concentricity error

The concentricity error may be specified between any two of the above mentioned diameters, and can be specified in the detail specification.

2.4 Tolerances

Tolerances on diameters can be specified in the detail specification.

Reference can also be made to test method 103 : Four concentric circles (as a compliance test).

2.5 Operational definitions

2.5.1 Definition of Multimode Fibre Diameter

The core diameter of a multimode optical fibre is defined from the refractive index profile as that diameter passing through the core center and intersecting the index profile at the points n_3 such that :

$$n_3 = n_2 + k (n_1 - n_2)$$

where :

n_2 - the refractive index of the homogeneous cladding
 n_1 - the maximum refractive index, and
 k - a constant commonly called the "k factor"

The refractive index profile can be measured by profiling techniques such as the refracted nearfield measurement (RNF) or transverse interferometry (TI), and by measurement of the near field of a fully illuminated core such as the transmitted near field measurement (TNF).

It is recommended that curve fitting be used with both the index profiling and the TNF techniques to improve the measurement precision of the core diameter.

Note 1 :

Typically, $k = 0,025$ for either the fitted profiling methods or the unfitted TNF method is equivalent to $k = 0$ for the fitted TNF method.

Note 2 :

For fibres with refractive index profiles that have gradual transition region at their core / cladding boundary, a value of $k = 0,05$ for the unfitted TNF method is equivalent to $k = 0$ for the fitted TNF method.

2.6 Method 101 — Refracted near field

2.6.1 *Object*

The refracted near-field measurement is straightforward, accurate and measures directly the refractive index variation across the fibre (core and cladding). The measurement is capable of good resolution and can be calibrated to give absolute values of refractive indexes. It can be used to obtain profiles of both single-mode and multimode fibres.

2.6.2 *Test apparatus*

A schematic diagram of the test apparatus is shown in figures 1 and 2.

2.6.2.1 *Source*

A stable laser giving a few milliwatts of power in the TEM₀₀ mode is required.

A HeNe laser, which has a wavelength of 633 nm, may be used, but a correction factor must be applied to the results for extrapolation at different wavelengths. It shall be noted that measurement at 633 nm may not give complete information at longer wavelengths, in particular non-uniform fibre doping can affect the correction.

A quarter-wave plate is introduced to change the beam from linear to circular polarization because the reflectivity of light at an air-glass interface is strongly angle and polarization dependent.

A pinhole placed at the focus of lens 1 acts as a spatial filter.

2.6.2.2 *Launch optics*

The launch optics, which are arranged to overfill the NA of the fibre, brings a beam of light to a focus on the flat end of the fibre. The optical axis of the beam of light should be within 1° of the axis of the fibre. The resolution of the equipment is determined by the size of the focused spot, which should be as small as possible in order to maximize the resolution, for example less than 1,5 µm. The equipment enables the focused spot to be scanned across the fibre diameter.

2.6.2.3 *Liquid cell*

The liquid in the liquid cell shall have a refractive index slightly higher than that of the fibre cladding.

2.6.2.4 *Sensing*

The refracted light is collected and brought to the detector in any convenient manner provided that all the refracted light is collected. By calculation, the required size of disc and its position along the central axis can be determined.

2.6.3 *Sample preparation*

A length of fibre of about 1 m is required.

All fibre coatings shall be removed from the section of fibre immersed in the liquid cell.

The fibre ends shall be clean, smooth and perpendicular to the fibre axis.

2.6.4 *Procedure*

Refer to the schematic diagram of the test apparatus (Figure 2).

2.6.4.1 *Fibre index profile plot*

The launch end of the fibre to be measured is immersed in a liquid cell whose refractive index is slightly higher than that of the fibre cladding. The fibre is back illuminated by light from a tungsten lamp. Lenses 2 and 3 produce a focused image of the fibre.

The position of lens 3 is adjusted to centre and focus the fibre image, and the laser beam is simultaneously centred and focused on the fibre.

The disc is centred on the output cone. For multimode fibre, the disc is positioned on the optical axis to just block the leaky modes. For single-mode fibre, the disc is positioned to give optimum resolution.

Refracted modes passing the disc are collected and focused onto a photodiode. The focused laser spot is traversed across the fibre end and a plot of fibre refractive index variation is directly obtained.

2.6.4.2 *Equipment calibration*

The equipment is calibrated with the fibre removed from the liquid cell. During the measurement the angle of the cone of light varies according to the refractive index seen at the entry point to the fibre (hence the change of power passing the disc). With the fibre removed and the liquid index and cell thickness known, this change in angle can be simulated by translating the disc along the optic axis. By moving the disc to a number of predetermined positions the profile can be scaled in terms of relative index. Absolute indices, i.e. n_1 and n_2 , can only be found if the cladding index or the liquid index, at the measurement wavelength and temperature, is known accurately.

2.6.4.3 *Results*

The following details shall be presented :

- Test arrangement and wavelength correction procedure.
- Relative humidity and ambient temperature.
- Fibre identification. Depending on specification requirement :
 - . Profile through core and cladding centres calibrated for a given wavelength.
 - . Profiles along the core major and minor axes calibrated for a given wavelength.
 - . Profiles along the cladding major and minor axes calibrated for a given wavelength.

By the raster scan of the cross-section of the profile, the following quantities may be calculated :

- Diameter of core.
- Diameter of cladding.
- Concentricity error core/cladding.
- Non-circularity of core.
- Non-circularity of cladding.
- Maximum theoretical numerical aperture.
- Index difference.
- Relative index difference.
- Indications of accuracy and reproducibility.

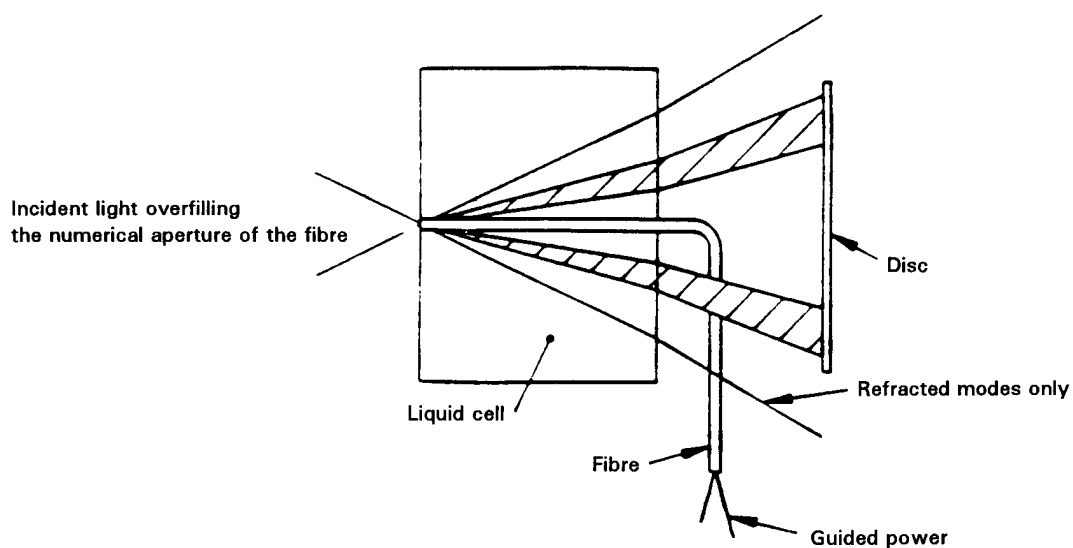


Figure 1 - Refracted near-field technique - Schematic diagram

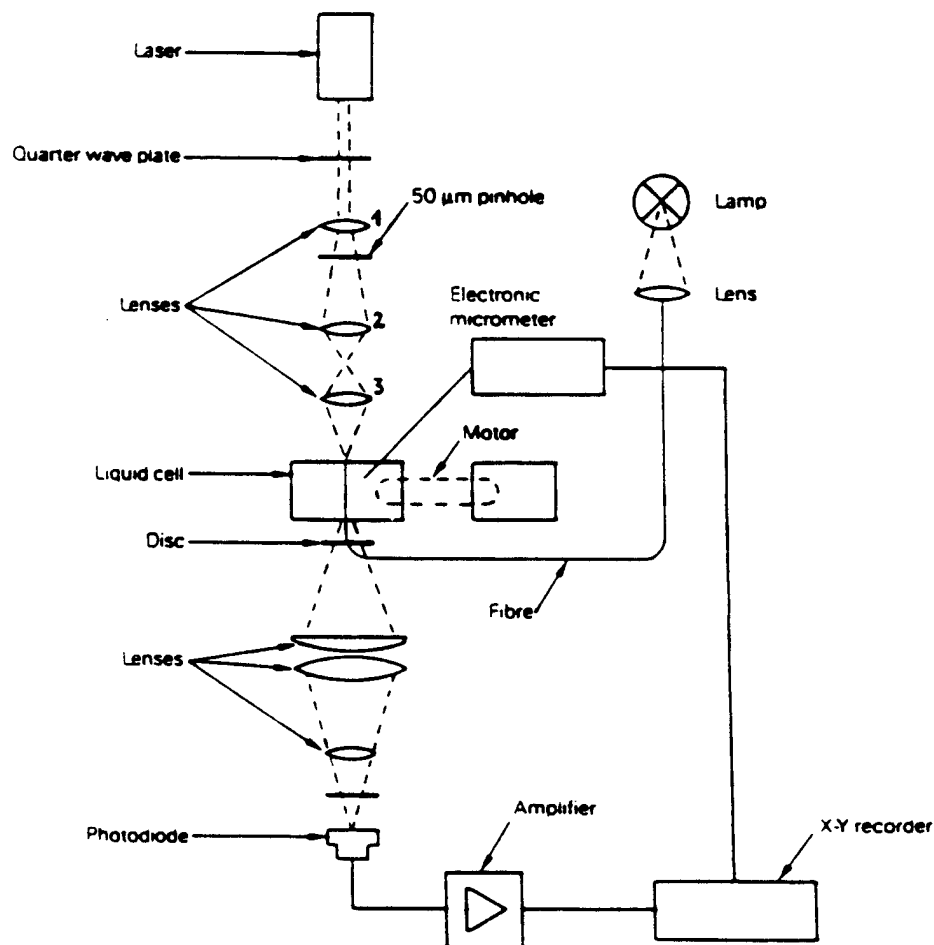


Figure 2 - Typical arrangement of the refracted near-field test set

2.7 Method 102 — Near field light distribution

2.7.1 *Object*

The following test is for incoming and/or outgoing inspection. Imaging is made on a cross section at the end of the fibre under test.

The image is magnified by an output optics, for example microscope and various kinds of sensors can be used (direct examination, photographic camera, digital video analyzer, scanning detector, etc.). Output optics and sensors may be combined in one apparatus.

2.7.2 *Sample preparation*

The sample shall be a short length of the optical fibre to be measured. This length shall be noted. The fibre ends shall be clean, smooth and perpendicular to the fibre axis.

2.7.3 *Apparatus*

2.7.3.1 *Light source*

The core illumination source shall be incoherent, adjustable in intensity and the type shall be noted. A second light source can be used to illuminate the fibre for cladding measurements purposes. The light source selected shall be stable for the required period of measurement.

2.7.3.2 *Detection systems*

Different detection systems can be used depending on the type of measurement to be done (visual inspection, photography, calculations on the complete pattern).

2.7.3.2.1 *Microscope*

An inverted metallurgical microscope or a biological microscope with a resolution near the diffraction limit shall be used (for example it should have a calibrated magnification of up to 600 x and be equipped with a filar micrometer).

2.7.3.2.2 *Microscope with a photographic camera*

The microscope described in Sub-clause 2.7.3.2.1. may be equipped with a camera for micro photography. A suitable scale shall be used to calibrate the dimensions in the photograph.

2.7.3.2.3 *Video analyzer*

The microscope described in Sub-clause 2.7.3.2.1. may be equipped with a TV camera. The output signal of the camera can be sent to a TV monitor for visual inspection or to a video analyzer in order to record the complete output near field of the fibre.

2.7.3.2.4 *Scanning detector*

The TV camera described in Sub-clause 2.7.3.2.3. can be replaced by a pinhole photodetector, to make one or several scans of the fibre output near field. The signal of the detector is sent to a XY recorder.

2.7.4 *Procedure*

- a) The end of the sample from which the image will be produced shall be prepared and so set as to make the end face perpendicular to the axis of the sample.
- b) The numerical aperture and hence the resolving power of the objective lens shall be compatible with the measuring accuracy required. The magnification shall be selected to be compatible with the fibre size and the field of view.
- c) The light source shall be attached to the other end of the sample, which may be prepared in the same way as the first end, and adjusted so that the fibre end image will be substantially free of any missing or unclear part. If necessary, index matching fluid shall be used to couple the optical power between source and sample.

2.7.4.1 *Microscope technique with visual inspection*

- a) The microscope shall be calibrated by measuring the length of an object of already known dimensions.
- b) The parameters of the sample to be measured may be determined by means of the filar micrometer and the known calibration. The minimum and maximum diameter shall be measured by rotating the image or the scale.

2.7.4.2 *Microscope technique with photography*

- a) The intensity of the front and back illumination, the shutter speed, 'f' stop and a film shall be selected to obtain a clear photograph, for example clearly showing the boundary between core and cladding.
- b) The overall image magnification shall be determined by photographing a scale of known calibration such as a stage micrometer.
- c) The size of the photographic image shall be more than 30 mm x 30 mm. the parameter to be measured shall be determined from the size of the image and the magnification.
- d) When using a scale as described in Sub-clause 2.7.3.2.2., a transparent scale shall be placed upon the photographs and judged.

2.7.4.3 *Microscope techniques with a video analyzer*

- a) The output field of the microscope is processed with a digital video analyzer controlled by a computer, such as a scanning vidicon, charge coupled device (CCD) or other pattern intensity recognition device.
- b) The complete image is monitored and the line being processed is indicated, for example by a cursor.
- c) The boundaries are found by contrast level criteria and referenced to a standard grating to give the geometrical parameters to be measured.

2.7.4.4 *Microscope technique with a pinhole scanning detector*

- a) Focus a magnified image of the sample core onto a plane.
- b) Determine the intensity of the magnified near field patterns. As examples, any of the following techniques may be used :
 - 1) scanning detector with pinhole ;
 - 2) scanning mirror with fixed pinhole aperture detector.
- c) Record the intensity as a function of detector position.
- d) Use a phase-locked amplifier system (or equivalent apparatus) to amplify the low level signals.
- e) Scan fibre core image or pinhole detector by means of a stepping motor translation stage or a scanning mirror.
- f) Record intensity (signal) as a function of position of the core diameter.
- g) The microscope shall be calibrated by measuring the length of an object of already known dimensions.

2.7.5 Documentation

The following data shall be presented :

- Fibre identification.
- Number of samples.
- Relative humidity and ambient temperature.
- Description of apparatus.
- Magnification.
- Parameters measured.
- Photographic images or video analyzer print out if applicable.

2.8 Method 103 — Four concentric circles

2.8.1 Object

The following is a compliance test for optical fibre dimensional parameters and tolerances. It is not valid for measuring the actual values of core and cladding diameter, non-circularity and concentricity errors.

This method gives evidence of compliance with the set of dimensional specification values. It should be used as an incoming and/or outgoing inspection.

The four concentric circles form two rings with the diameters :

$$\begin{array}{ll} D_{CL} + \Delta D_{CL} \\ D_{CL} - \Delta D_{CL} & \text{for the cladding} \\ D_{CO} + \Delta D_{CO} \\ D_{CO} - \Delta D_{CO} & \text{for the core} \end{array}$$

which define the tolerance field.

A fibre will pass this test if a position of fibre and tolerance field can be found where both the cladding contour and the core contour lie completely inside the two rings. Values for D_{CL} , ΔD_{CL} , D_{CO} and ΔD_{CO} should be taken from the detail specification.

2.8.2 Sample preparation/selection

The sample should be a short length of the optical fibre to be measured. This length should be noted.

2.8.3 *Apparatus*

2.8.3.1 *Light source*

See Sub-clause 2.7.3.1.

2.8.3.2 *Microscope*

See Sub-clause 2.7.3.2.1.

2.8.3.3 *Microscope with a photographic camera*

See Sub-clause 2.7.3.2.2.

2.8.3.4 *Video analyzer*

See Sub-clause 2.7.3.2.3. The comparison between the given four circles and core and cladding limits may be done by computation, visual or printed display.

2.8.3.5 *Scanning detector*

See Sub-clause 2.7.3.2.4

2.8.3.6 *Mask*

A mask with four concentric circles should be provided and inserted in the optical measuring system.

The accuracy of the mask shall be such that the accuracy given in the detail specification can be obtained on the sample.

One of the following methods can be applied :

- a) A mask in the ocular of the microscope.
- b) A transparent mask upon the photograph.
- c) Two separate objectives in the microscope for mask and sample respectively.

Note. - For a video analyzer a hardware mask is not required.

2.8.4 *Procedure*

The prepared sample is fixed in the sample holder and illuminated by the light source in such a way that the core and cladding contours are as clear as possible. By manipulating the sample the contours of core and cladding are brought inside the two rings. If this is possible the fibre has passed the test. If so desired a photograph is taken to indicate the test result (passed/not passed).

2.8.5 *Documentation*

The following data shall be presented :

- Fibre identification.
- Number of samples.
- Relative humidity and ambient temperature.
- (Photography)
- Description of apparatus type of microscope and mask.
- Test result : passed/not passed

2.9 **Method 104 — Mechanical diameter measurement**

2.9.1 *Object*

The following method applies to the mechanical measurement of the cladding diameter of an optical glass or silica fibre. In practice for smooth and substantially circular fibres, it gives a similar result to that obtained by methods 101 and 102, in which case non-circularity of fibre can also be determined. This method can also be used for the measurement of the coating diameter of some types of coated or buffered fibres or A3 or A4 fibres. In this method both sides of the object are contacted with flat parallel surface, and the separation of the surfaces is accurately measured.

2.9.2 *Scope*

The diameter of a fibre and coated fibre are fundamental values and shall be known for subsequent procedures such as handling, splicing, connectorization, cabling and measurements.

2.9.3 *Test apparatus*

2.9.3.1 *General*

The measurement uses two anvils with very flat faces to contact each side of the fibre. The faces of the anvils shall be parallel to each other and the contact force which the anvils apply to the fibre shall be precisely controlled to prevent physical distortion of the specimen or the anvils.

2.9.3.2 *Apparatus*

Refer to the schematic diagram of the test apparatus (Figure 3).

2.9.3.2.1 *Anvils*

There are two anvils, one fixed and the other mounted on a precision stage. The anvil faces are parallel to each other and perpendicular to the stage movement direction. They are made of a hard non-corrosive material, for example stainless steel or fused silica.

2.9.3.2.2 *Precision stage*

The precision stage holds the moveable anvil and the retroreflector for the electronic micrometer system. The stage is moved by a micrometer screw ; the stage is held against the screw by springs. The springs act to pull the anvils together.

2.9.3.2.3 *Electronic micrometer system*

An electronic micrometer system, such as a double-pass Michelson interferometer, may be used with a retroreflector to measure accurately the movement of the stage and thus the moveable anvil.

2.9.3.2.4 *Specimen supports*

These support the specimen between the faces of the anvils.

2.9.3.3 *Procedure*

2.9.3.3.1 *Principle of measurement*

The diameter of the specimen is measured by contacting opposite sides with the anvils. The contact force, which is controlled by the stage spring tension and the anvil contact surface, is adjusted so that negligible distortion of the specimen or anvils occurs. Values for individual materials shall be agreed between supplier and user.

For example, for a 125 μm diameter fused silica fibre this force is typically 0,2 N for anvils with a length of contact of 1 mm along the fibre.

The separation of the anvils is accurately measured with the electronic micrometer.

2.9.3.3.2 Measurement

The anvil faces are cleaned and the micrometer screw turned to bring the anvil faces into contact with each other. The micrometer screw is turned an extra amount so that the anvils are held together by the spring tension only. The electronic micrometer distance reading is recorded. The micrometer is next adjusted so that the gap between the anvil faces is larger than the specimen diameter. The specimen fibre is placed on the supports between the anvil faces. The micrometer screw is turned slowly to bring the anvil faces into contact with the fibre so that the anvils are held against the fibre by the spring tension only. The electronic micrometer distance reading is recorded. The difference between the first and second reading is the specimen diameter. The measurement should be repeated a few times to ensure repeatability.

2.9.3.4 Results

The specimen average diameter and standard deviation derived from a number of measurement should be given to indicate measurement repeatability.

Non-circularity of fibre can be determined by a series of measurements in which the fibre is rotated between each measurement.

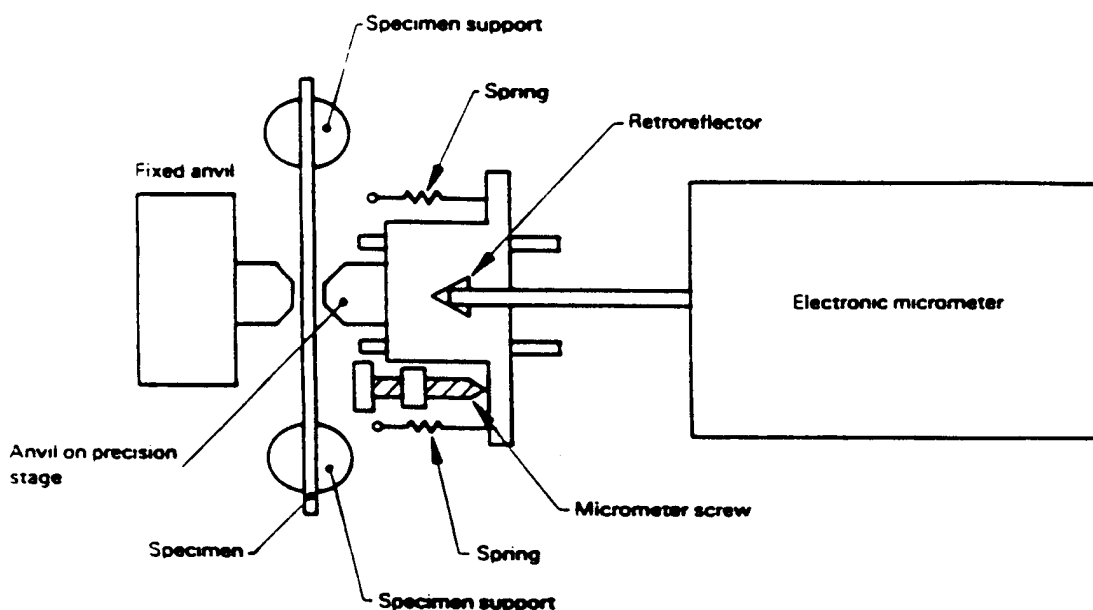


Figure 3 - Top view of electronic micrometer system

2.10 Method 105 — Mechanical length measurement

Under consideration.

2.11 Method 106 — Length measurement by delay measuring of transmitted pulse and/or reflected pulse

2.11.1 *Object*

The following method applies to measurements of the fibre length by the measurement of the propagation time of an optical pulse or a pulse train on the basis of a known value of the group index of the fibre.

Alternatively, this method is suitable to measure the group index of a fibre of known length. Therefore in practice this fibre length measurement method is calibrated against a known length of fibre of the same type.

The length of an optical fibre is one of the most fundamental values and shall be known for the evaluation of the transmission characteristics such as losses and bandwidths.

2.11.2 *Principle*

An optical pulse travelling through an optical fibre with length L and average group index N , experiences a travelling/delay time Δt :

$$\Delta t = \frac{NL}{c}$$

where :

Δt is the time delay, and

c the velocity of light in vacuum.

If N is known, the measurement of Δt gives L and on the other hand, the measurement of Δt gives the value of N when L is known.

Note. - Tolerances on the group index caused by tolerances on numerical aperture should be taken into account.

2.11.3 *Sample*

The sample can be a fibre (possibly in a cable). The value of N should be ascertained under conditions applicable to the sample under test (for example tension, temperature).

2.11.4 *Apparatus*

2.11.4.1 *General*

There are two methods for measuring the propagation time of an optical pulse as follows :

- a) time measurement of the transmitted pulse (Δt measured) ;
- b) time measurement of the reflected pulse ($2 \Delta t$ measured).

Two different arrangements corresponding to the two techniques applying a sampling oscilloscope, are illustrated in figure 4.

Instead of the sampling oscilloscope, backscattering equipment or a counter with separate start/stop gate and averaging capability (for example at least 10^4 counts) can be used.

2.11.4.2 *Optical source*

a) Measurement with the sampling oscilloscope

An optical pulse generator shall be preferably a high power laser diode, excited by an electrical pulse train generator tunable in frequency and width. The wavelength and the spectral width must be recorded.

b) Measurement with a counter or a backscattering apparatus

An optical pulse generator shall be preferably a high power laser diode, excited by an electrical pulse train generator tunable in width. The time between two pulses shall be longer than the travelling time of the transmitted pulse (Δt , with counter) or the reflected pulse ($2 \Delta t$, with backscattering-equipment). The wavelength and the spectral width of the laser diode shall be recorded.

2.11.4.3 *Optical detector*

The receiver shall be preferably a high speed avalanche photodiode. The sensitivity of the optical detector shall be sufficient at the measuring wavelength, and its bandwidth shall be large enough so as not to influence the shape of the pulse.

2.11.5 Procedure

a) Calibration

The delay time of the optical source to the launching point shall be measured (the delay time of the measurement apparatus itself).

b) Average group index value

On a known length of fibre, mechanically measured, the measurement of Δt gives the average value N of the group index of the fibre.

c) Length measurement

The length measurement is a time domain reading on the screen of an oscilloscope¹ (or the reading of the averaged travelling time on the display of an electronic counter to be corrected for the calibration value).

2.11.6 Results

The fibre length is obtained from the following equation :

a) Transmitted pulse method

$$L = \frac{\Delta t \cdot c}{N}$$

b) Reflected pulse method

$$L = \frac{\Delta t \cdot c}{2N}$$

where :

L = fibre length (m)
 Δt = transmission or reflection time (ns)
 c = light velocity in vacuum (m/ns)
 N = average group index

2.11.7 Documentation

The following data shall be presented :

- Fibre identification.
- Relative humidity and ambient temperature.
- Measuring method.
- Wavelength.
- Group index.
- Delay time of the measurement apparatus².
- Transmission or reflection time².
- Fibre length.

¹ An important practical improvement can be achieved in making the accuracy of the measurement independent from the actual length of the fibre by means of a dual channel oscilloscope method (see Figure 5).

² Optional.

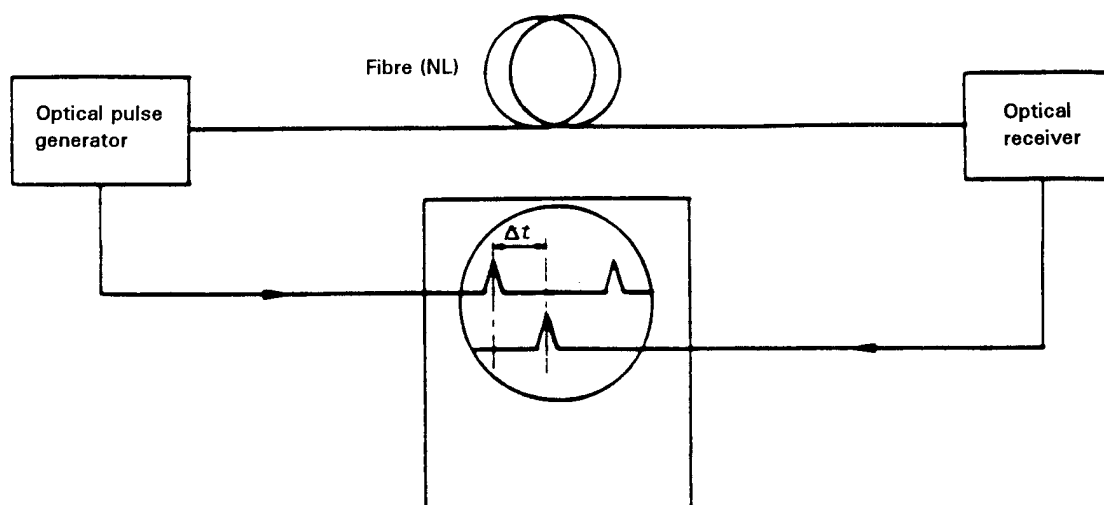


Figure 4a - Time measurement of the transmitted pulse

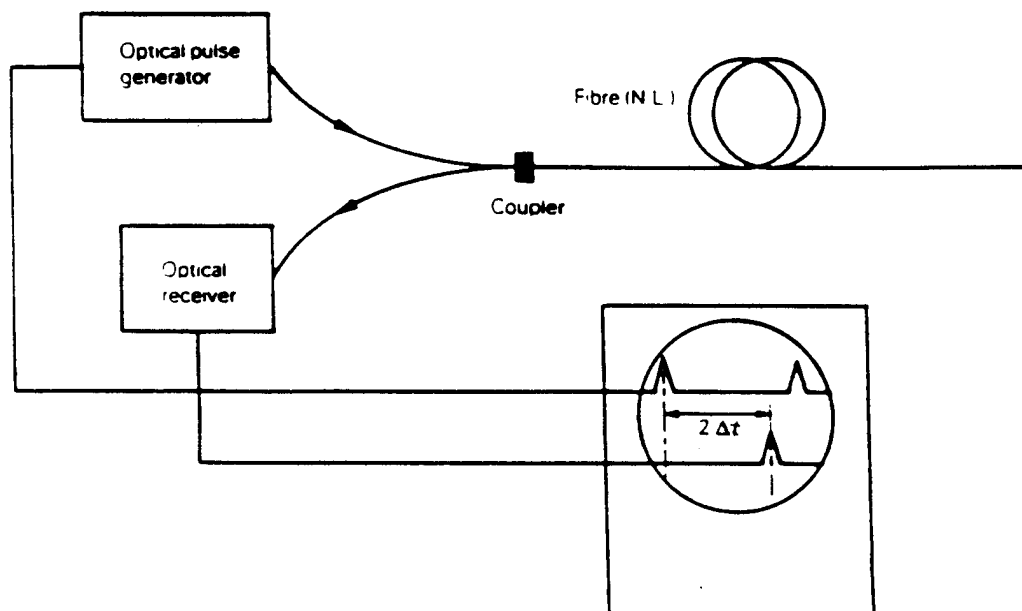


Figure 4b - Time measurement of the reflected pulse

Figure 4 - Measurement of fibre length by propagation time of optical pulses

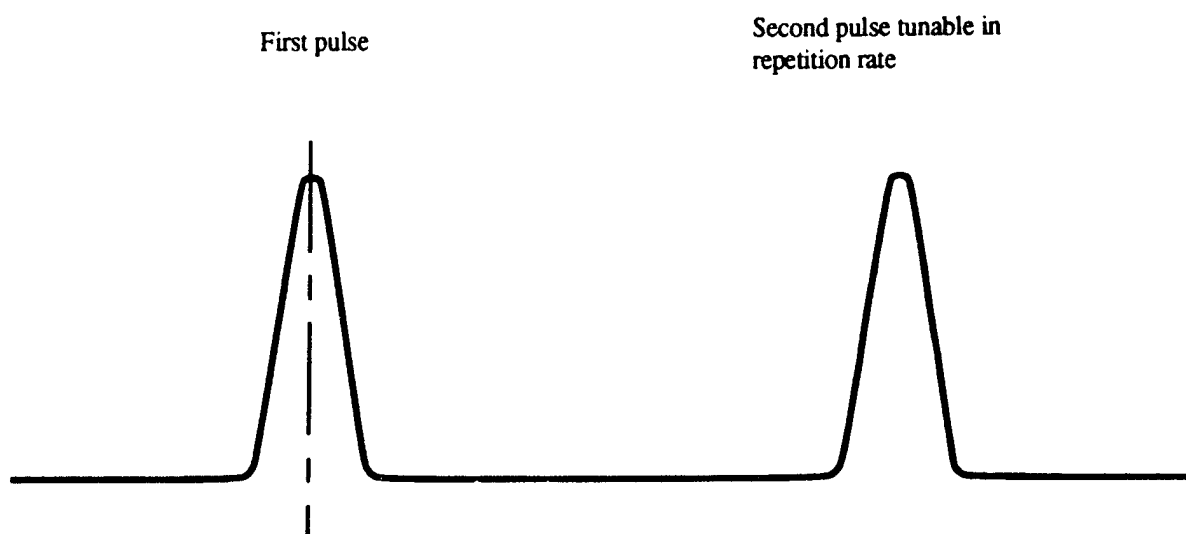


Figure 5a - Channel 1 : Emitted pulse

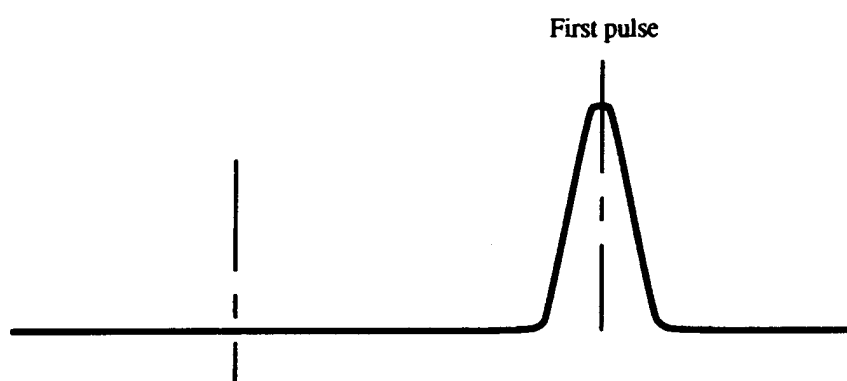


Figure 5b - Channel 2 : Transmitted pulse

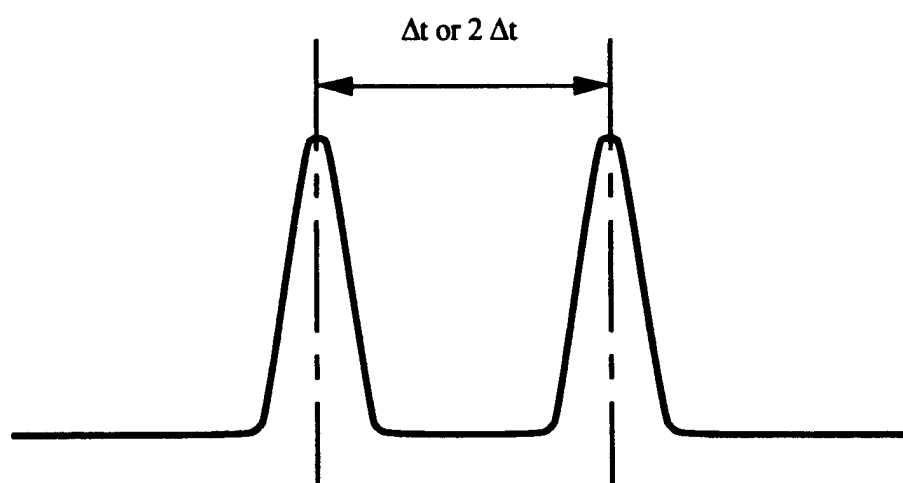


Figure 5c - Channel 1 : Emitted pulse after adjustment of the repetition rate in such a way that the second pulse in channel 1 coincides with the transmitted pulse of channel 2

Figure 5 - Principle of fibre-length measurement

SECTION THREE - MEASURING METHODS FOR MECHANICAL CHARACTERISTICS

3.1 Object

The test methods apply to the tests of mechanical strength, ease of handling or the recognition of physical defects of primary coated or primary buffered optical glass fibres. The methods are to be used for inspection of fibres for commercial purposes.

The mechanical characteristics of optical fibres shall be verified by subjecting samples to tests selected from Table III. The tests applied, acceptance criteria and number of samples shall be as specified in the detail specification.

TABLE III

Mechanical characteristics of optical fibres

Test method	Test	Characteristics covered by test method
201 202 203*	Optical fibre proof test Tensile strength for short length of fibre Tensile strength for long length of fibre	Mechanical strength
204*	Abrasion	Ease of handling
205* 303	Visual inspection Backscattering technique	Physical defects
206	Strippability	Strippability

* Under consideration.

3.2 Operational definitions

3.2.1 *Mechanical strength of a length of glass fibre*

- a) The mechanical strength of a length of glass fibre depends on the depth of the deepest flaw present in this length.

In submitting a length of fibre at ambient temperature and humidity conditions to a stress α the flaw depth will increase in accordance with a relation suggested by Charles :

$$\frac{da}{dt} = AK_1^n$$

in which K_1 according to Griffith is given by $K_1 = Y\alpha a^{1/2}$

where :

K_I = stress intensity factor

Y = shape factor (constant)

α = stress

n = stress corrosion susceptibility (constant)

a = flaw depth

A = proportionality constant, to be determined by experiment

In cases where the flaws have grown during a time Δt to a value where K_I becomes K_{Ic} (critical stress intensity factor) the fibre will break (see figure 6).

b) As an illustration :

When a fibre has been submitted to stress α_1 during a time $\Delta t = t_2 - t_1$, the flaw will have grown from a_{t1} to a_{t2} .

However, for commercial purposes it should be assumed that after a fibre has been submitted to a screen test with stress α_1 , the flaw has almost reached the value a_c (i.e. the value at which fibre breakage would occur), subsequent stress α_2 (at $t > t_2$) must remain below α_1 , if fibre breakage is to be avoided.

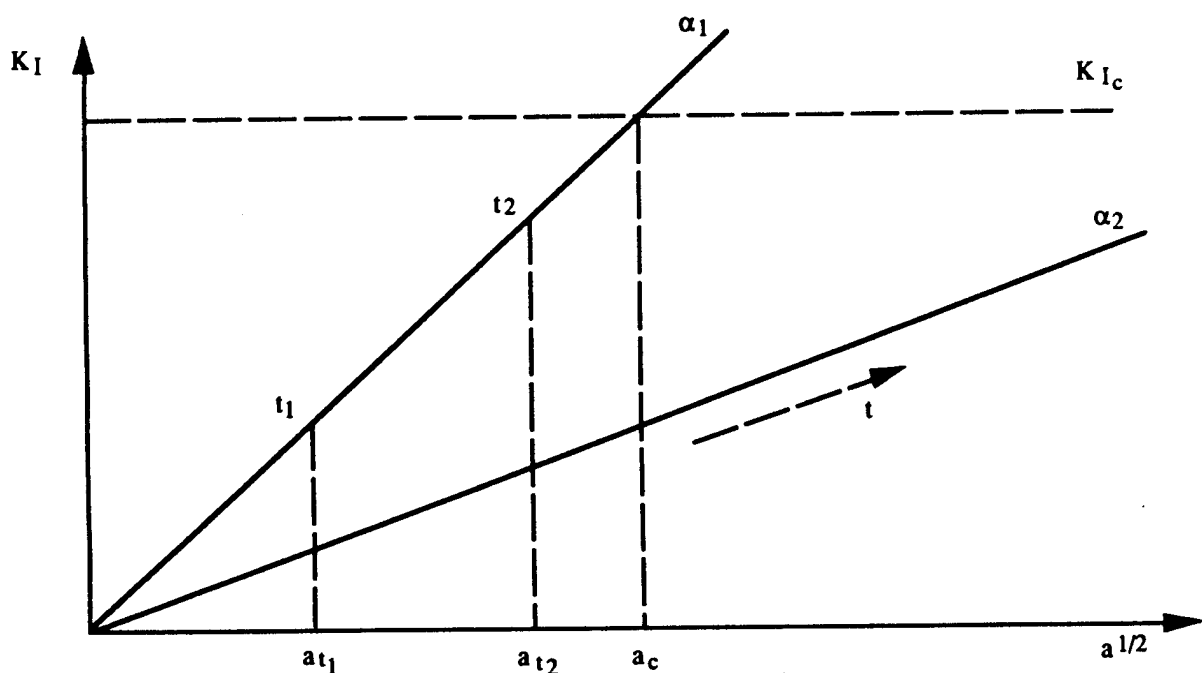


Figure 6 - Graph of flaw growth of optical glass fibre under stress

3.3 Physical defects

It is recognized that physical defects may exist within the fibre and influence both optical and mechanical performance for example inclusions and bubbles. Certain types of defects may be detected by means of reflection techniques or other measurement methods.

3.4 Method 201 — Optical fibre proof test

3.4.1 *Object*

In this test the entire length of an optical fibre is proof tested to eliminate points with mechanical strength equal to or lower than the proof test level.

3.4.2 *Conditions of testing*

The test shall be carried out at standard atmospheric conditions for testing in accordance with Sub-clause 5.3 of IEC 68-1.

3.4.3 *General test procedures*

3.4.3.1 The proof test shall be in accordance with one of the following methods :

- a) constant stress ;
- b) constant longitudinal strain ;
- c) constant bending strain.

3.4.3.2 The tests at constant stress and constant longitudinal strain are appropriate for fibre with protective coatings and buffers of elastic modulus and thickness adequate to withstand the longitudinal and radial forces imposed, and to protect the surface of the fibre from deleterious radial stresses. Where primary coatings and buffers are not adequate to withstand these forces, the test at constant bending strain may be appropriate.

3.4.3.3 The proof test level shall be that experienced by the optical fibre after correction has been made for the presence of any protective coatings and buffers.

3.4.3.4 Tension variations in fibre pay-out and take-up shall be isolated from the proof test region of the apparatus.

3.4.3.5 The speed of the fibre through the apparatus and the apparatus geometry shall be such that the proof test is applied for the time required in the detail specification.

3.4.4 *Constant stress proof test*

3.4.4.1 *Apparatus*

The constant stress proof test apparatus shall be generally in accordance with figure 7. A and C are driven wheels or pulleys, and B is the free running wheel or pulley coplanar with the other two, which has free spatial movement restricted to a vertical line through its axis. A weight W applied to B provides the stress-related tension T. It is an essential requirement that the coefficient of static friction between the optical fibre and wheels A, B and C shall be high, and means may be provided, such as pressure belts, to ensure that slippage is minimized. One of the wheels shall be driven at constant angular velocity, and means shall be provided to maintain a constant vertical position for wheel B by varying the angular velocity of wheel C. The feed tension T_i shall not exceed 10 % of the test tension T. The diameter of the wheels shall be such that the stress due to bending at any point of the optically transmitting element shall not exceed 10 % of the test value.

3.4.4.2 *Procedure*

The optical fibre shall pass through the apparatus as shown in figure 7 at a velocity corresponding to the proof test time required in the detail specification.

The mass of the weight W applied to the free running wheel or pulley B shall be stated in the detail specification.

3.4.4.3 *Requirements*

After the test, the optical fibre shall be examined for breaks using an optical time domain reflectometer or other means. The fibre shall exhibit no breaks.

3.4.5 *Constant longitudinal strain proof test*

3.4.5.1 *Apparatus*

The constant strain proof test apparatus shall be generally in accordance with figure 8 ; A and B are wheels or pulleys which are arranged to rotate with a peripheral velocity difference equal to the required strain.

The velocity difference may be achieved by arranging that the wheels have the same nominal diameter but rotate with an angular velocity difference corresponding with the required strain level, or that the diameters of the wheels are in a fixed ratio corresponding with the required strain level, but the wheels are coupled to rotate at the same angular velocity. The coefficient of static friction between the optical fibre and the wheels shall be high to minimize slippage, and pressure belts or similar devices may be used. The strain corresponding to the feed tension T_i shall not exceed 10 % of the test value. The diameter of the wheels shall be such that the strain due to bending at any point of the optically transmitting element shall not exceed 10 % of the test value.

3.4.5.2 *Procedure*

The strain applied shall be set to the value stated in the detail specification, either by adjusting the speed controls to the wheels to give the required rotational difference, or by fitting wheels with the required diameter difference.

The optical fibre shall be passed through the constant strain proof-test apparatus at a velocity corresponding to the test time stated in the detail specification.

3.4.5.3 *Requirements*

After the test the optical fibre shall be examined for breaks, using an optical time domain reflectometer or other means. The fibre shall exhibit no breaks.

3.4.6 *Constant bending strain proof test*

3.4.6.1 *Apparatus*

The constant bending strain test apparatus shall be generally in accordance with figure 9. A, B and C are three rollers that are free to rotate around parallel axes. The fibre is drawn along a path in which it is bent over the freely rotating rollers under sufficient tension that it conforms with the roller geometry. The roller diameters are chosen so that the maximum strain induced by bending in the surface of the fibre is equal to the required strain, after allowing for the thickness of any protective coatings or buffers.

In order to ensure a near constant maximum strain to all parts of the fibre surface a number of sets of rollers are used arranged at angles to the first.

Typically four sets of rollers at 45° to each other may be used (Figure 10).

The fibre pay-out and take-up arrangements are arranged to avoid twisting of the fibre as it passes through the machine.

3.4.6.2 Procedure

The strain shall be set to the value stated in the detail specification by the choice of roller diameter. The optical fibre shall be passed through the constant strain test apparatus at a velocity corresponding to the test time stated in the detail specification.

3.4.6.3 Requirements

After the test the optical fibre shall be examined for breaks, using an optical time reflectometer or other means. The fibre shall exhibit no breaks.

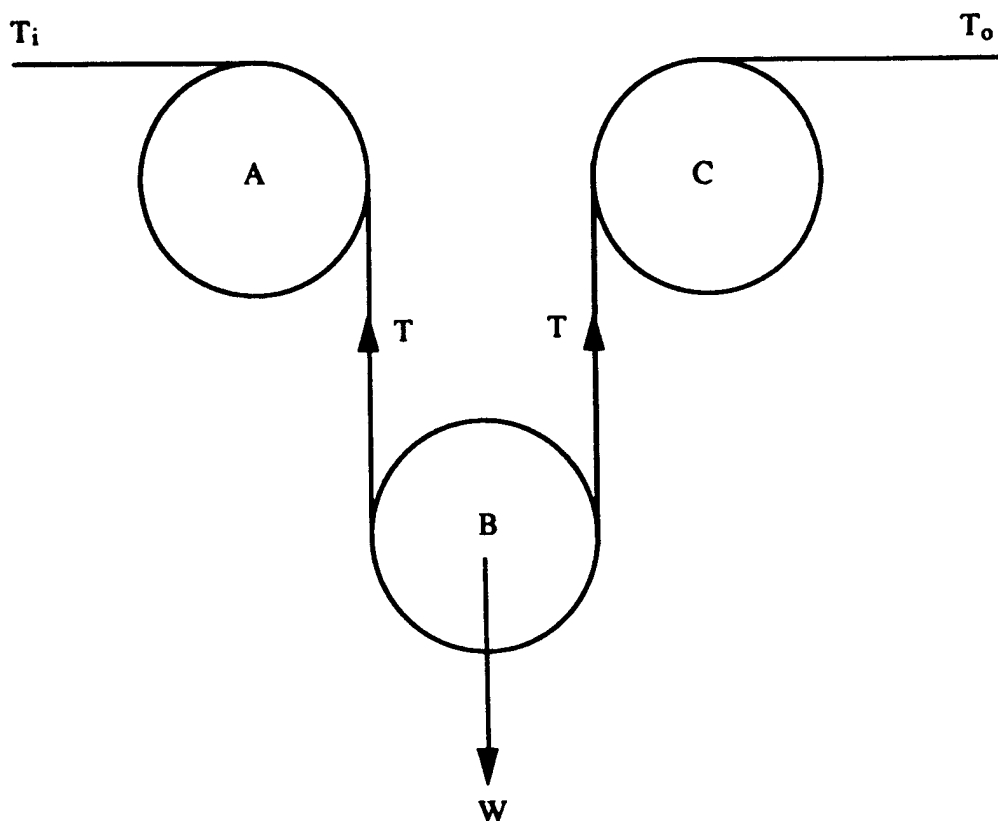


Figure 7 - Constant stress proof test apparatus

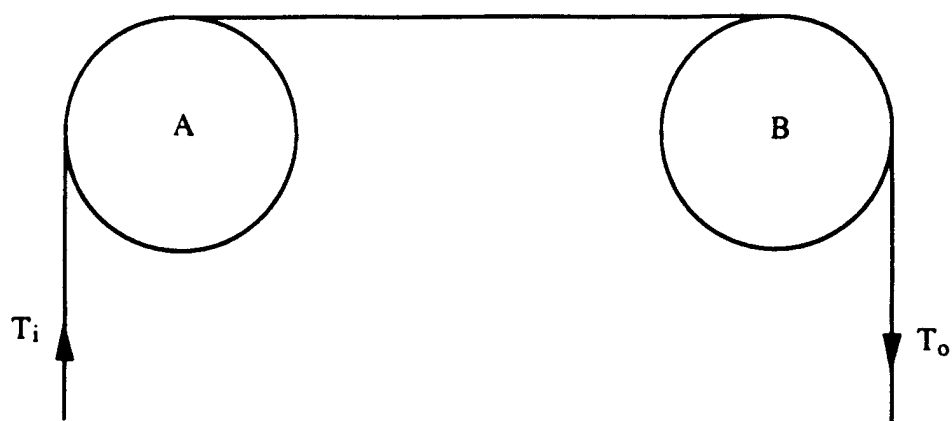


Figure 8 - Constant strain proof test apparatus

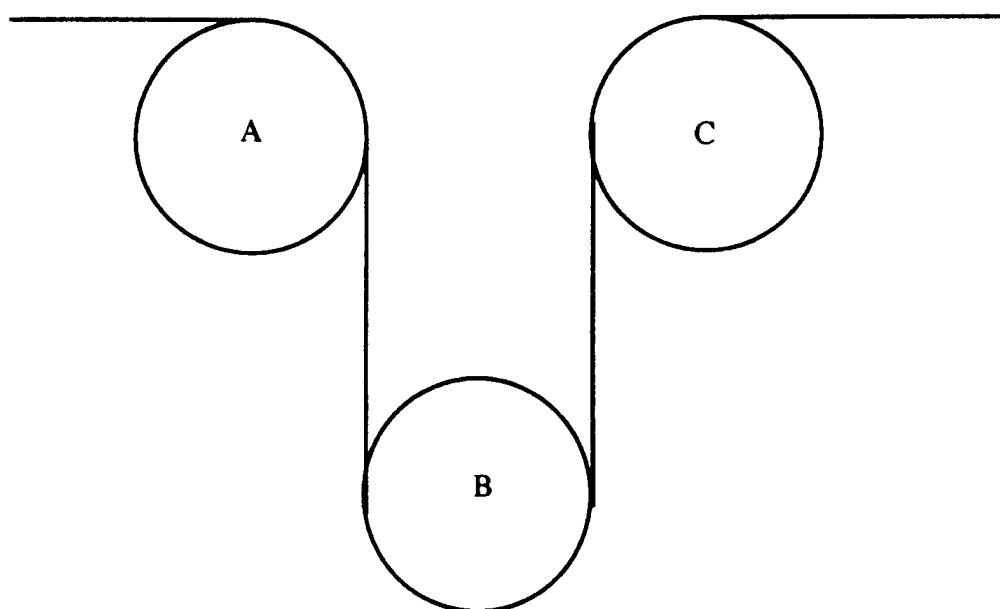


Figure 9 - Constant bending strain test apparatus

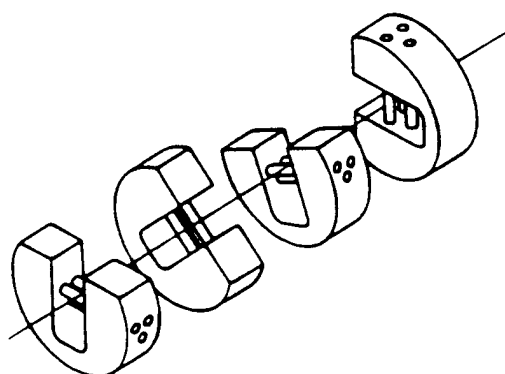


Figure 10 - Multiple rollers

3.5 Method 202 — Tensile strength for short lengths of optical fibres

3.5.1 *Object*

The test will give values of the tensile strength of short lengths of optical fibre. The distribution of the tensile strength values of a given fibre strongly depends on the sample length, loading velocity and environmental conditions. The test shall be for inspection where statistical data on fibre strength is required. The results should be reported by means of statistical quality control distribution. Normally the test is carried out after temperature and humidity conditioning of the sample. In some cases, it may be sufficient to measure the values at ambient temperature and humidity conditions.

3.5.2 *Sample preparation*

Samples shall be prepared such that the length under test will be up to 1 m.

3.5.3 *Apparatus*

A suitable tensile machine shall be used with clamping devices which avoid damaging and slipping of the sample. The pulling speed should be about 3 % - 5 % of the sample length per minute.

Note. - The tensile machine may have a vertical or a horizontal pulling direction. The fibre clamping can be achieved by means of chuck drums or other suitable means.

3.5.4 *Conditioning* (if required, see detail specification)

If required the samples can be conditioned in a bath of tap water with a temperature of 20 °C or in a climate chamber (with for example a controlled temperature 23 °C and a relative humidity of 95 %). The conditioning time should be not less than 24 h.

3.5.5 *Procedure*

Test A (without conditioning) :

The sample shall be placed in a tensile machine in such a way, that the free length between the jaws is up to 1 m. The speed is given in the fibre detail specification.

Test B (with conditioning) :

The test shall be started within 5 min after removing the sample from the conditioning device under the same procedure as described in the test A.

3.5.6 Results

The following data shall be presented :

- Gauge length.
- Type of clamping fixtures.
- Pulling speed.
- Relative humidity and ambient temperature.
- Fibre identification.
- Length of sample.
- Strength values ; the strain value under which the fibre breaks shall be reported as the strength of fibre.
- As a reference, the quality distribution of the same category should also be reported, for example by means of a Weibull distribution. The relevance of the distribution plot depends upon the total length of fibre tested as well as the lengths of the test samples.

Note. - In case of fracture near the clamping region (for example 10 mm to 15 mm) the value should not be incorporated in the statistical quality control distribution but should be reported separately.

3.6 Method 203 — Tensile strength for long lengths of optical fibres

Under consideration.

3.7 Method 204 — Abrasion

Under consideration.

3.8 Method 205 — Visual inspection

Under consideration.

3.9 Method 206 -- Strippability

3.9.1 Object

3.9.1.1

This test quantifies the force required to mechanically remove the protective coating from optical fibres along their longitudinal axis. This test is not intended as a means to maximise fibre strength after the coating is removed nor it is intended to specify the best conditions for field stripping of optical fibres.

3.9.1.2

This test is intended primarily for testing either fibres as produced by a fibre manufacturer or subsequently overcoated (tight buffered) using various polymers. The test can be performed either on fibres as produced or after exposure to various environments.

3.9.1.3 This test applies to A1, A2, A3 and B fibres.

3.9.2 *Apparatus*

3.9.2.1 *Tensile Equipment*

A suitable device, for example a vertical tensile tester, shall be used which provides relative motion between the test fibre and a stripping tool.

It shall be capable of imparting constant motion, without jerking, to the fibre under test, or alternatively to the stripping tool.

The movement shall be at the rate given in Paragraph 3.9.4.2 below.

The device shall be capable of providing relative motion in two directions to allow resetting. Suitable means shall be included for clamping and maintaining the stripping tool blades perpendicular to the fibre axis or in a position which prevents fibre bending, and for securing one end of the test fibre. To prevent fibre breakage, the means used to secure the fibre at the clamping point shall not stress the fibre excessively.

Examples of test arrangements are shown in Figure 11.

3.9.2.2 *Load Cell*

Use any appropriate device which is capable of sensing the force imparted to the fibre during the removal of the fibre coating.

3.9.2.3 *Transducer Amplifier*

This device receives signals from the load cell and indicates the tensile force on the test fibre up to the point when the coating is stripped off. The readout shall be continuous, such as a strip chart recorder, and shall provide sufficient information to calculate the maximum and average forces and the amplitude and frequencies of any oscillations in the force during stripping.

The accuracy of the force measurement shall be as specified in the Detail Specification.

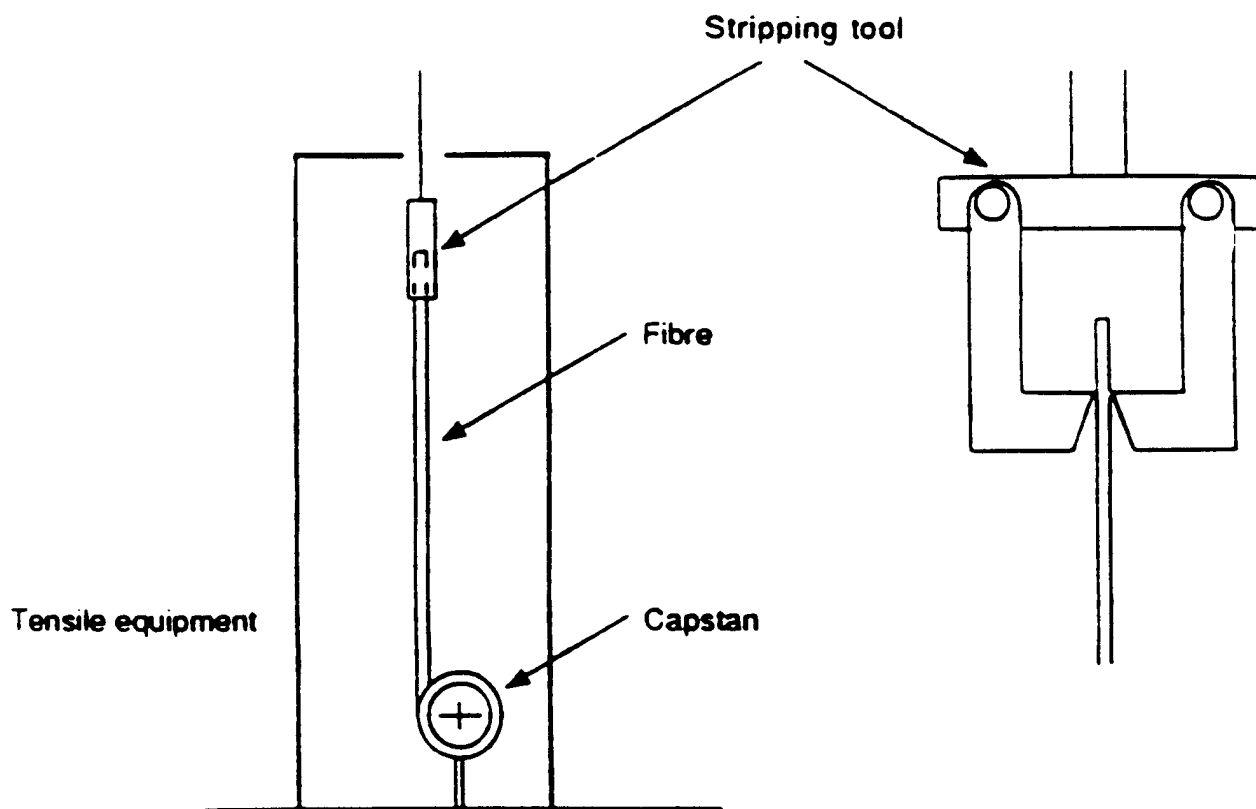
3.9.2.4 *Stripping Tool*

3.9.2.4.1

Because the results from this test are strongly dependent upon the design of tool used, it is important that the following tool design guidelines be observed:

a) Unless otherwise specified in the Detail Specification, the diameter of the hole in the tool blades or the distance between the blades shall be greater than the nominal cladding diameter of the fibre to be stripped in order not to damage the cladding surface. A practical example is a hole or distance between the blades which is 50 μm larger than the nominal cladding diameter.

b) The stripping tool blades shall be constructed such that the blades do not cause fibre bending. Stripping tools in which the blades butt together in the same plane are preferred in this test.



Either Stripping tool
or capstan is fixed

Figure 11

3.9.2.4.2

The stripping tool shall be mounted on the test fixture and held closed around the fibre using suitable clamps.

3.9.2.4.3

Stripping tools shall be replaced at intervals as dictated by a documented quality schedule or whenever wear is sufficient to affect the test results. (Note: Tool wear can affect any or all of the following : fibre breakage, the amount of residue left on the glass surface, the way in which the coating is removed from the fibre, and the force required to remove the coatings).

3.9.2.5 *Fibre Guide*

The fibre which extends past the stripping tool blade shall be held straight by use of a suitable guide (which may be designed into the stripping tool itself) which meets the following requirements:

- a) The guide shall support the fibre to prevent sagging due to the weight of the fibre.
- b) The guide shall prevent bending of the fibre caused by buckling of the fibre coating as it is removed.
- c) The guide shall be located as close to the stripping tool as possible without interfering with the stripping operation.
- d) The guide shall allow for easy insertion into the test set-up and for easy cleaning, and shall provide freedom from interference if the coating buckles.

3.9.3 *Sample preparation*

3.9.3.1 *Representative Samples*

The sample shall be representative of the population of fibres under evaluation. Because of the test variability, a minimum of 10 test pieces shall be tested and averaged to obtain one result for a particular sample.

3.9.3.2 *Sample Length*

The length of fibre stripped can affect the strip force. However for 250 μm nominal coating diameter fibres, the length of fibre stripped has minimal effect on the strip force. The length of fibre stripped shall be specified in the Detail Specification (For 250 μm nominal coating diameter fibres, preferred values are 20, 30 or 50 mm. For larger coating diameter, shorter stripping lengths are preferred).

Total sample length is determined by the distance between the secured fibre end and the stripping tool, the length of fibre specified to extend past the stripping tool (see figure 12), and the length of fibre required to secure it to the test fixture. Test results depend, in part, on the length of the fibre extending past the stripping tool; results are not dependent upon total sample length.

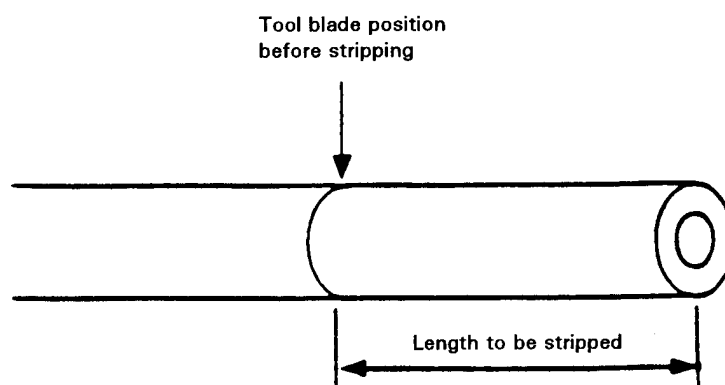


Figure 12

3.9.4 Procedure

3.9.4.1 Introduction

This procedure involves (a) severing the coating at the prescribed distance from the end of the fibre, and (b) then removing the coating from the fibre while measuring the force required to accomplish this removal.

3.9.4.2 Stripping Rate

The force required to remove coatings from fibre is dependent, in part on the stripping rate. If results of different tests are to be comparable, the same stripping rate shall be used. The test equipment shall be set so as to impart a relative motion between the fibre and the stripping tool at the rate specified in the Detail Specification (a preferred value for 250 μm nominal coating diameter fibre is 100 or 500 mm/min, for larger coating diameters, 100 mm/min is preferred).

3.9.4.3 Preconditioning

Unless otherwise specified, the test samples shall be preconditioned for a minimum of 24 hours at $(25 \pm 5)^\circ\text{C}$ and 30% to 60% RH.

3.9.4.4 *Calibrating the Transducer Amplifier*

The Transducer and load cell shall be calibrated before each series of tests or as dictated by a documented calibration schedule.

3.9.4.5 *Loading the Test Sample*

The area around both blades of the stripping tool shall be free of debris and/or build-up from any previous use before loading the fibre.

One end of the test fibre shall be secured to the test fixture so that it will not slip under load (eg 3 turns of fibre around an 80 mm diameter capstan). The other end is threaded through the stripping tool and inserted through the fibre guide/support.

3.9.4.6 *Stripping the Coating*

3.9.4.6.1 Start the test apparatus to provide a constant relative motion between the fibre and the stripping tool.

3.9.4.6.2 Observe and record the force required to remove the coating from the glass fibre. Exclude data from fibres which break during the test.

3.9.4.6.3 The test is complete when the coating has been completely removed from the fibre.

Note: Any remaining coating residue visible to the naked eye shall be easily removable by gently wiping the fibre with a laboratory tissue.

3.9.5 *Results*

3.9.5.1 The following information shall be reported with each test:

- 3.9.5.1.1 Test date.
- 3.9.5.1.2 Identification of the fibre tested including coating outer diameter and coating material type.
- 3.9.5.1.3 Identification of type of stripping tool used including manufacturer and nominal blade hole size.
- 3.9.5.1.4 The strip rate.
- 3.9.5.1.5 Length of coating stripped.
- 3.9.5.1.6 Test results including:

- a) Number of unbroken or undamaged fibres tested.
- b) Average of results obtained on 10 or more test pieces for the mean stripping force, excluding the first peak.
- c) Standard deviation or range of the sample population.
- d) Number of fibres tested which broke or were damaged before completely removing the coating.
- e) Environmental conditions for preconditioning and during the test including temperature and relative humidity.
- f) If the coating residue is not readily removable per 3.9.4.6.3 report so.

SECTION FOUR - MEASURING METHODS FOR TRANSMISSION AND OPTICAL CHARACTERISTICS

4.1 Object

The measuring methods apply to the practical measurements of transmission and optical parameters of an optical fibre. The methods are to be used for inspection of fibres and cables for commercial purposes.

The transmission and optical characteristics of optical fibres shall be verified by carrying out the selected test from those shown in Table IV. The tests applied and acceptance criteria shall be as specified in the detail specification.

TABLE IV
Transmission and optical characteristics of optical fibres

Tests methods of multimode and single-mode fibres		
Test method	Test	Characteristics covered by test method
301 302 303	Cut-back technique Insertion loss technique Backscattering technique	Attenuation
101 102 XXX	Refracted near field Near field light distribution Transverse Interferometry (For future consideration)	Refractive index profile
303	Backscattering technique	Point defects
307 303	Transmitted or radiated light power Backscattering technique	Optical continuity
308 309	Phase shift method Spectral Group delay measurement in the time domain	Chromatic dispersion
316 317	Transmitted power Monitoring Backscattering Monitoring	Change of optical transmittance during mechanical and environmental tests

TABLE IV (continued)

Tests methods of multimode fibres		
Test method	Test	Characteristics covered by test method
304	Impulse response	Baseband response
305	Frequency response	
311	Far field light distribution	Numerical aperture

Tests methods of single-mode fibres		
Test method	Test	Characteristics covered by test method
306	Microbending sensitivity	Microbending sensitivity
318	Macrobending sensitivity	Macrobending sensitivity
310 xxx	Differential Phase Shift Interferometry (For future consideration)	Chromatic Dispersion
312	Cut-off wavelength measurement	Fibre cut-off wavelength
313	Cable cut-off wavelength measurement	Cabled fibre cut-off wavelength
314 315 xxx xxx	Far field scan Variable aperture Knife edge scan (For future consideration) Near field scan (For future consideration)	Mode field diameter

4.2 Attenuation

Attenuation is a measure of the decreasing optical power in a fibre. It depends on the nature and length of the fibre and is also affected by measurement conditions.

Uncontrolled launching conditions normally excite higher order lossy modes that produce transient losses and result in attenuation that is not proportional to the length of the fibre. A controlled steady state launching condition yields attenuation that is proportional to the fibres length. Under steady state conditions, an attenuation coefficient of a fibre can be determined and the attenuation of concatenated fibres add linearly.

4.3 Operational definitions

The attenuation $A(\lambda)$ at wavelength λ between two cross-sections 1 and 2 separated by distance L of a fibre is defined as :

$$A(\lambda) = \left| 10 \log_{10} \frac{P_1}{P_2} \right| \text{ (dB)}$$

where P_1 is the optical power traversing the cross-section 1 and P_2 is the optical power traversing the cross-section 2. For a uniform fibre under steady state conditions, it is possible to define the attenuation per unit length, or the attenuation coefficient :

$$a(\lambda) = \frac{A(\lambda)}{L} \text{ (dB) (unit length)}^{-1}$$

which is independent of the chosen length of the fibre.

4.4 Description of attenuation measuring techniques

Three methods are described below for attenuation measurements :

a) Cut-back technique

The cut-back technique is a direct application of the definition of attenuation, in which the power levels P_1 and P_2 are measured at two points of the fibre without change of input conditions. P_2 is the power emerging from the end of the guide and P_1 is the power emerging from a point near the input after cutting the fibre.

By the measurement principle it is not possible to get information on the attenuation behaviour over the length of the fibre. Also it is difficult to measure the change of attenuation under changing conditions. But for a given condition, this method gives

