IEC 60793-2-50

Edition 6.0 2018-12
REDLINE VERSION

INTERNATIONAL STANDARD

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Optical fibres –
Part 2-50: Product specifications – Sectional specification for class B single-mode fibres

IEC 60793-2-50:2018-12 RLV(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.180.10

ISBN 978-2-8322-6361-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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International Standard IEC 60793-2-50 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The sixth edition cancels and replaces the fifth edition published in 2015. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

a) Introduction of a revised naming convention which better matches with those found in ITU-T Recommendations G.652, G.653, G.654, G.655, G.656, and G.657. These changes are outlined in the scope of this document along with a cross reference table for the new names. Annexes have been rearranged to improve clarity based on the new naming;

b) Further details on the requirements for 200 micron coated single-mode fibre;

c) Harmonization with the following ITU-T Recommendations published in November 2016: G.652, G.654, G.657 including revised chromatic dispersion specifications, new categories and new application spaces for these fibre categories;

d) Descriptions of fibre types have been added to the titles of Annexes A to F.

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

FDIS	Report on voting
86A/1884/FDIS	86A/1898/RVD

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

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

A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, 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- withdrawn,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 FIBRES –

Part 2-50: Product specifications – Sectional specification for class B single-mode fibres

1 Scope

This part of IEC 60793 is applicable to optical fibre categories ~~B1.1, B1.2, B1.3, B2, B4, B5 and B6~~ B-652, B-653, B-654, B-655, B-656 and B-657. A map illustrating the connection of IEC designations to ITU-T designations is shown in ~~Annex I~~ Table 1. These fibres are used or can be incorporated in information transmission equipment and optical fibre cables.

Three types of requirements apply to these fibres:

- general requirements, as defined in IEC 60793-2;
- specific requirements common to the class B single-mode fibres covered in this document and which are given in Clause 5;
- particular requirements applicable to individual fibre categories or specific applications, which are defined in Annexes A to ~~G~~ F.

For some fibre categories (shown in the relevant family specifications), there are sub-categories that are distinguished on the basis of difference in transmission attribute specifications. The designations for these sub-categories are documented in the individual family specifications.

Table 1 shows a map from the IEC designations to the ITU-T recommendations. The table also provides the normative annex in this document that contains the detailed specification as well as the name used to describe this fibre type in IEC 60793-2-50:2015. The ITU-T recommendations as well as the IEC categories/sub-categories within each recommendation are given. In some cases, as for Recommendation G.652, a given IEC designation maps to multiple categories in the ITU-T because the ITU-T categories are distinguished by cabled fibre attribute (PMD_Q) performance which are not distinguished in the IEC fibre specifications.

Table 1 – Map of IEC designation to ITU-T Recommendations and IEC 60793-2-50:2015 designation

Annex	Category	Sub Category	Description	IEC 60793-2-50:2015	ITU-T Rec
	B-652		Dispersion unshifted fibre		G.652
A		B-652.B		B1.1	G.652.B
A		B-652.D		B1.3	G.652.D
	B-653		Dispersion shifted fibre		G.653
B		B-653.A		B2_a	G.653.A
B		B-653.B		B2_b	G.653.B
	B-654		Cut-off shifted fibre		G.654
C		B-654.A		B1.2_a	G.654.A
C		B-654.B		B1.2_b	G.654.B
C		B-654.C		B1.2_c	G.654.C
C		B-654.D		N/A	G.654.D
C		B-654.E		N/A	G.654.E
C	B-655		Non-zero dispersion shifted fibre	B4	G.655
D		B-655.C		B4_c	G.655.C
D		B-655.D		B4_d	G.655.D
D		B-655.E		B4_e	G.655.E
E	B-656		Wideband non-zero dispersion shifted fibre	B5	G.656
F	B-657		Bending loss insensitive fibre	B6	G.657
F		B-657.A1		B6_a1	G.657.A1
F		B-657.A2		B6_a2	G.657.A2
F		B-657.B2		B6_b2	G.657.B2
F		B-657.B3		B6_b3	G.657.B3

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 60793-1 (all parts), *Optical fibres ~~– Measurement methods and test procedures~~*

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

IEC 60793-1-20, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

IEC 60793-1-21, *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry*

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

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

IEC 60793-1-31, *Optical fibres – Part 1-31: Measurement methods and test procedures – Tensile strength*

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

IEC 60793-1-33, *Optical fibres – Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility*

IEC 60793-1-34, *Optical fibres – Part 1-34: Measurement methods and test procedures – Fibre curl*

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

IEC 60793-1-42, *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-45, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*

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

IEC 60793-1-47, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*

IEC 60793-1-48, *Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion*

IEC 60793-1-50, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state) tests*

IEC 60793-1-51, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat (steady state) tests*

IEC 60793-1-52, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature tests*

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

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*

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

~~IEC TR 62316, *Guidance for the interpretation of OTDR backscattering traces*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60793-2 and the IEC 60793-1 series apply.

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

NOTE General definitions for fibres are provided in IEC 60793-2. The definitions of the specified attributes are contained in the relevant test methods standard of the IEC 60793-1 series, while general definitions for testing are provided in IEC 60793-1-1.

4 Abbreviated terms and symbols

For the purposes of this document, the following abbreviated terms and symbols apply:

F_{avg}	Average strip force
F_{peak}	Peak strip force
λ_0	Zero dispersion wavelength
λ_c	Fibre cut-off wavelength
λ_{cc}	Cable cut-off wavelength
MFD	Mode field diameter
n_d	Stress corrosion parameter – dynamic
PMD	Polarization mode dispersion
PMD_Q	PMD link design value

5 Specifications

5.1 General

The fibre shall consist of a glass core and glass cladding in accordance with the construction of optical fibre class B – single-mode fibre – as given in IEC 60793-2.

The term “glass” usually refers to material consisting of non-metallic oxides. The composition of some fibres may be all glass, or glass and glass/hard polymeric composites.

5.2 Dimensional requirements

Relevant dimensional attributes and measurement methods are given in Table 2.

Requirements common to all categories of class B single-mode fibres are given in Table 3.

Cladding diameter, cladding non-circularity, and core – cladding concentricity error shall be specified in the family specifications

Table 2 – Dimensional attributes and measurement methods

Attribute	Measurement method
Cladding diameter	IEC 60793-1-20
Cladding non-circularity	IEC 60793-1-20
Core – cladding concentricity error	IEC 60793-1-20
Primary coating diameter	IEC 60793-1-21
Primary coating non-circularity	IEC 60793-1-21
Primary coating-cladding concentricity error	IEC 60793-1-21
Fibre length	IEC 60793-1-22

Table 3 – Dimensional requirements common to all category B fibres

Attribute	Unit	Limit
Primary coating diameter – uncoloured	µm	235 to 255 [a]
Primary coating diameter – coloured	µm	235 to 265 [a]
Primary coating-cladding concentricity error	µm	≤ 12,5
Fibre length	km	[b]

[a] The above limits on primary coating diameter are most commonly used in telecommunications cables. There are other applications, such as fibre for use within optical sub-systems, pigtails, or specialty applications such as for submarines cables or for compact FTTH cables, which use other primary coating diameters, several of which are listed below.

~~Alternative nominal primary coating diameters and ranges:~~

~~200 µm ± 10 µm (uncoloured; 190 µm to 220 µm coloured)~~

~~400 µm ± 40 µm~~

~~500 µm ± 30 µm~~

~~700 µm ± 100 µm~~

~~900 µm ± 100 µm~~

~~The primary coating cladding concentricity error should be limited to a maximum 10 µm for 200 µm.~~

180 µm to 210 µm uncoloured; 180 µm to 220 µm coloured

400 µm ± 40 µm

500 µm ± 50 µm

700 µm ± 70 µm

900 µm ± 90 µm

Alternative coating diameters may impact fibre connectivity such as ribbons, multi-fibre connectors, mechanical splices, and fusion splice protectors; they may also need adjustments to connectivity tools and/or tighter coating tolerances.

[b] Length requirements vary and should be agreed between supplier and customer.

5.3 Mechanical requirements

Relevant mechanical attributes and test methods are given in Table 4. The relationship between some of these attributes and mechanical reliability are described in IEC TR 62048 and ITU-T G.Sup.59.

Requirements common to all categories of class B single-mode fibres are given in Table 5.

Table 4 – Mechanical attributes and test methods

Attribute	Test method
Proof test	IEC 60793-1-30
Tensile strength	IEC 60793-1-31
Coating strippability	IEC 60793-1-32
Stress corrosion susceptibility	IEC 60793-1-33
Fibre curl	IEC 60793-1-34

Table 5 – Mechanical requirements common to all class B fibres

Attribute	Unit	Limit
Proof stress level	GPa	≥ 0,69 [a]
Coating strip force (average) [b, c]	N	$1,0 \leq F_{ave} \leq 5,0$
Coating strip force (peak) [b, c]	N	$1,0 \leq F_{peak} \leq 8,9$
Fibre curl radius	m	≥ 2 [d]
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8
Stress corrosion susceptibility parameter, n_d	–	≥ 18

[a] The proof test value of 0,69 GPa equals about 1 % strain or about 8,8 N force. For the relation between these different units, see IEC TR 62048:2014, ~~7.4~~ clause 8.4.

[b] Either average strip force or peak strip force, which are defined in the test procedure, may be specified with agreement between supplier and customer.

[c] In case of alternative nominal primary coating diameters (see Table 2), associated alternative coating strip force values need to be agreed between supplier and customer or provided in the detailed specifications provided in Annexes of this document.

[d] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

5.4 Transmission requirements

Relevant transmission attributes and measurement methods are given in Table 6.

Requirements common to all categories of class B single-mode fibres are shown in Table 7.

Requirements that shall be specified in the family specifications are listed in Table 8.

Table 6 – Transmission attributes and measurement methods

Attribute	Measurement method
Attenuation coefficient	IEC 60793-1-40 [a]
Chromatic dispersion	IEC 60793-1-42
Cut-off wavelength [b]	IEC 60793-1-44
Mode field diameter	IEC 60793-1-45
Change of optical transmission	IEC 60793-1-46
Macrobending loss	IEC 60793-1-47
Polarization mode dispersion	IEC 60793-1-48
~~NOTE~~ The indicated maximum attenuation values apply to cabled and uncabled optical fibres. Tighter specifications for the fibre may be requested to account for added attenuation in the cabling process; for the maximum cabled attenuation values, reference is made to IEC 60794-2, which can be used in conjunction with this document.	
[a] The attenuation coefficient at various wavelengths can be calculated using the measured values at a few wavelengths using a spectral model such as that given in IEC 60793-1-40. For example, the attenuation at 1 480 nm can be calculated and used for design of systems that employ remote pumping of optical amplifiers. When using Method C, OTDR, additional guidance information in IEC TR 62316 shall be taken into account. As reported in IEC 60793-1-40:20xx, the spectral attenuation model~~, to date,~~ has ~~only~~ been demonstrated on ~~B1 and B2~~ all class B fibres.	
[b] There are two ways to measure cut-off wavelength, leading to: fibre cut-off wavelength λ_c and to cable cut-off wavelength λ_{cc}, respectively. The correlation of the measured values of λ_c and λ_{cc} depends on the specific fibre and cable design and the test conditions. While in general $\lambda_{cc} < \lambda_c$ a general quantitative relationship cannot be easily established, the importance of ensuring single-mode transmission in the minimum cable length between joints at the minimum operating wavelength is paramount. This may be performed by recommending the maximum cable cut-off wavelength λ_{cc} of a cabled single-mode fibre to be 1 260 nm or for worst case length and bends by recommending a maximum fibre cut-off wavelength λ_c to be ~~1 250~~ 1 260 nm.	

Table 7 – Transmission, requirements common to all class B fibres

Attribute	Unit	Limit
Polarization mode dispersion (PMD) coefficient link design value (PMD_Q)	$ps/\sqrt{km}$	[a]
[a] A maximum value of PMD_Q on uncabled fibre shall be agreed between supplier and customer to satisfy the primary requirement of cable PMD, given in IEC 60794-3.		

Table 8 – Additional transmission attributes required in the family specifications

Attribute
Attenuation coefficient and wavelengths
Chromatic dispersion characteristics
Nominal mode field diameter (MFD) range and wavelength
Mode field diameter tolerance
Cable cut-off wavelength, λ_{cc}
Macrobending loss including: wavelength, mandrel size, and number of turns
Cladding diameter
Cladding non-circularity
Core – cladding concentricity error

For category ~~B4~~ B-655 fibre, information for system design is given in Annex G.

5.5 Environmental requirements

5.5.1 General

Environmental exposure tests and measurement methods are documented in two forms:

- relevant environmental attributes and test methods are given in Table 9;
- measurements of a particular mechanical or transmission attributes that may change on the application of the environment are listed in Table 10.

Table 9 – Environmental exposure tests

Attribute	Test method
Damp heat tests	IEC 60793-1-50
Dry heat tests	IEC 60793-1-51
Change of temperature tests	IEC 60793-1-52
Water immersion tests	IEC 60793-1-53

Table 10 – Attributes measured in environmental exposure tests

Attribute	Test method
Change in optical transmission	IEC 60793-1-46
Attenuation	IEC 60793-1-40
Coating strip force	IEC 60793-1-32
Tensile strength	IEC 60793-1-31
Stress corrosion susceptibility	IEC 60793-1-33

These tests are normally conducted periodically as type-tests for a fibre and coating design. Unless otherwise indicated, the recovery period allowed between the completion of the environmental exposure and performing the attribute measurements shall be as stated in the particular environmental test method.

5.5.2 Optical environmental requirements – Attenuation

Change in attenuation from the initial value shall be less than the values in Table 11. Attenuation shall be measured periodically during the entire exposure to each environment and after removal.

Table 11 – Change in attenuation for environmental tests

Environment	Wavelength nm	Maximum attenuation increase dB/km
Damp heat	1 550, 1 625	≤ 0,05
Dry heat	1 550, 1 625	≤ 0,05
Change of temperature	1 550, 1 625	≤ 0,05
Water immersion	1 550, 1 625	≤ 0,05
NOTE Attenuation changes at wavelengths lower than the test wavelength are smaller than the attenuation change at the test wavelength.		

5.5.3 Mechanical environmental requirements

5.5.3.1 General

These tests are, in practice, the most severe requirements amongst the environments defined in Table 9.

5.5.3.2 Coating strip force

The attributes given in Table 12 shall be verified following removal of the fibre from the particular environment.

Table 12 – Coating strip force for environmental tests

Environment	Average strip force N	Peak strip force N
Damp heat	$1,0 \leq F_{avg} \leq 5,0$	$1,0 \leq F_{peak} \leq 8,9$
Water immersion	$1,0 \leq F_{avg} \leq 5,0$	$1,0 \leq F_{peak} \leq 8,9$
NOTE In case of alternative nominal primary coating diameters (see Table 2), associated alternative coating strip force values need to be agreed between supplier and customer unless specified in the detailed product specifications or provided in the annexes of this document.		

5.5.3.3 Tensile strength

The attributes given in Table 13 shall be verified following removal of the fibre from the environment indicated.

Table 13 – Tensile strength for environmental tests

Environment	Median tensile strength (GPa), specimen length: 0,5 m	15 percentile of the tensile strength distribution (GPa), specimen length: 0,5 m
Damp heat	≥ 3,03	≥ 2,76
NOTE These requirements do not apply to hermetically coated fibre. (A hermetic coating is a protective layer that completely segregates the glass fibre from moisture, thereby ensuring a high level of stress corrosion resistance. Typical hermetic coating is a carbon layer of several microns thickness applied on the glass surface.)		

5.5.3.4 Stress corrosion susceptibility

The attribute given in Table 14 shall be verified following removal of the fibre from the environment indicated.

Table 14 – Stress corrosion susceptibility for environmental tests

Environment	Stress corrosion susceptibility parameter, n_d
Damp heat	≥ 18
NOTE This requirement does not apply to hermetically coated fibre (see definition for hermetic coating in Table 13).	

Annex A
(normative)

Family specification for category ~~B1.1~~ B-652 Dispersion unshifted single-mode fibres

A.1 General

This dispersion unshifted single-mode fibre is optimized for use in the 1 310 nm region but can be used in the 1 550 nm and 1 625 nm regions. Depending on link length and bit rates, dispersion may need accommodation in the 1 550 nm and 1 625 nm regions.

The clauses and tables in Annex A contain particular requirements applicable to category ~~B1.1~~ B-652 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "Reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "ss".

A.2 Dimensional requirements

Table A.1 contains dimensional requirements specific to category ~~B1.1~~ B-652.B fibres.

Table A.1 – Dimensional requirements specific to category ~~B1.1~~ B-652.B fibres

Attribute	Unit	Limit (250 µm coating)	Limit (200 µm coating)	Reference
Cladding diameter	µm	125 ± 1	125 ± 1	5.2
Cladding non-circularity	%	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 10,0	5.2
Fibre length	km	See ~~5.1~~ 5.2	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.				

Table A.2 contains dimensional requirements specific to category B-652.D fibres.

Table A.2 – Dimensional requirements specific to category B-652.D fibres

Attribute	Unit	Limit (250 µm coating)	Limit (200 µm coating)	Reference
Cladding diameter	µm	125 ± 0,7	125 ± 0,7	5.2
Cladding non-circularity	%	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 10,0	5.2
Fibre length	km	See 5.2	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.				

A.3 Mechanical requirements

Table A.3 contains mechanical requirements specific to category ~~B1.1~~ B-652 fibres.

Table A.3 – Mechanical requirements specific to category ~~B1.1~~ B-652 fibres

Attribute	Unit	Limit (250 µm coating)	Limit (200 µm coating)	Reference
Proof stress level	GPa	≥ 0,69 [SS]		5.3
Coating strip force (average) [SS]	N	$1,0 \leq F_{ave} \leq 5,0$	$0.4 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) [SS]	N	$1,0 \leq F_{peak} \leq 8,9$	$0.4 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	m	≥ 2 [a]		5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8		5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18		5.3
[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.				

A.4 Transmission requirements

Table A.4 contains transmission requirements specific to sub-category ~~B1.1~~ B-652.B fibres and Table A.5 contains transmission requirements specific to sub-category B-652.D fibres. Table A.6 provides chromatic dispersion values for sub-category B-652.D fibres.

Table A.4 – Transmission requirements specific to sub-category ~~B1.1~~ B-652.B fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 1 310 nm	dB/km	≤ 0,4~~0~~	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,~~30~~ 35	5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4~~0~~	5.4
Zero dispersion wavelength, λ_0	nm	1 300 ≤ λ_0 ≤ 1 324	5.4
Zero dispersion slope	ps/(nm^2 x km)	≤ 0,092	5.4
Nominal MFD range at 1 310 nm [a]	µm	8,6 to 9,5	5.4
MFD tolerance	µm	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
NOTE In the 1 550 nm region, the chromatic dispersion can be approximated as a linear function with wavelength. A typical value for the chromatic dispersion at 1 550 nm is 17 ps/(nm x km) with a typical slope at 1 550 nm of 0,056 ps/(nm² x km).			
[a] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

Table A.5 – Transmission requirements specific to sub-category B-652.D Fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient from 1 310 nm to 1 625 nm [a]	dB/km	≤ 0,40	5.4
Attenuation coefficient at 1 383 nm ± 3 nm	dB/km	≤ 0,40	5.4
Attenuation coefficient 1 530 nm – 1 565 nm	dB/km	≤ 0,30	5.4
Chromatic dispersion	See Table A.6		5.4
Nominal MFD range at 1 310 nm [b]	µm	8,6 to 9,2	5.4
MFD tolerance	µm	± 0,4	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
[a] This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.			
[b] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

Table A.6 – Chromatic dispersion properties for sub-category B-652.D fibres

Attribute [a]	Detail	Limit	Unit
3-term Sellmeier fitting (1260 nm to 1460 nm)	λ_{0min}	1 300	nm
	λ_{0max}	1 324	nm
	S_{0min}	0,073	ps/(nm^2 × km)
	S_{0max}	0,092	ps/(nm^2 × km)
Linear fitting (1460 nm to 1625 nm)	Minimum at 1 550 nm	13,3	ps/(nm × km)
	Maximum at 1 550 nm	18,6	ps/(nm × km)
	Minimum at 1 625 nm	17,2	ps/(nm × km)
	Maximum at 1 625 nm	23,7	ps/(nm × km)
[a] Details of the equations used that define these attributes are provided in section 6.10 of ITU-T G.652.			

A.5 Hydrogen ageing for sub-category B-652.D

Select a fibre specimen at least 1 km long. After spooling the fibre to a test configuration that minimizes the effect of winding on attenuation at 1 310 nm, measure the attenuation coefficient of the specimen at 1 240 nm and at 1 383 nm. This measurement gives the baseline attenuation for the specimen. Expose the fibre to 0,01 atmospheres of hydrogen at room temperature (reference test). For practical considerations, such as the availability of equipment and testing time, higher H_2 concentrations (e.g. 1 atm) can be used with proper care as mentioned in Note 4. During this exposure, monitor the attenuation coefficient of the specimen at 1 240 nm. This wavelength is indicative of the molecular hydrogen present in the specimen. Constructing the change in attenuation as the monitored results minus the baseline value, continue exposure until the 1 240 nm attenuation changes by ≥ 0,03 dB/km. At this time, the attenuation increase at 1 383 nm may be considered fully saturated, and the specimen may be removed from the hydrogen atmosphere. After at least 14 days in the normal laboratory environment, measure the attenuation coefficient of the fibre at 1 383 nm using methods A, B or C of IEC 60793-1-40.

NOTE 1 This is a type test performed periodically to ensure that the manufacturing process reliably yields fibre with acceptable ageing characteristics. For example, 10 fibre samples can be tested every 6 months.

NOTE 2 This test is not appropriate for hermetically coated fibre (see definition for hermetic coating in Table 12).

NOTE 3 For non-hermetic fibres, typical hydrogen exposure is from 4 days to 6 days (see definition for hermetic coating in Table 12).

NOTE 4 Hydrogen ageing should be performed in H_2 concentrations that produce results representative of the actual field conditions. Although increased H_2 concentration reduces testing time, it tends to produce slightly higher values of added loss at equivalent exposure time (see threshold for increases at 1 240 nm). The 0,01 atmosphere test is a compromise between impractically long testing times and unrealistically high added loss. When testing with higher H_2 concentration, the reduced testing time can require increased safety measures.

A.6 Environmental requirements

The requirements of 5.5 shall be met.

Annex C
(normative)

Family specification for category B1.3 single-mode fibres

C.1 General

This dispersion unshifted single-mode fibre can be used from 1 260 nm up to 1 625 nm. Chromatic dispersion in this band may impose requirements either on the maximum link length or on the need for accommodation.

The clauses and tables in Annex C contain particular requirements applicable to category B1.3 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "Reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

C.2 Dimensional requirements

Table C.1 contains dimensional requirements specific to category B1.3 fibres.

Table C.1 – Dimensional requirements specific to category B1.3 fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	125 ± 1	5.2
Cladding non-circularity	%	≤ 1,0	5.2
Core concentricity error	µm	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	5.2
Fibre length	km	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.			

C.3 Mechanical requirements

Table C.2 contains mechanical requirements specific to category B1.3 fibres.

Table C.2 – Mechanical requirements specific to category B1.3 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 [SS]	5.3
Coating strip force (average)[SS]	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak)[SS]	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	m	≥ 2 [a]	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3
[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.			

C.4 Transmission requirements

Table C.3 contains transmission requirements specific to category B1.3 fibres.

Table C.3 – Transmission requirements specific to category B1.3 fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient from 1 310 nm [a] to 1 625 nm	dB/km	≤ 0,40	
Attenuation coefficient at 1 383 nm ± 3 nm	dB/km	≤ 0,40 [b]	
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,30	
Zero dispersion wavelength, λ_0	nm	1 300 ≤ λ_0 ≤ 1 324	
Zero dispersion slope	ps/nm^2 • km	≤ 0,092	
Nominal MFD range at 1 310 nm [c]	µm	8,6 to 9,5	
MFD tolerance	µm	± 0,6	
Cable cut-off wavelength	nm	≤ 1 260	
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,1	
Polarization mode dispersion (PMD) coefficient	ps/√km	See 5.4	

NOTE In the 1 550 nm region, the chromatic dispersion can be approximated as a linear function with wavelength. A typical value for the chromatic dispersion at 1 550 nm is 17 ps/nm • km with a typical slope at 1 550 nm of 0,056 ps/nm^2 • km.

[a] This wavelength region can be extended to 1 260 nm by adding 0,07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.

[b] The average attenuation coefficient after ageing according to the test outlined in the following paragraph shall be less than the value specified for the range of 1 310 nm to 1 625 nm.

[c] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

C.5 Hydrogen ageing for category B1.3

Select a fibre specimen at least 1 km long. After spooling the fibre to a test configuration that minimizes the effect of winding on attenuation at 1 310 nm, measure the attenuation coefficient of the specimen at 1 240 nm and at 1 383 nm. This measurement gives the baseline attenuation for the specimen. Expose the fibre to 0,01 atmospheres of hydrogen at room temperature (reference test). For practical considerations, such as the availability of equipment and testing time, higher H_2 concentrations (e.g. 1 atm) can be used with proper care as mentioned in Note 4. During this exposure, monitor the attenuation coefficient of the specimen at 1 240 nm. This wavelength is indicative of the molecular hydrogen present in the specimen. Constructing the change in attenuation as the monitored results minus the baseline value, continue exposure until the 1 240 nm attenuation changes by ≥ 0,03 dB/km. At this time, the attenuation increase at 1 383 nm may be considered fully saturated, and the specimen may be removed from the hydrogen atmosphere. After at least 14 days in the normal laboratory environment, measure the attenuation coefficient of the fibre at 1 383 nm using methods A, B or C of IEC 60793-1-40:2001.

NOTE 1 This is a type test performed periodically to ensure that the manufacturing process reliably yields fibre with acceptable ageing characteristics. For example, 10 fibre samples can be tested every 6 months.

NOTE 2 This test is not appropriate for hermetically coated fibre (see definition for hermetic coating in Table 12).

NOTE 3 For non-hermetic fibres, typical hydrogen exposure is from 4 days to 6 days (see definition for hermetic coating in Table 12).

NOTE 4 To be useful, hydrogen ageing is performed in H_2 concentrations that produce results representative of the actual field conditions. Although increased H_2 concentration reduces testing time, it tends to produce slightly

~~higher values of added loss at equivalent exposure time (see threshold for increases at 1 240 nm). The 0,01 atmosphere test is a compromise between impractically long testing times and unrealistically high added loss. When testing with higher H_2 concentration, the reduced testing time can require increased safety measures.~~

~~C.6 Environmental requirements~~

~~The requirements of 5.5 shall be met.~~

Annex B
(normative)

Family specification for category ~~B2~~ B-653 Dispersion shifted single-mode fibres

B.1 General

This dispersion-shifted single-mode fibre is optimized for single-channel transmission in the 1 550 nm region. Multiple channels can only be transmitted if care is taken to avoid the effects of four-wave mixing by, for example, moderating the power levels or appropriate spacing or placement of the channels.

The clauses and tables in Annex B contain particular requirements applicable to category ~~B2~~ B-653 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "Reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "ss".

There are two sub-categories which are designated as with suffixes, ~~"_a" and "_b"~~ ".A" and ".B". These sub-categories are distinguished by the glass geometry tolerances, mode field diameter tolerance, and chromatic dispersion coefficient and mode field diameter attribute specifications.

B.2 Dimensional requirements

Table B.1 contains dimensional requirements specific to category ~~B2~~ B-653 fibres.

Table B.1 – Dimensional requirements specific to category ~~B2~~ B-653 fibres

Attribute	Unit	B-653.A Limit	B-653.B Limit	Reference
Cladding diameter	µm	125 ± 1	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 12,5	5.2
Fibre length	km	See 5.2	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.				

~~D.3 Mechanical requirements~~

Table B.2 contains mechanical requirements specific to category ~~B2~~ B-653 fibres.

Table B.2 – Mechanical requirements specific to category ~~B2~~ B-653 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 a	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3

a Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

B.3 Transmission requirements

B.3.1 General

Table B.3 contains transmission requirements specific to category ~~B2~~ B-653 fibres.

Table B.3 – Transmission requirements specific to category ~~B2~~ B-653 fibres

Attribute	Unit	B-653.A Limit	B-653.B Limit	Reference
Attenuation coefficient at 1 310 nm[a]	dB/km	≤ 0,50	≤ 0,50	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,~~30~~ 35	≤ 0,~~30~~ 35	5.4
Attenuation coefficient at 1 625 nm[a]	dB/km	≤ 0,40	≤ 0,40	5.4
Chromatic dispersion coefficient	ps/(nm x km)	See B.3.2	See B.3.3	5.4
Nominal MFD range at 1 550 nm [b]	µm	7,8 to 8,5	7,8 to 8,5	5.4
MFD tolerance	µm	± 0,8	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 270	≤ 1 270	5.4
Macrobending loss at 1 550 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,5	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	See 5.4	5.4

a This attenuation coefficient is not specified in ITU-T G.653 at this time. If ITU-T specifies this parameter the value in the ITU-T document takes precedent.

b The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

B.3.2 Chromatic dispersion coefficient requirement for sub-category ~~B2_a~~ B-653.A fibres

The requirement is given as a combined requirement on the absolute value of the chromatic dispersion coefficient for a range of wavelength and a limit on the zero-dispersion wavelength, λ_0, and slope at λ_0, S_0.

$$|D(\lambda)| \leq 3,5 \text{ ps/(nm} \times \text{km) for } 1\,525 \text{ nm} \leq \lambda \leq 1\,575 \text{ nm} \quad \text{(B.1)}$$

and

$$1\ 500\ \text{nm} \le \lambda_0 \le 1\ 600\ \text{nm} \tag{B.2}$$

and

$$S_0 \le 0{,}085\ \text{ps/(nm}^2 \times \text{km)}. \tag{B.3}$$

B.3.3 Chromatic dispersion coefficient requirement for sub-category ~~B2_b~~ B-653. B fibres

The requirement is given as a series of bounding line segments versus wavelength. These line segment boundaries are equivalent to the requirements stated in D.4.2. The units of chromatic dispersion coefficient, $D(\lambda)$, are ps/(nm x km) and the units of wavelength, λ, are nm.

$$0{,}085\ (\lambda - 1\ 525) - 3{,}5 \le D(\lambda) \text{ for } 1\ 460\ \text{nm} \le \lambda \le 1\ 525\ \text{nm} \tag{B.4}$$

$$\frac{3{,}5}{75}(\lambda - 1\ 600) \le D(\lambda) \text{ for } 1\ 525\ \text{nm} \le \lambda \le 1\ 625\ \text{nm} \tag{B.5}$$

$$D(\lambda) \le \frac{3{,}5}{75}(\lambda - 1\ 500) \text{ for } 1\ 460\ \text{nm} \le \lambda \le 1\ 575\ \text{nm} \tag{B.6}$$

$$D(\lambda) \le 0{,}85\ (\lambda - 1\ 575) + 3{,}5 \text{ for } 1\ 575\ \text{nm} \le \lambda \le 1\ 625\ \text{nm} \tag{B.7}$$

B.4 Environmental requirements

The requirements of 5.5 shall be met.

Annex C
(normative)

Family specification for category ~~B1.2~~ B-654 cut-off shifted single-mode fibres

C.1 General

This dispersion unshifted single-mode fibre is optimized for low loss in the 1 550 nm region, with the cutoff wavelength shifted above the 1 310 nm region.

The clauses and tables in Annex C contain particular requirements applicable to category ~~B1.2~~ B-654 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “Reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

There are ~~three~~ five sub-categories which are designated as with suffixes, ~~“_b”, “_c” and “_d”~~ ".A", ".B", ".C", ".D" and ".E". These sub-categories are distinguished by the chromatic dispersion coefficient and mode field diameter attribute specifications.

C.2 Dimensional requirements

Table C.1 contains dimensional requirements specific to category ~~B1.2~~ B-654 fibres.

Table C.1 – Dimensional requirements specific to category ~~B1.2~~ B-654 fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	5.2
Fibre length	km	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.			

C.3 Mechanical requirements

Table C.2 contains mechanical requirements specific to category ~~B1.2~~ B-654 fibres.

Table C.2 – Mechanical requirements specific to category ~~B1.2~~ B-654 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 [a]	5.3
Tensile strength (median) for 0.5 m specimen length	GPa	≥ 3.8	5.3
Stress corrosion ~~susceptibility~~ parameter, n_d	-	≥ 18	5.3

[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

~~B.4 Transmission requirements~~

Table C.3 contains transmission requirements specific to category ~~B1.2~~ B-654 fibres. There are ~~three~~ five sub-categories designated as ~~"_b", "_c" and "_d"~~ ".A", ".B", ".C", ".D", and ".E".

Table C.3 – Transmission requirements specific to category ~~B1.2~~ B-654 fibres

Attribute	Unit	.A Limit	~~_b~~ .B Limit	~~_c~~ .C Limit	~~_d~~ .D Limit	.E Limit	Ref
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,22	≤ 0,22	≤ 0,22	≤ 0,20	≤ 0,23	5.4
Attenuation coefficient at 1 625 nm[a]	dB/km	NA	≤ 0,40	≤ 0,40	≤ 0,40	NA	5.4
Chromatic dispersion slope at 1 550 nm	ps/(nm^2 x km)	≤ 0,070	≤ 0,070	≤ 0,070	≤ 0,070	≤ 0,070 ≥ 0.050	5.4
Chromatic dispersion coefficient at 1 550 nm	ps/(nm x km)	≤ 20	≤ 22	≤ 20	≤ 23	≤ 23 ≥ 17	5.4
Nominal MFD range at 1 550 nm [b]	µm	9,5 to 10,5	9,5 to 13,0	9,5 to 10,5	11,5 to 15,0	11,5 to 12,5	5.4
MFD tolerance	µm	±0,7	±0,7	±0,7	±0,7	±0,7	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 530	≤ 1 530	≤ 1 530	≤ 1 530	≤ 1 530	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,50	≤ 0,50	≤ 0,50	≤ 2,0 [c]	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	See 5.4	See 5.4	See 5.4	See 5.4	5.4

[a] This attenuation coefficient is not specified in ITU-T G.654 at this time. If ITU-T specifies this parameter the value in in the ITU-T document takes precedent.

[b] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

[c] Other application specific test conditions and requirements (bending radius and number of turns) at 1 550 nm are under study.

C.4 Chromatic dispersion parameters for B-654.E fibres

For B-654.E fibre, the chromatic dispersion parameters indicated in Table C.3 are specified in order to bind the minimum/maximum chromatic dispersion coefficient $D(\lambda)$ at wavelength λ from 1 530 nm to 1 625 nm. This allows more accurate system design, in which dispersion-compensating schemes are incorporated. The quadratic fitting for the group delay found in Table D.1 of IEC 60793-1-42:2013 is applied, and the $D(\lambda)$ is bound by the following inequality:

$$D_{1\,550\text{min}} + S_{1\,550\text{min}}(\lambda - 1\,550) \leq D(\lambda) \leq D_{1\,550\text{max}} + S_{1\,550\text{max}}(\lambda - 1\,550) \quad \text{(C.1)}$$

where $D_{1\ 550\text{min}}$, $D_{1\ 550\text{max}}$, $S_{1\ 550\text{min}}$, and $S_{1\ 550\text{max}}$ are listed in Table C.3 and below:

$D1550_{min}$ = 17 ps/(nm x km)

$D1550_{max}$ = 23 ps/(nm x km)

$S1550_{min}$ = 0,050 ps/(nm^2 x km)

$S1550_{max}$ = 0,070 ps/(nm^2 x km).

C.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex D
(normative)

Family specification for category ~~B4~~ B-655 non-zero dispersion shifted single-mode fibres

D.1 General

This non-zero dispersion-shifted single-mode fibre is optimized for multiple channel transmission in the 1 550 nm region with a cut-off wavelength that may be shifted above the 1 310 nm region. The chromatic dispersion coefficient is required to be non-zero throughout the band from 1 530 nm to 1 565 nm, but may be either positive or negative. Depending on the chromatic dispersion characteristics, multiple channel transmission may be possible at bands either above or below the normal 1 550 nm region.

The clauses and tables in Annex D contain particular requirements applicable to category ~~B4~~ B-655 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

There are three sub-categories which are designated as with suffixes, ~~"_c", "_d", and "_e"~~ ".C", ".D", and ".E". These sub-categories are distinguished by the chromatic dispersion coefficient attribute specifications. For sub-category ~~B4_c~~ B-655.C, the traditional "box specification" is maintained. For sub-categories ~~B4_d and B4_e~~ B-655.D and B-655.E fibres, the chromatic dispersion limits are in the form of a pair of curves versus wavelength. See Annex G for more information on these curves.

D.2 Dimensional requirements

Table D.1 contains dimensional requirements specific to category ~~B4~~ B-655 fibres.

Table D.1 – Dimensional requirements specific to category ~~B4~~ B-655 fibres

Attribute	Unit	B-655.C Limit	B-655.D Limit	B-655.E Limit	Reference
Cladding diameter	µm	125 ± 1			5.2
Cladding non-circularity	%	≤ 2,0	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255			5.2
Primary coating diameter – coloured [a]	µm	235 to 265			5.2
Primary coating-cladding concentricity error	µm	≤ 12,5			5.2
Fibre length	km	See 5.2			5.2

[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.

D.3 Mechanical requirements

Table D.2 contains mechanical requirements specific to category ~~B4~~ B-655 fibres.

Table D.2 – Mechanical requirements specific to category ~~B4~~ B-655 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 a	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3
a Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.			

D.4 Transmission requirements

D.4.1 General

Table D.3 contains transmission requirements specific to category ~~B4~~ B-655 fibres.

Table D.3 – Transmission requirements specific to category ~~B4~~ B-655 fibres

Attribute	Unit	Limit		Reference
		B-655.C	B-655.D,E	
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,~~30~~ 35		5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4~~0~~		5.4
Chromatic dispersion coefficient	ps/(nm x km)	See D.4.2, D.4.3, and D.4.4		5.4
Nominal MFD range at 1 550 nm a	µm	8,0 to 11,0		5.4
MFD tolerance	µm	± 0,7	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 450		5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,50	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$		See 5.4	5.4
a The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.				

NOTE Annex G includes implementation examples that do not preclude any other possible implementations.

D.4.2 Chromatic dispersion coefficient limits for sub-category ~~B4_c~~ B-655.C fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met:

$$1,0 \text{ ps/nm} \cdot \text{km} \leq D_{min} \leq |D(\lambda)| \leq D_{max} \leq 10,0 \text{ ps/nm} \cdot \text{km} \quad \text{(D.1)}$$

for 1 530 nm ≤ λ ≤ 1 565 nm

and

$$D_{max} - D_{min} \leq 5,0 \text{ ps/nm} \cdot \text{km} \quad \text{(D.2)}$$

The sign of the chromatic dispersion coefficient may be positive or negative, but $D(\lambda)$ shall not cross zero in the range of wavelengths from 1 530 nm to 1 565 nm.

The values of D_{min} and D_{max} as well as the sign shall be agreed between customer and supplier.

D.4.3 Chromatic dispersion coefficient limits for sub-category ~~B4_d~~ B-655.D fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm × km) and varies with wavelength, λ. The following inequalities shall be met:

$$\frac{7{,}00}{90}(\lambda - 1460) - 4{,}20 \le D(\lambda) \le \frac{2{,}91}{90}(\lambda - 1460) + 3{,}29 \quad \text{(D.3)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{2{,}97}{75}(\lambda - 1\,550) + 2{,}80 \le D(\lambda) \le \frac{5{,}06}{75}(\lambda - 1\,550) + 6{,}20 \quad \text{(D.4)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

D.4.4 Chromatic dispersion coefficient limits for sub-category ~~B4_e~~ B-655.E fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met.

$$\frac{5{,}42}{90}(\lambda - 1460) + 0{,}64 \le D(\lambda) \le \frac{4{,}65}{90}(\lambda - 1460) + 4{,}66 \quad \text{(D.5)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3{,}30}{75}(\lambda - 1\,550) + 6{,}06 \le D(\lambda) \le \frac{4{,}12}{75}(\lambda - 1\,550) + 9{,}31 \quad \text{(D.6)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

D.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex E
(normative)

Family specification for category ~~B5~~ B-656 Wideband non-zero dispersion shifted single-mode fibres

E.1 General

This non-zero dispersion-shifted single-mode fibre is optimized for multiple channel transmission in the wavelength range of 1 460 nm to 1 625 nm with the positive value of the chromatic dispersion coefficient that is greater than some non-zero value. This fibre can be used for both CWDM and DWDM systems throughout the wavelength region between 1 460 nm and 1 625 nm.

The clauses and tables in Annex E contain particular requirements applicable to category ~~B5~~ B-656 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

E.2 Dimensional requirements

Table E.1 contains dimensional requirements specific to category ~~B5~~ B-656 fibres.

Table E.1 – Dimensional requirements specific to category ~~B5~~ B-656 fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	5.2
Fibre length	km	See 5.2	5.2

[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.

E.3 Mechanical requirements

Tableau E.2 contains mechanical requirements specific to category ~~B5~~ B-656 fibres.

Table E.2 – Mechanical requirements specific to category ~~B5~~ B-656 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 a	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3
a Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions, such as ribbon cable.			

E.4 Transmission requirements

E.4.1 General

Table E.3 contains transmission requirements specific to category ~~B5~~ B-656 fibres.

Table E.3 – Transmission requirements specific to category ~~B5~~ B-656 fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 1 460 nm	dB/km	≤ 0,4~~0~~	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,~~30~~ 35	5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4~~0~~	5.4
Chromatic dispersion coefficient a	ps/(nm x km)	See E.4.2	5.4
Nominal MFD range at 1 550 nm b	µm	7,0 to 11,0	5.4
MFD tolerance	µm	± 0,7	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 450	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤0,50	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
a If a Raman pump is used outside the wavelength region from 1 460 nm to 1 625 nm, fibre properties have to be suitable for accommodating this pump, for example λ_0 may need to be less than the pump wavelength.			
b The value of nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

E.4.2 Chromatic dispersion coefficient for category ~~B5~~ B-656 fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met:

$$\frac{2,60}{90}(\lambda - 1460) + 1,00 \leq D(\lambda) \leq \frac{4,68}{90}(\lambda - 1460) + 4,60 \qquad \text{(E.1)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{0{,}98}{75}(\lambda - 1550) + 3{,}60 \leq D(\lambda) \leq \frac{4{,}72}{75}(\lambda - 1550) + 9{,}28 \quad \text{(E.2)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

E.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex F
(normative)

Family specification for category ~~B6~~ B-657 Bending loss insensitive single-mode fibres

F.1 General

~~This specification describes two main sub-category groups of bending loss insensitive single-mode optical fibre which are suitable for use in the access networks, including inside buildings at the end of these networks.~~

This document describes two categories of single-mode optical fibre A and B with improved bending loss performance compared with that of the B-652 category. Both categories A and B contain two subcategories which differ in macrobending loss.

The clauses and tables in Annex F contain particular requirements applicable to category ~~B6~~ B-657 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the "reference" column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

There are four sub-categories which are designated with suffixes ~~"_a1", "_a2", "_b2" and "_b3"~~ ".A1", ".A2", ".B2" and ".B3". The fibres are suitable to be used in the O, E, S, C and L-band (i.e. throughout the 1 260 nm to 1 625 nm range). They have improved bending loss and tighter dimensional specifications compared to ~~B1.3~~ B-652.D fibres for improved connectivity.

Sub-categories ~~B6_a1 and B6_a2~~ B-657.A1 and B-657.A2 fibres are a subset of category ~~B1.3~~ B-652.D fibres and therefore are compliant with ~~B1.3~~ B-652.D fibres and have the same transmission properties.

NOTE 1 Compliance here means adherence to the referenced fibre category (~~B1.3~~ B-652.D) meeting or exceeding the values of the specified attributes.

Sub-category ~~B6_a1~~ B-657.A1 fibres are appropriate for a minimum bend radius of 10 mm; sub-category ~~B6_a2~~ B-657.A2 fibres for a minimum bend radius of 7,5 mm.

Sub-categories ~~B6_b2 and B6_b3~~ B-657.B2 and B-657.B3 fibres are intended to be used for restricted distances (less than 1 000 m) at the end of access networks, in particular inside buildings or near buildings (e.g. outside building riser cabling). Application length of ~~B6_b~~ B-657.B fibre, however, depends on the deployment strategy of each network operator.

Sub-category ~~B6_b~~ B-657.B fibres are not necessarily compliant with category ~~B1.3~~ B-652 fibres in terms of chromatic dispersion coefficient specifications. These fibres, however, are system compatible with ~~B6_a~~ B-657.A (and ~~B1.3~~ B-652.D) fibres in Access networks.

NOTE 2 Compatibility here means that the product in this sub-category will introduce negligible system impairment or deployment issues but may not be compliant with the referenced fibre category (~~B1.3~~ B-652.D).

Sub-category ~~B6_b2~~ B-652.B2 fibres are appropriate for a minimum bend radius of 7,5 mm; sub-category ~~B6_b3~~ B-652.B3 fibres for a minimum bend radius of 5 mm.

NOTE 3 Most category ~~B1.1 and B1.3~~ B-652 fibres deployed have macrobending losses of several dBs over ten turns at 1 625 nm with 15 mm bend radius.

F.2 Dimensional requirements

Table F.1 contains dimensional requirements specific to category ~~B6~~ B-657 fibres.

Table F.1 – Dimensional requirements specific to category ~~B6~~ B-657 fibres

Attribute	Unit	Limit (250µm coating)	Limit (200µm coating)	Reference
Cladding diameter	µm	125 ± 0,7		5.2
Cladding non-circularity	%	≤ 1,0		5.2
Core – cladding concentricity error	µm	≤ 0,5		5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 10,0	5.2
Fibre length	Km	See 5.2		5.2

[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.

F.3 Mechanical requirements

Table F.2 contains mechanical requirements specific to category ~~B6~~ B-657 fibres.

Table F.2 – Mechanical requirements specific to category ~~B6~~ B-657 fibres

Attribute	Unit	Limit		Reference
		(250 µm coating)	(200 µm coating)	
Proof stress level [a]	GPa	≥ 0,69[SS]		5.3
Coating strip force (average) [SS]	N	$1,0 \leq F_{ave} \leq 5,0$	$0,4 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) [SS]	N	$1,0 \leq F_{peak} \leq 8,9$	$0,4 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	m	≥ 2 [b]		5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8		5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18		5.3

[a] The failure probability for fibre under 30 mm of radius bend as described in category ~~B1.3~~ B-657 of this document, increases with decreasing bend radius. ~~The mechanical reliability of optical fibre in this application space is a function of the characteristics of the cable structure, the installation techniques and deployment conditions. Attention is drawn to the fact that, for some installations, additional constraints on installation, such as higher fibre proof test levels or other factors may be required to ensure the full expected life. It is recommended that the proof stress level applied to fibre and other factors along with the required reliability level during its lifetime are agreed between supplier and customer considering the environmental conditions imposed on the fibres during and after installation.~~ See ITU-T G.Sup.59 for more guidance on cabled fibre reliability.

[b] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions, such as ribbon cable.

F.4 Transmission requirements

Table F.3 contains transmission requirements specific to category ~~B6~~ B-657 fibres.

~~NOTE Some limits are not specified for sub-categories of B6 fibres. These are indicated by NS in Table G.3.~~

Table F.3 – Transmission requirements specific to category ~~B6~~ B-657 fibres

~~Attribute~~	~~Unit~~	~~B6_a1 Limit~~	~~B6_a2 Limit~~	~~B6_b2 Limit~~	~~B6_b3 Limit~~	~~Reference~~
~~Attenuation coefficient from 1 310 nm to 1 625 nm [a]~~	~~dB/km~~	~~≤ 0,40~~	~~≤ 0,40~~	~~≤ 0,40~~	~~≤ 0,40~~	
~~Attenuation coefficient at 1 383 nm ± 3 nm [b]~~	~~dB/km~~	~~≤ 0,40~~	~~≤0,40~~	~~≤ 0,40~~	~~≤ 0,40~~	
~~Attenuation coefficient at 1 550 nm~~	~~dB/km~~	~~≤ 0,30~~	~~≤ 0,30~~	~~≤ 0,30~~	~~≤ 0,30~~	
~~Zero dispersion wavelength, λ_0~~	~~nm~~	~~1 300 ≤ λ_0 ≤ 1 324~~	~~1 300 ≤ λ_0 ≤ 1 324~~	~~1 250 ≤ λ_0 ≤ 1 350~~	~~1 250 ≤ λ_0 ≤ 1 350~~	
~~Zero dispersion slope~~	~~ps/nm^2 · km~~	~~≤ 0,092~~	~~≤ 0,092~~	~~≤ 0,11~~	~~≤ 0,11~~	
~~Nominal MFD range at 1 310 nm [c]~~	~~µm~~	~~8,6 to 9,5~~	~~8,6 to 9,5~~	~~8,6 to 9,5~~	~~8,6 to 9,5~~	
~~MFD tolerance~~	~~µm~~	~~± 0,4~~	~~± 0,4~~	~~± 0,4~~	~~± 0,4~~	
~~Cable cut-off wavelength~~	~~nm~~	~~≤ 1 260~~	~~≤ 1 260~~	~~≤ 1 260~~	~~≤ 1 260~~	
~~Macrobending loss at 1 550 nm, 10 turns on a 15 mm radius mandrel~~	~~dB~~	~~≤ 0,25~~	~~≤ 0,03~~	~~≤ 0,03~~	~~NS~~	
~~Macrobending loss at 1 550 nm, 1 turn on a 10 mm radius mandrel~~	~~dB~~	~~≤ 0,75~~	~~≤ 0,1~~	~~≤ 0,1~~	~~≤ 0,03~~	
~~Macrobending loss at 1 550 nm, 1 turn on a 7,5 mm radius mandrel~~	~~dB~~	~~NS~~	~~≤ 0,5~~	~~≤ 0,5~~	~~≤0,08~~	
~~Macrobending loss at 1 550 nm, 1 turn on a 5 mm radius mandrel~~	~~dB~~	~~NS~~	~~NS~~	~~NS~~	~~≤ 0,15~~	
~~Macrobending loss at 1 625 nm, 10 turns on a 15 mm radius mandrel~~	~~dB~~	~~≤ 1,0~~	~~≤0,1~~	~~≤ 0,1~~	~~NS~~	
~~Macrobending loss at 1 625 nm, 1 turn on a 10 mm radius mandrel~~	~~dB~~	~~≤ 1,5~~	~~≤0,2~~	~~≤ 0,2~~	~~≤ 0,1~~	
~~Macrobending loss at 1 625 nm, 1 turn on a 7,5 mm radius mandrel~~	~~dB ps/nm · km~~	~~NS~~	~~≤1,0~~	~~≤1,0~~	~~≤ 0,25~~	
~~Macrobending loss at 1 625 nm, 1 turn on a 5 mm radius mandrel~~	~~dB~~	~~NS~~	~~NS~~	~~NS~~	~~≤ 0,45~~	
~~Polarization mode dispersion (PMD) coefficient~~	~~ps/√km~~	~~See 5.4~~	~~See 5.4~~	~~See 5.4~~	~~See 5.4~~	

Attribute	Unit	B-657.A1 Limit	B-657.A2 Limit	B-657.B2 Limit	B-657.B3 Limit	Reference
Attenuation coefficient from 1 310 nm to 1 625 nm [a]	dB/km	≤ 0,40				5.4
Attenuation coefficient at 1 383 mm ± 3 nm [b]	dB/km	≤ 0,40				5.4
Attenuation coefficient 1 530 nm – 1565 nm	dB/km	≤ 0,30				5.4
Zero dispersion wavelength, λ_0	nm	Matches specification for B-652.D fibre see Table A.6		1 250 ≤ λ_0 ≤ 1 350		5.4
Zero dispersion slope	ps/(nm^2 × km)	Matches specification for B-652.D fibre see Table A.6		≤ 0,11		5.4
Nominal MFD range at 1 310 nm[c]	µm	8,6 to 9,2				5.4
MFD tolerance	µm	± 0,4				5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260				5.4
Macrobending loss at 1 550 nm, 10 turns on a 15 mm radius mandrel	dB	≤ 0,25	≤ 0,03	≤ 0,03	NA	5.4
Macrobending loss at 1 550 nm, 1 turn on a 10 mm radius mandrel	dB	≤ 0,75	≤ 0,1	≤ 0,1	≤ 0,03	5.4
Macrobending loss at 1 550 nm, 1 turn on a 7,5 mm radius mandrel	dB	NA	≤ 0,5	≤ 0,5	≤0,08	5.4
Macrobending loss at 1 550 nm, 1 turn on a 5 mm radius mandrel	dB	NA	NA	NA	≤ 0,15	5.4
Macrobending loss at 1 625 nm, 10 turns on a 15 mm radius mandrel	dB	≤ 1,0	≤0,1	≤ 0,1	NA	5.4
Macrobending loss at 1 625 nm, 1 turn on a 10 mm radius mandrel	dB	≤ 1,5	≤0,2	≤ 0,2	≤ 0,1	5.4
Macrobending loss at 1 625 nm, 1 turn on a 7,5 mm radius mandrel	dB	NA	≤1,0	≤1,0	≤ 0,25	5.4
Macrobending loss at 1 625 nm, 1 turn on a 5 mm radius mandrel	dB	NA	NA	NA	≤ 0,45	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4				5.4

~~NOTE For B6_a1 and B6_a2 fibres the chromatic dispersion in the 1 550 nm region, can be approximated as a linear function with wavelength. A typical value for the chromatic dispersion at 1 550 nm is 17 ps/nm · km with a typical slope at 1 550 nm of 0,056.~~

[a] This wavelength region can be extended to 1 260 nm by adding 0,07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.

[b] The average attenuation coefficient after ageing according to the test outlined in Clause A.5, "Hydrogen ageing for ~~B1.3~~ B-652.D" shall be less than the value specified for the range of 1 310 nm to 1 625 nm.

[c] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

F.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex G
(informative)

System design information for category ~~B4~~ B-655 non-zero disperion shifted single-mode fibres

G.1 General

The following are examples of implementations that are designed to optimize various trade-offs in power, channel spacing, amplifier separation, link length and bit rate. All these examples given in Table G.1 are primarily variations in the allowed chromatic dispersion, chromatic dispersion slope, and non-linear coefficient. These are examples only, which do not preclude other possible implementations. The order of the examples is arbitrary and does not reflect any priority.

Table G.1 – Examples for λ_{min} = 1 530 nm and λ_{max} = 1 565 nm

Example ID	D_{min} ps/(nm x km)	D_{max} ps/(nm x km)	Sign	Typical chromatic dispersion coefficient at 1 550 nm ps/(nm x km)	Typical chromatic dispersion slope at 1 550 nm ps/(nm^2 x km)
A	1,3	5,8	+	3,7	0,070
B	2,0	6,0	+	4,2	0,085
C	2,6	6,0	+	4,4	0,045
D	5,0	10,0	+	8,0	0,058
E	1,0	6,0	–	–2,3	0,065

The specification values found in D.4.3 and D.4.4 were determined from two surveys in which multiple vendors of these sub-categories responded with average and standard deviation of the chromatic dispersion coefficient versus wavelength. The bounding curves enclose all these results at average plus or minus three standard deviations. The bounding curves resulting from enclosing the average plus or minus one standard deviation may be useful for system design. These are given in the following clauses.

G.2 One standard deviation limits for sub-category ~~B4_d~~ B-655.D fibres

The following represent limits derived from considering multiple vendors of sub-category ~~B4_d~~ B-655.D fibres and average plus or minus one standard deviation:

$$\frac{6,94}{90}(\lambda - 1460) - 3,4 \le D(\lambda) \le \frac{2,78}{90}(\lambda - 1460) + 2,60 \qquad \text{(G.1)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3,13}{75}(\lambda - 1\,550) + 3,0 \le D(\lambda) \le \frac{5,28}{75}(\lambda - 1550) + 5,38 \qquad \text{(G.2)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

Figure G.1 shows the chromatic dispersion coefficient limits associated with the specification, i.e. three sigma limits, and the values that could be used in system design, i.e.1 sigma limits.

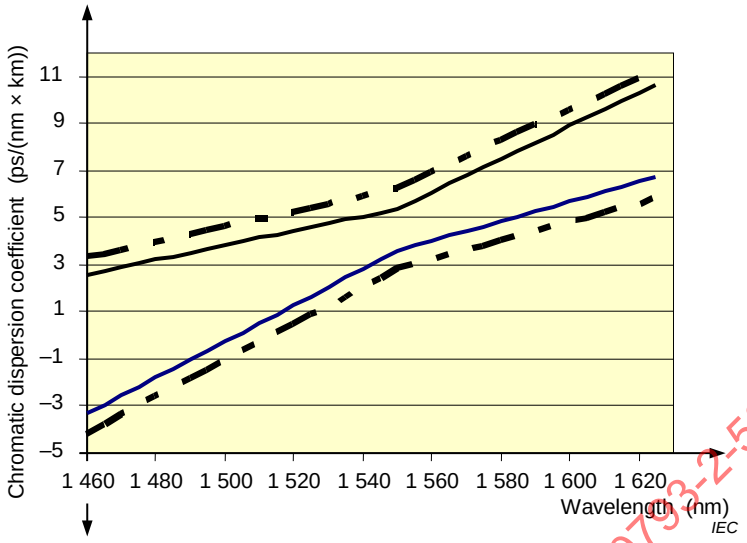

Figure G.1 – Sub-category ~~B4_d~~ B-655.D chromatic dispersion coefficient limits

G.3 One standard deviation limits for sub-category ~~B4_e~~ B-655.E fibres

The following represent limits derived from considering multiple vendors of sub-category ~~B4_e~~ B-655.E fibres and average plus or minus one standard deviation:

$$\frac{5{,}28}{90}(\lambda - 1460) + 1{,}68 \le D(\lambda) \le \frac{4{,}56}{90}(\lambda - 1460) + 3{,}89 \qquad \text{(G.3)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3{,}05}{75}(\lambda - 1\,550) + 6{,}96 \le D(\lambda) \le \frac{3{,}96}{75}(\lambda - 1\,550) + 8{,}45 \qquad \text{(G.4)}$$

for 1 500 nm ≤ λ ≤ 1 625 nm

Figure G.2 shows the chromatic dispersion coefficient limits associated with the specification, i.e. three sigma limits, and the values that could be used in system design, i.e. one sigma limit.

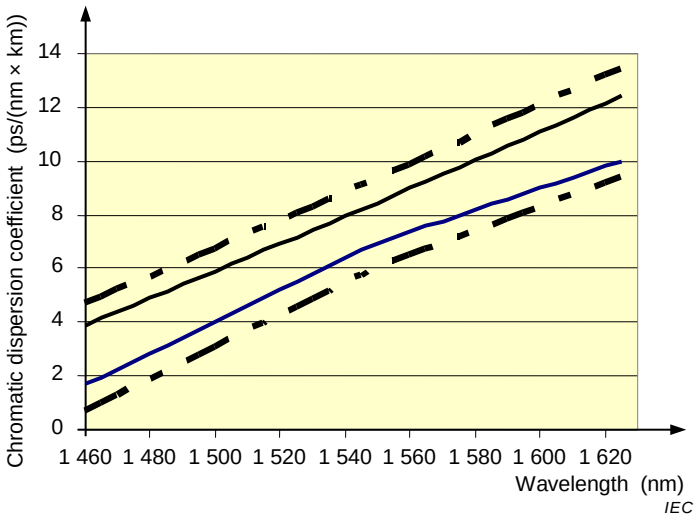

Figure G.2 – Sub-category ~~B4_e~~ B-655.E chromatic dispersion coefficient limits

Annex I
(informative)

Map from IEC nomenclature to ITU-T recommendations

Table I.1 shows a map from the IEC designations to the ITU-T recommendations. The ITU-T recommendations as well as the IEC categories/sub-categories within each recommendation are given. In some cases, as for Recommendation G.652, a given IEC designation maps to multiple categories in the ITU-T because the ITU categories are distinguished by cabled fibre attribute (PMD_Q) performance which are not distinguished in the IEC fibre specifications.

Table I.1 – Map of IEC to ITU

IEC	ITU-T
B1.1	G.652.A/B
B1.2_b	G.654.B
B1.2_c	G.654.C
B1.2_d	G.654.D
B1.3	G.652.C/D
B2_a	G.653.A
B2_b	G.653.B
B4_c	G.655.C
B4_d	G.655.D
B4_e	G.655.E
B5	G.656
B6_a1	G.657.A1
B6_a2	G.657.A2
B6_b2	G.657.B2
B6_b3	G.657.B3
NOTE In the ITU-T column, "A" means category A, while "A/B" means categories A and B.	

Bibliography

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

~~IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*~~

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

IEC TR 62048~~:2014~~, *Optical fibres – Reliability – Power law theory*

IEC TR 62316, *Guidance for the interpretation of OTDR backscattering traces for single-mode fibres*

ITU-T Rec. G.652, *Characteristics of a single-mode optical fibre and cable*

ITU-T Rec. G.653, *Characteristics of a dispersion-shifted, single-mode optical fibre and cable*

ITU-T Rec. G.654, *Characteristics of a cut-off shifted single-mode optical fibre and cable*

ITU-T Rec. G.655, *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*

ITU-T Rec. G.656, *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*

ITU-T Rec. G.657, *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*

ITU-T G.Sup.59:2018, *Guidance on optical fibre and cable reliability*

IEC 60793-2-50

Edition 6.0 2018-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
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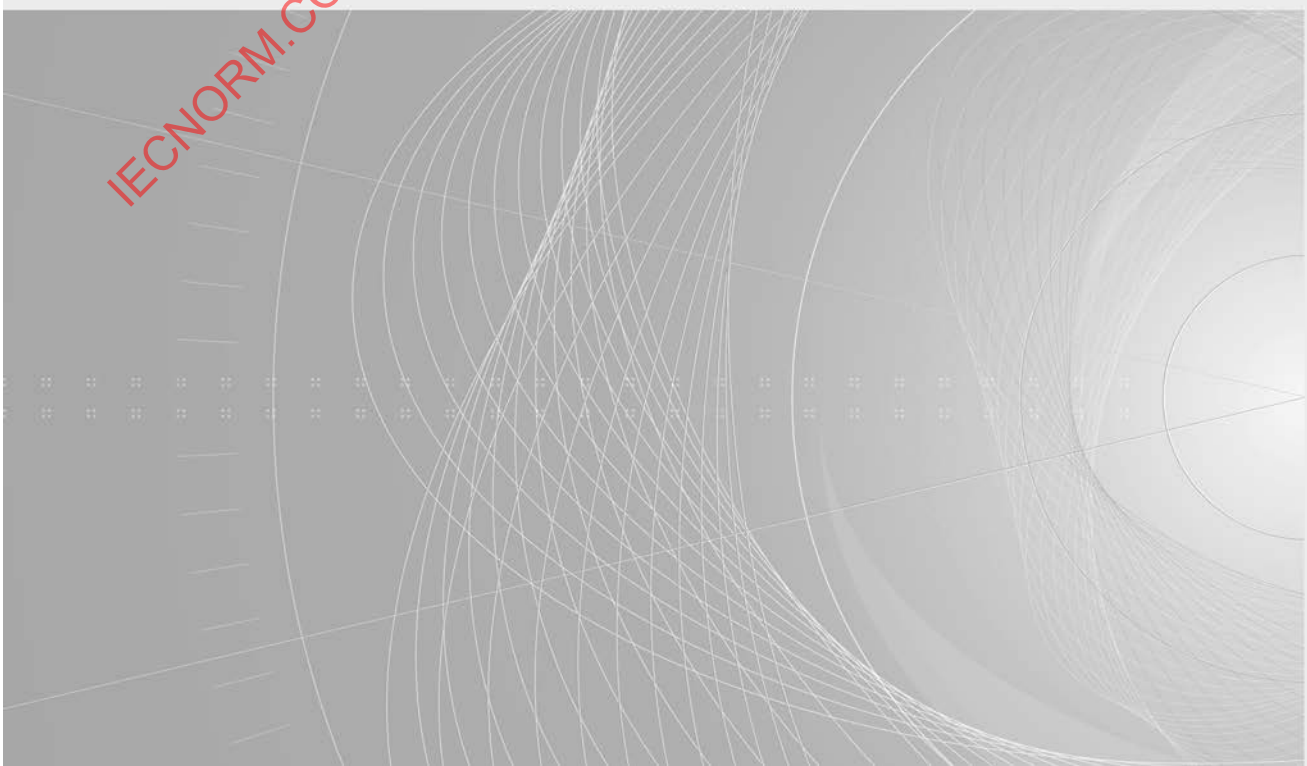
Fibres optiques –
Partie 2-50: Spécifications de produits – Spécification intermédiaire pour les fibres unimodales de classe B



IEC 60793-2-50:2018-12(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

OPTICAL FIBRES –

Part 2-50: Product specifications – Sectional specification for class B single-mode fibres

FOREWORD

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International Standard IEC 60793-2-50 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The sixth edition cancels and replaces the fifth edition published in 2015. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

a) Introduction of a revised naming convention which better matches with those found in ITU-T Recommendations G.652, G.653, G.654, G.655, G.656, and G.657. These changes are outlined in the scope of this document along with a cross reference table for the new names. Annexes have been rearranged to improve clarity based on the new naming;
b) Further details on the requirements for 200 micron coated single-mode fibre;
c) Harmonization with the following ITU-T Recommendations published in November 2016: G.652, G.654, G.657 including revised chromatic dispersion specifications, new categories and new application spaces for these fibre categories;

d) Descriptions of fibre types have been added to the titles of Annexes A to F.

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

FDIS	Report on voting
86A/1884/FDIS	86A/1898/RVD

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

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

A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, 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 FIBRES –

Part 2-50: Product specifications – Sectional specification for class B single-mode fibres

1 Scope

This part of IEC 60793 is applicable to optical fibre categories B-652, B-653, B-654, B-655, B-656 and B-657. A map illustrating the connection of IEC designations to ITU-T designations is shown in Table 1. These fibres are used or can be incorporated in information transmission equipment and optical fibre cables.

Three types of requirements apply to these fibres:

- general requirements, as defined in IEC 60793-2;
- specific requirements common to the class B single-mode fibres covered in this document and which are given in Clause 5;
- particular requirements applicable to individual fibre categories or specific applications, which are defined in Annexes A to F.

For some fibre categories (shown in the relevant family specifications), there are sub-categories that are distinguished on the basis of difference in transmission attribute specifications. The designations for these sub-categories are documented in the individual family specifications.

Table 1 shows a map from the IEC designations to the ITU-T recommendations. The table also provides the normative annex in this document that contains the detailed specification as well as the name used to describe this fibre type in IEC 60793-2-50:2015. The ITU-T recommendations as well as the IEC categories/sub-categories within each recommendation are given. In some cases, as for Recommendation G.652, a given IEC designation maps to multiple categories in the ITU-T because the ITU-T categories are distinguished by cabled fibre attribute (PMD_Q) performance which are not distinguished in the IEC fibre specifications.

Table 1 – Map of IEC designation to ITU-T Recommendations and IEC 60793-2-50:2015 designation

Annex	Category	Sub Category	Description	IEC 60793-2-50:2015	ITU-T Rec
	B-652		Dispersion unshifted fibre		G.652
A		B-652.B		B1.1	G.652.B
A		B-652.D		B1.3	G.652.D
	B-653		Dispersion shifted fibre		G.653
B		B-653.A		B2_a	G.653.A
B		B-653.B		B2_b	G.653.B
	B-654		Cut-off shifted fibre		G.654
C		B-654.A		B1.2_a	G.654.A
C		B-654.B		B1.2_b	G.654.B
C		B-654.C		B1.2_c	G.654.C
C		B-654.D		N/A	G.654.D
C		B-654.E		N/A	G.654.E
C	B-655		Non-zero dispersion shifted fibre	B4	G.655
D		B-655.C		B4_c	G.655.C
D		B-655.D		B4_d	G.655.D
D		B-655.E		B4_e	G.655.E
E	B-656		Wideband non-zero dispersion shifted fibre	B5	G.656
F	B-657		Bending loss insensitive fibre	B6	G.657
F		B-657.A1		B6_a1	G.657.A1
F		B-657.A2		B6_a2	G.657.A2
F		B-657.B2		B6_b2	G.657.B2
F		B-657.B3		B6_b3	G.657.B3

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 60793-1 (all parts), *Optical fibres*

IEC 60793-1-20, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

IEC 60793-1-21, *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry*

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

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

IEC 60793-1-31, *Optical fibres – Part 1-31: Measurement methods and test procedures – Tensile strength*

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

IEC 60793-1-33, *Optical fibres – Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility*

IEC 60793-1-34, *Optical fibres – Part 1-34: Measurement methods and test procedures – Fibre curl*

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

IEC 60793-1-42, *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-45, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*

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

IEC 60793-1-47, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*

IEC 60793-1-48, *Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion*

IEC 60793-1-50, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state) tests*

IEC 60793-1-51, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat (steady state) tests*

IEC 60793-1-52, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature tests*

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

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60793-2 and the IEC 60793-1 series apply.

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

NOTE General definitions for fibres are provided in IEC 60793-2. The definitions of the specified attributes are contained in the relevant test methods standard of the IEC 60793-1 series, while general definitions for testing are provided in IEC 60793-1-1.

4 Abbreviated terms and symbols

For the purposes of this document, the following abbreviated terms and symbols apply:

F_{avg}	Average strip force
F_{peak}	Peak strip force
λ_0	Zero dispersion wavelength
λ_c	Fibre cut-off wavelength
λ_{cc}	Cable cut-off wavelength
MFD	Mode field diameter
n_d	Stress corrosion parameter – dynamic
PMD	Polarization mode dispersion
PMD_Q	PMD link design value

5 Specifications

5.1 General

The fibre shall consist of a glass core and glass cladding in accordance with the construction of optical fibre class B – single-mode fibre – as given in IEC 60793-2.

The term “glass” usually refers to material consisting of non-metallic oxides. The composition of some fibres may be all glass, or glass and glass/hard polymeric composites.

5.2 Dimensional requirements

Relevant dimensional attributes and measurement methods are given in Table 2.

Requirements common to all categories of class B single-mode fibres are given in Table 3.

Cladding diameter, cladding non-circularity, and core – cladding concentricity error shall be specified in the family specifications

Table 2 – Dimensional attributes and measurement methods

Attribute	Measurement method
Cladding diameter	IEC 60793-1-20
Cladding non-circularity	IEC 60793-1-20
Core – cladding concentricity error	IEC 60793-1-20
Primary coating diameter	IEC 60793-1-21
Primary coating non-circularity	IEC 60793-1-21
Primary coating-cladding concentricity error	IEC 60793-1-21
Fibre length	IEC 60793-1-22

Table 3 – Dimensional requirements common to all category B fibres

Attribute	Unit	Limit
Primary coating diameter – uncoloured	µm	235 to 255 [a]
Primary coating diameter – coloured	µm	235 to 265 [a]
Primary coating-cladding concentricity error	µm	≤ 12,5
Fibre length	km	[b]

[a] The above limits on primary coating diameter are most commonly used in telecommunications cables. There are other applications, such as fibre for use within optical sub-systems, pigtails, or specialty applications such as for submarines cables or for compact FTTH cables, which use other primary coating diameters, several of which are listed below.

180 µm to 210 µm uncoloured; 180 µm to 220 µm coloured

400 µm ± 40 µm

500 µm ± 50 µm

700 µm ± 70 µm

900 µm ± 90 µm

Alternative coating diameters may impact fibre connectivity such as ribbons, multi-fibre connectors, mechanical splices, and fusion splice protectors; they may also need adjustments to connectivity tools and/or tighter coating tolerances.

[b] Length requirements vary and should be agreed between supplier and customer.

5.3 Mechanical requirements

Relevant mechanical attributes and test methods are given in Table 4. The relationship between some of these attributes and mechanical reliability are described in IEC TR 62048 and ITU-T G.Sup.59.

Requirements common to all categories of class B single-mode fibres are given in Table 5.

Table 4 – Mechanical attributes and test methods

Attribute	Test method
Proof test	IEC 60793-1-30
Tensile strength	IEC 60793-1-31
Coating strippability	IEC 60793-1-32
Stress corrosion susceptibility	IEC 60793-1-33
Fibre curl	IEC 60793-1-34

Table 5 – Mechanical requirements common to all class B fibres

Attribute	Unit	Limit
Proof stress level	GPa	≥ 0,69 [a]
Coating strip force (average) [b, c]	N	$1,0 \leq F_{ave} \leq 5,0$
Coating strip force (peak) [b, c]	N	$1,0 \leq F_{peak} \leq 8,9$
Fibre curl radius	m	≥ 2 [d]
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8
Stress corrosion susceptibility parameter, n_d	–	≥ 18

[a] The proof test value of 0,69 GPa equals about 1 % strain or about 8,8 N force. For the relation between these different units, see IEC TR 62048:2014, clause 8.4.

[b] Either average strip force or peak strip force, which are defined in the test procedure, may be specified with agreement between supplier and customer.

[c] In case of alternative nominal primary coating diameters (see Table 2), associated alternative coating strip force values need to be agreed between supplier and customer or provided in the detailed specifications provided in Annexes of this document.

[d] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

5.4 Transmission requirements

Relevant transmission attributes and measurement methods are given in Table 6.

Requirements common to all categories of class B single-mode fibres are shown in Table 7.

Requirements that shall be specified in the family specifications are listed in Table 8.

Table 6 – Transmission attributes and measurement methods

Attribute	Measurement method
Attenuation coefficient	IEC 60793-1-40 [a]
Chromatic dispersion	IEC 60793-1-42
Cut-off wavelength [b]	IEC 60793-1-44
Mode field diameter	IEC 60793-1-45
Change of optical transmission	IEC 60793-1-46
Macrobending loss	IEC 60793-1-47
Polarization mode dispersion	IEC 60793-1-48
The indicated maximum attenuation values apply to cabled and uncabled optical fibres. Tighter specifications for the fibre may be requested to account for added attenuation in the cabling process; for the maximum cabled attenuation values, reference is made to IEC 60794-2, which can be used in conjunction with this document.	

[a] The attenuation coefficient at various wavelengths can be calculated using the measured values at a few wavelengths using a spectral model such as that given in IEC 60793-1-40. For example, the attenuation at 1 480 nm can be calculated and used for design of systems that employ remote pumping of optical amplifiers. When using Method C, OTDR, additional guidance information in IEC TR 62316 shall be taken into account. As reported in IEC 60793-1-40:20xx, the spectral attenuation model has been demonstrated on all class B fibres.

[b] There are two ways to measure cut-off wavelength, leading to: fibre cut-off wavelength λ_c and to cable cut-off wavelength λ_{cc}, respectively. The correlation of the measured values of λ_c and λ_{cc} depends on the specific fibre and cable design and the test conditions. While in general $\lambda_{cc} < \lambda_c$ a general quantitative relationship cannot be easily established, the importance of ensuring single-mode transmission in the minimum cable length between joints at the minimum operating wavelength is paramount. This may be performed by recommending the maximum cable cut-off wavelength λ_{cc} of a cabled single-mode fibre to be 1 260 nm or for worst case length and bends by recommending a maximum fibre cut-off wavelength λ_c to be 1 260 nm.

Table 7 – Transmission, requirements common to all class B fibres

Attribute	Unit	Limit
Polarization mode dispersion (PMD) coefficient link design value (PMD_Q)	$ps/\sqrt{km}$	[a]
[a] A maximum value of PMD_Q on uncabled fibre shall be agreed between supplier and customer to satisfy the primary requirement of cable PMD, given in IEC 60794-3.		

Table 8 – Additional transmission attributes required in the family specifications

Attribute
Attenuation coefficient and wavelengths
Chromatic dispersion characteristics
Nominal mode field diameter (MFD) range and wavelength
Mode field diameter tolerance
Cable cut-off wavelength, λ_{cc}
Macrobending loss including: wavelength, mandrel size, and number of turns
Cladding diameter
Cladding non-circularity
Core – cladding concentricity error

For category B-655 fibre, information for system design is given in Annex G.

5.5 Environmental requirements

5.5.1 General

Environmental exposure tests and measurement methods are documented in two forms:

- relevant environmental attributes and test methods are given in Table 9;
- measurements of a particular mechanical or transmission attributes that may change on the application of the environment are listed in Table 10.

Table 9 – Environmental exposure tests

Attribute	Test method
Damp heat tests	IEC 60793-1-50
Dry heat tests	IEC 60793-1-51
Change of temperature tests	IEC 60793-1-52
Water immersion tests	IEC 60793-1-53

Table 10 – Attributes measured in environmental exposure tests

Attribute	Test method
Change in optical transmission	IEC 60793-1-46
Attenuation	IEC 60793-1-40
Coating strip force	IEC 60793-1-32
Tensile strength	IEC 60793-1-31
Stress corrosion susceptibility	IEC 60793-1-33

These tests are normally conducted periodically as type-tests for a fibre and coating design. Unless otherwise indicated, the recovery period allowed between the completion of the environmental exposure and performing the attribute measurements shall be as stated in the particular environmental test method.

5.5.2 Optical environmental requirements – Attenuation

Change in attenuation from the initial value shall be less than the values in Table 11. Attenuation shall be measured periodically during the entire exposure to each environment and after removal.

Table 11 – Change in attenuation for environmental tests

Environment	Wavelength nm	Maximum attenuation increase dB/km
Damp heat	1 550, 1 625	≤ 0,05
Dry heat	1 550, 1 625	≤ 0,05
Change of temperature	1 550, 1 625	≤ 0,05
Water immersion	1 550, 1 625	≤ 0,05
NOTE Attenuation changes at wavelengths lower than the test wavelength are smaller than the attenuation change at the test wavelength.		

5.5.3 Mechanical environmental requirements

5.5.3.1 General

These tests are, in practice, the most severe requirements amongst the environments defined in Table 9.

5.5.3.2 Coating strip force

The attributes given in Table 12 shall be verified following removal of the fibre from the particular environment.

Table 12 – Coating strip force for environmental tests

Environment	Average strip force N	Peak strip force N
Damp heat	$1{,}0 \leq F_{avg} \leq 5{,}0$	$1{,}0 \leq F_{peak} \leq 8{,}9$
Water immersion	$1{,}0 \leq F_{avg} \leq 5{,}0$	$1{,}0 \leq F_{peak} \leq 8{,}9$
NOTE In case of alternative nominal primary coating diameters (see Table 2), associated alternative coating strip force values need to be agreed between supplier and customer unless specified in the detailed product specifications or provided in the annexes of this document.		

5.5.3.3 Tensile strength

The attributes given in Table 13 shall be verified following removal of the fibre from the environment indicated.

Table 13 – Tensile strength for environmental tests

Environment	Median tensile strength (GPa), specimen length: 0,5 m	15 percentile of the tensile strength distribution (GPa), specimen length: 0,5 m
Damp heat	≥ 3,03	≥ 2,76
NOTE These requirements do not apply to hermetically coated fibre. (A hermetic coating is a protective layer that completely segregates the glass fibre from moisture, thereby ensuring a high level of stress corrosion resistance. Typical hermetic coating is a carbon layer of several microns thickness applied on the glass surface.)		

5.5.3.4 Stress corrosion susceptibility

The attribute given in Table 14 shall be verified following removal of the fibre from the environment indicated.

Table 14 – Stress corrosion susceptibility for environmental tests

Environment	Stress corrosion susceptibility parameter, n_d
Damp heat	≥ 18
NOTE This requirement does not apply to hermetically coated fibre (see definition for hermetic coating in Table 13).	

Annex A
(normative)

Family specification for category B-652 Dispersion unshifted single-mode fibres

A.1 General

This dispersion unshifted single-mode fibre is optimized for use in the 1 310 nm region but can be used in the 1 550 nm and 1 625 nm regions. Depending on link length and bit rates, dispersion may need accommodation in the 1 550 nm and 1 625 nm regions.

The clauses and tables in Annex A contain particular requirements applicable to category B-652 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “Reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript "SS".

A.2 Dimensional requirements

Table A.1 contains dimensional requirements specific to category B-652.B fibres.

Table A.1 – Dimensional requirements specific to category B-652.B fibres

Attribute	Unit	Limit (250 μm coating)	Limit (200 μm coating)	Reference
Cladding diameter	μm	125 ± 1	125 ± 1	5.2
Cladding non-circularity	%	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	μm	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	μm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	μm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	μm	≤ 12,5	≤ 10,0	5.2
Fibre length	km	See 5.2	See 5.2	5.2

[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.

Table A.2 contains dimensional requirements specific to category B-652.D fibres.

Table A.2 – Dimensional requirements specific to category B-652.D fibres

Attribute	Unit	Limit (250 µm coating)	Limit (200 µm coating)	Reference
Cladding diameter	µm	125 ± 0,7	125 ± 0,7	5.2
Cladding non-circularity	%	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 10,0	5.2
Fibre length	km	See 5.2	See 5.2	5.2
[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.				

A.3 Mechanical requirements

Table A.3 contains mechanical requirements specific to category B-652 fibres.

Table A.3 – Mechanical requirements specific to category B-652 fibres

Attribute	Unit	Limit (250 µm coating)	Limit (200 µm coating)	Reference
Proof stress level	GPa	≥ 0,69 [SS]		5.3
Coating strip force (average) [SS]	N	$1,0 \leq F_{ave} \leq 5,0$	$0.4 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) [SS]	N	$1,0 \leq F_{peak} \leq 8,9$	$0.4 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	m	≥ 2 [a]		5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8		5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18		5.3
[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.				

A.4 Transmission requirements

Table A.4 contains transmission requirements specific to sub-category B-652.B fibres and Table A.5 contains transmission requirements specific to sub-category B-652.D fibres. Table A.6 provides chromatic dispersion values for sub-category B-652.D fibres.

Table A.4 – Transmission requirements specific to sub-category B-652.B fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 1 310 nm	dB/km	≤ 0,4	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,35	5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4	5.4
Zero dispersion wavelength, λ_0	nm	1 300 ≤ λ_0 ≤ 1 324	5.4
Zero dispersion slope	ps/(nm^2 x km)	≤ 0,092	5.4
Nominal MFD range at 1 310 nm [a]	µm	8,6 to 9,5	5.4
MFD tolerance	µm	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
NOTE In the 1 550 nm region, the chromatic dispersion can be approximated as a linear function with wavelength. A typical value for the chromatic dispersion at 1 550 nm is 17 ps/(nm x km) with a typical slope at 1 550 nm of 0,056 ps/(nm² x km).			
[a] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

Table A.5 – Transmission requirements specific to sub-category B-652.D Fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient from 1 310 nm to 1 625 nm [a]	dB/km	≤ 0,40	5.4
Attenuation coefficient at 1 383 nm ± 3 nm	dB/km	≤ 0,40	5.4
Attenuation coefficient 1 530 nm – 1 565 nm	dB/km	≤ 0,30	5.4
Chromatic dispersion	See Table A.6		5.4
Nominal MFD range at 1 310 nm [b]	µm	8,6 to 9,2	5.4
MFD tolerance	µm	± 0,4	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
[a] This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.			
[b] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

Table A.6 – Chromatic dispersion properties for sub-category B-652.D fibres

Attribute [a]	Detail	Limit	Unit
3-term Sellmeier fitting (1260 nm to 1460 nm)	λ_{0min}	1 300	nm
	λ_{0max}	1 324	nm
	S_{0min}	0,073	ps/(nm^2 × km)
	S_{0max}	0,092	ps/(nm^2 × km)
Linear fitting (1460 nm to 1625 nm)	Minimum at 1 550 nm	13,3	ps/(nm × km)
	Maximum at 1 550 nm	18,6	ps/(nm × km)
	Minimum at 1 625 nm	17,2	ps/(nm × km)
	Maximum at 1 625 nm	23,7	ps/(nm × km)
[a] Details of the equations used that define these attributes are provided in section 6.10 of ITU-T G.652.			

A.5 Hydrogen ageing for sub-category B-652.D

Select a fibre specimen at least 1 km long. After spooling the fibre to a test configuration that minimizes the effect of winding on attenuation at 1 310 nm, measure the attenuation coefficient of the specimen at 1 240 nm and at 1 383 nm. This measurement gives the baseline attenuation for the specimen. Expose the fibre to 0,01 atmospheres of hydrogen at room temperature (reference test). For practical considerations, such as the availability of equipment and testing time, higher H_2 concentrations (e.g. 1 atm) can be used with proper care as mentioned in Note 4. During this exposure, monitor the attenuation coefficient of the specimen at 1 240 nm. This wavelength is indicative of the molecular hydrogen present in the specimen. Constructing the change in attenuation as the monitored results minus the baseline value, continue exposure until the 1 240 nm attenuation changes by ≥ 0,03 dB/km. At this time, the attenuation increase at 1 383 nm may be considered fully saturated, and the specimen may be removed from the hydrogen atmosphere. After at least 14 days in the normal laboratory environment, measure the attenuation coefficient of the fibre at 1 383 nm using methods A, B or C of IEC 60793-1-40.

NOTE 1 This is a type test performed periodically to ensure that the manufacturing process reliably yields fibre with acceptable ageing characteristics. For example, 10 fibre samples can be tested every 6 months.

NOTE 2 This test is not appropriate for hermetically coated fibre (see definition for hermetic coating in Table 12).

NOTE 3 For non-hermetic fibres, typical hydrogen exposure is from 4 days to 6 days (see definition for hermetic coating in Table 12).

NOTE 4 Hydrogen ageing should be performed in H_2 concentrations that produce results representative of the actual field conditions. Although increased H_2 concentration reduces testing time, it tends to produce slightly higher values of added loss at equivalent exposure time (see threshold for increases at 1 240 nm). The 0,01 atmosphere test is a compromise between impractically long testing times and unrealistically high added loss. When testing with higher H_2 concentration, the reduced testing time can require increased safety measures.

A.6 Environmental requirements

The requirements of 5.5 shall be met.

Annex B
(normative)

Family specification for category B-653 Dispersion shifted single-mode fibres

B.1 General

This dispersion-shifted single-mode fibre is optimized for single-channel transmission in the 1 550 nm region. Multiple channels can only be transmitted if care is taken to avoid the effects of four-wave mixing by, for example, moderating the power levels or appropriate spacing or placement of the channels.

The clauses and tables in Annex B contain particular requirements applicable to category B-653 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “Reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript “ss”.

There are two sub-categories which are designated as with suffixes, “.A” and “.B”. These sub-categories are distinguished by the glass geometry tolerances, mode field diameter tolerance, and chromatic dispersion coefficient and mode field diameter attribute specifications.

B.2 Dimensional requirements

Table B.1 contains dimensional requirements specific to category B-653 fibres.

Table B.1 – Dimensional requirements specific to category B-653 fibres

Attribute	Unit	B-653.A Limit	B-653.B Limit	Reference
Cladding diameter	µm	125 ± 1	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 12,5	5.2
Fibre length	km	See 5.2	See 5.2	5.2

[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.

Table B.2 contains mechanical requirements specific to category B-653 fibres.

Table B.2 – Mechanical requirements specific to category B-653 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 [a]	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3

[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

B.3 Transmission requirements

B.3.1 General

Table B.3 contains transmission requirements specific to category B-653 fibres.

Table B.3 – Transmission requirements specific to category B-653 fibres

Attribute	Unit	B-653.A Limit	B-653.B Limit	Reference
Attenuation coefficient at 1 310 nm[a]	dB/km	≤ 0,50	≤ 0,50	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,35	≤ 0,35	5.4
Attenuation coefficient at 1 625 nm[a]	dB/km	≤ 0,40	≤ 0,40	5.4
Chromatic dispersion coefficient	ps/(nm x km)	See B.3.2	See B.3.3	5.4
Nominal MFD range at 1 550 nm [b]	µm	7,8 to 8,5	7,8 to 8,5	5.4
MFD tolerance	µm	± 0,8	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 270	≤ 1 270	5.4
Macrobending loss at 1 550 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,5	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	See 5.4	5.4

[a] This attenuation coefficient is not specified in ITU-T G.653 at this time. If ITU-T specifies this parameter the value in the ITU-T document takes precedent.

[b] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

B.3.2 Chromatic dispersion coefficient requirement for sub-category B-653.A fibres

The requirement is given as a combined requirement on the absolute value of the chromatic dispersion coefficient for a range of wavelength and a limit on the zero-dispersion wavelength, λ_0, and slope at λ_0, S_0.

$$|D(\lambda)| \leq 3,5 \text{ ps/(nm} \times \text{km) for 1 525 nm} \leq \lambda \leq \text{1 575 nm} \quad \text{(B.1)}$$

and

$$1\,500 \text{ nm} \leq \lambda_0 \leq 1\,600 \text{ nm} \quad \text{(B.2)}$$

and

$$S_0 \leq 0{,}085 \text{ ps/(nm}^2 \times \text{km)}. \quad \text{(B.3)}$$

B.3.3 Chromatic dispersion coefficient requirement for sub-category B-653.B fibres

The requirement is given as a series of bounding line segments versus wavelength. These line segment boundaries are equivalent to the requirements stated in D.4.2. The units of chromatic dispersion coefficient, $D(\lambda)$, are ps/(nm x km) and the units of wavelength, λ, are nm.

$$0{,}085\ (\lambda - 1\,525) - 3{,}5 \leq D(\lambda) \text{ for } 1\,460 \text{ nm} \leq \lambda \leq 1\,525 \text{ nm} \quad \text{(B.4)}$$

$$\frac{3{,}5}{75}(\lambda - 1\,600) \leq D(\lambda) \text{ for } 1\,525 \text{ nm} \leq \lambda \leq 1\,625 \text{ nm} \quad \text{(B.5)}$$

$$D(\lambda) \leq \frac{3{,}5}{75}(\lambda - 1\,500) \text{ for } 1\,460 \text{ nm} \leq \lambda \leq 1\,575 \text{ nm} \quad \text{(B.6)}$$

$$D(\lambda) \leq 0{,}85\ (\lambda - 1\,575) + 3{,}5 \text{ for } 1\,575 \text{ nm} \leq \lambda \leq 1\,625 \text{ nm} \quad \text{(B.7)}$$

B.4 Environmental requirements

The requirements of 5.5 shall be met.

Annex C
(normative)

Family specification for category B-654 cut-off shifted single-mode fibres

C.1 General

This dispersion unshifted single-mode fibre is optimized for low loss in the 1 550 nm region, with the cutoff wavelength shifted above the 1 310 nm region.

The clauses and tables in Annex C contain particular requirements applicable to category B-654 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “Reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript ”SS”.

There are five sub-categories which are designated as with suffixes, ".A", ".B", ".C", ".D" and ".E". These sub-categories are distinguished by the chromatic dispersion coefficient and mode field diameter attribute specifications.

C.2 Dimensional requirements

Table C.1 contains dimensional requirements specific to category B-654 fibres.

Table C.1 – Dimensional requirements specific to category B-654 fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	5.2
Fibre length	km	See 5.2	5.2

[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.

C.3 Mechanical requirements

Table C.2 contains mechanical requirements specific to category B-654 fibres.

Table C.2 – Mechanical requirements specific to category B-654 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 [a]	5.3
Tensile strength (median) for 0.5 m specimen length	GPa	≥ 3.8	5.3
Stress corrosion parameter, n_d	-	≥ 18	5.3

[a] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.

Table C.3 contains transmission requirements specific to category B-654 fibres. There are five sub-categories designated as ".A", ".B", ".C", ".D", and ".E".

Table C.3 – Transmission requirements specific to category B-654 fibres

Attribute	Unit	.A Limit	.B Limit	.C Limit	.D Limit	.E Limit	Ref
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,22	≤ 0,22	≤ 0,22	≤ 0,20	≤ 0,23	5.4
Attenuation coefficient at 1 625 nm[a]	dB/km	NA	≤ 0,40	≤ 0,40	≤ 0,40	NA	5.4
Chromatic dispersion slope at 1 550 nm	ps/(nm^2 x km)	≤ 0,070	≤ 0,070	≤ 0,070	≤ 0,070	≤ 0,070 ≥ 0.050	5.4
Chromatic dispersion coefficient at 1 550 nm	ps/(nm x km)	≤ 20	≤ 22	≤ 20	≤ 23	≤ 23 ≥ 17	5.4
Nominal MFD range at 1 550 nm [b]	µm	9,5 to 10,5	9,5 to 13,0	9,5 to 10,5	11,5 to 15,0	11,5 to 12,5	5.4
MFD tolerance	µm	±0,7	±0,7	±0,7	±0,7	±0,7	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 530	≤ 1 530	≤ 1 530	≤ 1 530	≤ 1 530	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,50	≤ 0,50	≤ 0,50	≤ 2,0 [c]	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	See 5.4	See 5.4	See 5.4	See 5.4	5.4

[a] This attenuation coefficient is not specified in ITU-T G.654 at this time. If ITU-T specifies this parameter the value in in the ITU-T document takes precedent.

[b] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

[c] Other application specific test conditions and requirements (bending radius and number of turns) at 1 550 nm are under study.

C.4 Chromatic dispersion parameters for B-654.E fibres

For B-654.E fibre, the chromatic dispersion parameters indicated in Table C.3 are specified in order to bind the minimum/maximum chromatic dispersion coefficient $D(\lambda)$ at wavelength λ from 1 530 nm to 1 625 nm. This allows more accurate system design, in which dispersion-compensating schemes are incorporated. The quadratic fitting for the group delay found in Table D.1 of IEC 60793-1-42:2013 is applied, and the $D(\lambda)$ is bound by the following inequality:

$$D_{1\,550\text{min}} + S_{1\,550\text{min}}(\lambda - 1\,550) \leq D(\lambda) \leq D_{1\,550\text{max}} + S_{1\,550\text{max}}(\lambda - 1\,550) \quad \text{(C.1)}$$

where $D_{1\ 550\text{min}}$, $D_{1\ 550\text{max}}$, $S_{1\ 550\text{min}}$, and $S_{1\ 550\text{max}}$ are listed in Table C.3 and below:

$D1550_{min}$ = 17 ps/(nm x km)

$D1550_{max}$ = 23 ps/(nm x km)

$S1550_{min}$ = 0,050 ps/(nm^2 x km)

$S1550_{max}$ = 0,070 ps/(nm^2 x km).

C.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex D
(normative)

Family specification for category B-655 non-zero dispersion shifted single-mode fibres

D.1 General

This non-zero dispersion-shifted single-mode fibre is optimized for multiple channel transmission in the 1 550 nm region with a cut-off wavelength that may be shifted above the 1 310 nm region. The chromatic dispersion coefficient is required to be non-zero throughout the band from 1 530 nm to 1 565 nm, but may be either positive or negative. Depending on the chromatic dispersion characteristics, multiple channel transmission may be possible at bands either above or below the normal 1 550 nm region.

The clauses and tables in Annex D contain particular requirements applicable to category B-655 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript “SS”.

There are three sub-categories which are designated as with suffixes, ".C", ".D", and ".E". These sub-categories are distinguished by the chromatic dispersion coefficient attribute specifications. For sub-category B-655.C, the traditional “box specification” is maintained. For sub-categories B-655.D and B-655.E fibres, the chromatic dispersion limits are in the form of a pair of curves versus wavelength. See Annex G for more information on these curves.

D.2 Dimensional requirements

Table D.1 contains dimensional requirements specific to category B-655 fibres.

Table D.1 – Dimensional requirements specific to category B-655 fibres

Attribute	Unit	B-655.C Limit	B-655.D Limit	B-655.E Limit	Reference
Cladding diameter	µm	125 ± 1			5.2
Cladding non-circularity	%	≤ 2,0	≤ 1,0	≤ 1,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	≤ 0,6	≤ 0,6	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255			5.2
Primary coating diameter – coloured [a]	µm	235 to 265			5.2
Primary coating-cladding concentricity error	µm	≤ 12,5			5.2
Fibre length	km	See 5.2			5.2
[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.					

D.3 Mechanical requirements

Table D.2 contains mechanical requirements specific to category B-655 fibres.

Table D.2 – Mechanical requirements specific to category B-655 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 a	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3
a Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions – such as ribbon cable.			

D.4 Transmission requirements

D.4.1 General

Table D.3 contains transmission requirements specific to category B-655 fibres.

Table D.3 – Transmission requirements specific to category B-655 fibres

Attribute	Unit	Limit		Reference
		B-655.C	B-655.D,E	
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,35		5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4		5.4
Chromatic dispersion coefficient	ps/(nm x km)	See D.4.2, D.4.3, and D.4.4		5.4
Nominal MFD range at 1 550 nm a	µm	8,0 to 11,0		5.4
MFD tolerance	µm	± 0,7	± 0,6	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 450		5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤ 0,50	≤ 0,1	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$		See 5.4	5.4
a The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.				

NOTE Annex G includes implementation examples that do not preclude any other possible implementations.

D.4.2 Chromatic dispersion coefficient limits for sub-category B-655.C fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met:

$$1,0 \text{ ps/nm} \cdot \text{km} \leq D_{min} \leq |D(\lambda)| \leq D_{max} \leq 10,0 \text{ ps/nm} \cdot \text{km} \quad \text{(D.1)}$$

for 1 530 nm ≤ λ ≤ 1 565 nm

and

$$D_{max} - D_{min} \leq 5,0 \text{ ps/nm} \cdot \text{km} \quad \text{(D.2)}$$

The sign of the chromatic dispersion coefficient may be positive or negative, but $D(\lambda)$ shall not cross zero in the range of wavelengths from 1 530 nm to 1 565 nm.

The values of D_{min} and D_{max} as well as the sign shall be agreed between customer and supplier.

D.4.3 Chromatic dispersion coefficient limits for sub-category B-655.D fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm × km) and varies with wavelength, λ. The following inequalities shall be met:

$$\frac{7{,}00}{90}(\lambda - 1460) - 4{,}20 \le D(\lambda) \le \frac{2{,}91}{90}(\lambda - 1460) + 3{,}29 \quad \text{(D.3)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{2{,}97}{75}(\lambda - 1\,550) + 2{,}80 \le D(\lambda) \le \frac{5{,}06}{75}(\lambda - 1\,550) + 6{,}20 \quad \text{(D.4)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

D.4.4 Chromatic dispersion coefficient limits for sub-category B-655.E fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met.

$$\frac{5{,}42}{90}(\lambda - 1460) + 0{,}64 \le D(\lambda) \le \frac{4{,}65}{90}(\lambda - 1460) + 4{,}66 \quad \text{(D.5)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3{,}30}{75}(\lambda - 1\,550) + 6{,}06 \le D(\lambda) \le \frac{4{,}12}{75}(\lambda - 1\,550) + 9{,}31 \quad \text{(D.6)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

D.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex E
(normative)

Family specification for category B-656 Wideband non-zero dispersion shifted single-mode fibres

E.1 General

This non-zero dispersion-shifted single-mode fibre is optimized for multiple channel transmission in the wavelength range of 1 460 nm to 1 625 nm with the positive value of the chromatic dispersion coefficient that is greater than some non-zero value. This fibre can be used for both CWDM and DWDM systems throughout the wavelength region between 1 460 nm and 1 625 nm.

The clauses and tables in Annex E contain particular requirements applicable to category B-656 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript “SS”.

E.2 Dimensional requirements

Table E.1 contains dimensional requirements specific to category B-656 fibres.

Table E.1 – Dimensional requirements specific to category B-656 fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	125 ± 1	5.2
Cladding non-circularity	%	≤ 2,0	5.2
Core – cladding concentricity error	µm	≤ 0,8	5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	5.2
Fibre length	km	See 5.2	5.2

[a] Alternative nominal primary coating diameters may be used, (see Table 2), to be agreed between supplier and customer.

E.3 Mechanical requirements

Tableau E.2 contains mechanical requirements specific to category B-656 fibres.

Table E.2 – Mechanical requirements specific to category B-656 fibres

Attribute	Unit	Limit	Reference
Proof stress level	GPa	≥ 0,69 SS	5.3
Coating strip force (average) SS	N	$1,0 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) SS	N	$1,0 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	M	≥ 2 a	5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8	5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18	5.3
a Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions, such as ribbon cable.			

E.4 Transmission requirements

E.4.1 General

Table E.3 contains transmission requirements specific to category B-656 fibres.

Table E.3 – Transmission requirements specific to category B-656 fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 1 460 nm	dB/km	≤ 0,4	5.4
Attenuation coefficient at 1 550 nm	dB/km	≤ 0,35	5.4
Attenuation coefficient at 1 625 nm	dB/km	≤ 0,4	5.4
Chromatic dispersion coefficient a	ps/(nm x km)	See E.4.2	5.4
Nominal MFD range at 1 550 nm b	µm	7,0 to 11,0	5.4
MFD tolerance	µm	± 0,7	5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 450	5.4
Macrobending loss at 1 625 nm, 100 turns on a 30 mm radius mandrel	dB	≤0,50	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4	5.4
a If a Raman pump is used outside the wavelength region from 1 460 nm to 1 625 nm, fibre properties have to be suitable for accommodating this pump, for example λ_0 may need to be less than the pump wavelength.			
b The value of nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.			

E.4.2 Chromatic dispersion coefficient for category B-656 fibres

The chromatic dispersion coefficient, $D(\lambda)$, is given in ps/(nm x km) and varies with wavelength, λ. The following inequalities shall be met:

$$\frac{2,60}{90}(\lambda - 1460) + 1,00 \leq D(\lambda) \leq \frac{4,68}{90}(\lambda - 1460) + 4,60 \qquad \text{(E.1)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{0{,}98}{75}(\lambda - 1550) + 3{,}60 \leq D(\lambda) \leq \frac{4{,}72}{75}(\lambda - 1550) + 9{,}28 \quad \text{(E.2)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

E.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex F
(normative)

Family specification for category B-657 Bending loss insensitive single-mode fibres

F.1 General

This document describes two categories of single-mode optical fibre A and B with improved bending loss performance compared with that of the B-652 category. Both categories A and B contain two subcategories which differ in macrobending loss.

The clauses and tables in Annex F contain particular requirements applicable to category B-657 fibres. Common requirements, repeated here for ease of reference from the sectional specification, are noted by an entry in the “reference” column. Relevant notes from the sectional specification are not repeated but indicated with a superscript “SS”.

There are four sub-categories which are designated with suffixes ".A1", ".A2", ".B2" and ".B3". The fibres are suitable to be used in the O, E, S, C and L-band (i.e. throughout the 1 260 nm to 1 625 nm range). They have improved bending loss and tighter dimensional specifications compared to B-652.D fibres for improved connectivity.

Sub-categories B-657.A1 and B-657.A2 fibres are a subset of category B-652.D fibres and therefore are compliant with B-652.D fibres and have the same transmission properties.

NOTE 1 Compliance here means adherence to the referenced fibre category (B-652.D) meeting or exceeding the values of the specified attributes.

Sub-category B-657.A1 fibres are appropriate for a minimum bend radius of 10 mm; sub-category B-657.A2 fibres for a minimum bend radius of 7,5 mm.

Sub-categories B-657.B2 and B-657.B3 fibres are intended to be used for restricted distances (less than 1 000 m) at the end of access networks, in particular inside buildings or near buildings (e.g. outside building riser cabling). Application length of B-657.B fibre, however, depends on the deployment strategy of each network operator.

Sub-category B-657.B fibres are not necessarily compliant with category B-652 fibres in terms of chromatic dispersion coefficient specifications. These fibres, however, are system compatible with B-657.A (and B-652.D) fibres in Access networks.

NOTE 2 Compatibility here means that the product in this sub-category will introduce negligible system impairment or deployment issues but may not be compliant with the referenced fibre category (B-652.D).

Sub-category B-652.B2 fibres are appropriate for a minimum bend radius of 7,5 mm; sub-category B-652.B3 fibres for a minimum bend radius of 5 mm.

NOTE 3 Most category B-652 fibres deployed have macrobending losses of several dBs over ten turns at 1 625 nm with 15 mm bend radius.

F.2 Dimensional requirements

Table F.1 contains dimensional requirements specific to category B-657 fibres.

Table F.1 – Dimensional requirements specific to category B-657 fibres

Attribute	Unit	Limit (250µm coating)	Limit (200µm coating)	Reference
Cladding diameter	µm	125 ± 0,7		5.2
Cladding non-circularity	%	≤ 1,0		5.2
Core – cladding concentricity error	µm	≤ 0,5		5.2
Primary coating diameter – uncoloured [a]	µm	235 to 255	180 to 210	5.2
Primary coating diameter – coloured [a]	µm	235 to 265	180 to 220	5.2
Primary coating-cladding concentricity error	µm	≤ 12,5	≤ 10,0	5.2
Fibre length	Km	See 5.2		5.2

[a] Alternative nominal primary coating diameters may be used (see Table 2), to be agreed between supplier and customer.

F.3 Mechanical requirements

Table F.2 contains mechanical requirements specific to category B-657 fibres.

Table F.2 – Mechanical requirements specific to category B-657 fibres

Attribute	Unit	Limit		Reference
		(250 µm coating)	(200 µm coating)	
Proof stress level [a]	GPa	≥ 0,69[SS]		5.3
Coating strip force (average) [SS]	N	$1,0 \leq F_{ave} \leq 5,0$	$0,4 \leq F_{ave} \leq 5,0$	5.3
Coating strip force (peak) [SS]	N	$1,0 \leq F_{peak} \leq 8,9$	$0,4 \leq F_{peak} \leq 8,9$	5.3
Fibre curl radius	m	≥ 2 [b]		5.3
Tensile strength (median) for 0,5 m specimen length	GPa	≥ 3,8		5.3
Stress corrosion susceptibility parameter, n_d	–	≥ 18		5.3

[a] The failure probability for fibre under 30 mm of radius bend as described in category B-657 of this document, increases with decreasing bend radius. See ITU-T G.Sup.59 for more guidance on cabled fibre reliability.

[b] Depending on splicing methods, a minimum of 4 m may be specified for fibre intended to be used in some cable constructions, such as ribbon cable.

F.4 Transmission requirements

Table F.3 contains transmission requirements specific to category B-657 fibres.

Table F.3 – Transmission requirements specific to category B-657 fibres

Attribute	Unit	B-657.A1 Limit	B-657.A2 Limit	B-657.B2 Limit	B-657.B3 Limit	Reference
Attenuation coefficient from 1 310 nm to 1 625 nm [a]	dB/km	≤ 0,40				5.4
Attenuation coefficient at 1 383 mm ± 3 nm [b]	dB/km	≤ 0,40				5.4
Attenuation coefficient 1 530 nm – 1565 nm	dB/km	≤ 0,30				5.4
Zero dispersion wavelength, λ_0	nm	Matches specification for B-652.D fibre see Table A.6		1 250 ≤ λ_0 ≤ 1 350		5.4
Zero dispersion slope	ps/(nm^2 × km)	Matches specification for B-652.D fibre see Table A.6		≤ 0,11		5.4
Nominal MFD range at 1 310 nm[c]	µm	8,6 to 9,2				5.4
MFD tolerance	µm	± 0,4				5.4
Cable cut-off wavelength, λ_{cc}	nm	≤ 1 260				5.4
Macrobending loss at 1 550 nm, 10 turns on a 15 mm radius mandrel	dB	≤ 0,25	≤ 0,03	≤ 0,03	NA	5.4
Macrobending loss at 1 550 nm, 1 turn on a 10 mm radius mandrel	dB	≤ 0,75	≤ 0,1	≤ 0,1	≤ 0,03	5.4
Macrobending loss at 1 550 nm, 1 turn on a 7,5 mm radius mandrel	dB	NA	≤ 0,5	≤ 0,5	≤0,08	5.4
Macrobending loss at 1 550 nm, 1 turn on a 5 mm radius mandrel	dB	NA	NA	NA	≤ 0,15	5.4
Macrobending loss at 1 625 nm, 10 turns on a 15 mm radius mandrel	dB	≤ 1,0	≤0,1	≤ 0,1	NA	5.4
Macrobending loss at 1 625 nm, 1 turn on a 10 mm radius mandrel	dB	≤ 1,5	≤0,2	≤ 0,2	≤ 0,1	5.4
Macrobending loss at 1 625 nm, 1 turn on a 7,5 mm radius mandrel	dB	NA	≤1,0	≤1,0	≤ 0,25	5.4
Macrobending loss at 1 625 nm, 1 turn on a 5 mm radius mandrel	dB	NA	NA	NA	≤ 0,45	5.4
Polarization mode dispersion (PMD) coefficient	$ps/\sqrt{km}$	See 5.4				5.4

[a] This wavelength region can be extended to 1 260 nm by adding 0,07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.

[b] The average attenuation coefficient after ageing according to the test outlined in Clause A.5, "Hydrogen ageing for B-652.D" shall be less than the value specified for the range of 1 310 nm to 1 625 nm.

[c] The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.

F.5 Environmental requirements

The requirements of 5.5 shall be met.

Annex G
(informative)

System design information for category B-655 non-zero disperion shifted single-mode fibres

G.1 General

The following are examples of implementations that are designed to optimize various trade-offs in power, channel spacing, amplifier separation, link length and bit rate. All these examples given in Table G.1 are primarily variations in the allowed chromatic dispersion, chromatic dispersion slope, and non-linear coefficient. These are examples only, which do not preclude other possible implementations. The order of the examples is arbitrary and does not reflect any priority.

Table G.1 – Examples for λ_{min} = 1 530 nm and λ_{max} = 1 565 nm

Example ID	D_{min} ps/(nm x km)	D_{max} ps/(nm x km)	Sign	Typical chromatic dispersion coefficient at 1 550 nm ps/(nm x km)	Typical chromatic dispersion slope at 1 550 nm ps/(nm^2 x km)
A	1,3	5,8	+	3,7	0,070
B	2,0	6,0	+	4,2	0,085
C	2,6	6,0	+	4,4	0,045
D	5,0	10,0	+	8,0	0,058
E	1,0	6,0	–	–2,3	0,065

The specification values found in D.4.3 and D.4.4 were determined from two surveys in which multiple vendors of these sub-categories responded with average and standard deviation of the chromatic dispersion coefficient versus wavelength. The bounding curves enclose all these results at average plus or minus three standard deviations. The bounding curves resulting from enclosing the average plus or minus one standard deviation may be useful for system design. These are given in the following clauses.

G.2 One standard deviation limits for sub-category B-655.D fibres

The following represent limits derived from considering multiple vendors of sub-category B-655.D fibres and average plus or minus one standard deviation:

$$\frac{6,94}{90}(\lambda - 1460) - 3,4 \le D(\lambda) \le \frac{2,78}{90}(\lambda - 1460) + 2,60 \qquad \text{(G.1)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3,13}{75}(\lambda - 1\,550) + 3,0 \le D(\lambda) \le \frac{5,28}{75}(\lambda - 1550) + 5,38 \qquad \text{(G.2)}$$

for 1 550 nm ≤ λ ≤ 1 625 nm

Figure G.1 shows the chromatic dispersion coefficient limits associated with the specification, i.e. three sigma limits, and the values that could be used in system design, i.e.1 sigma limits.

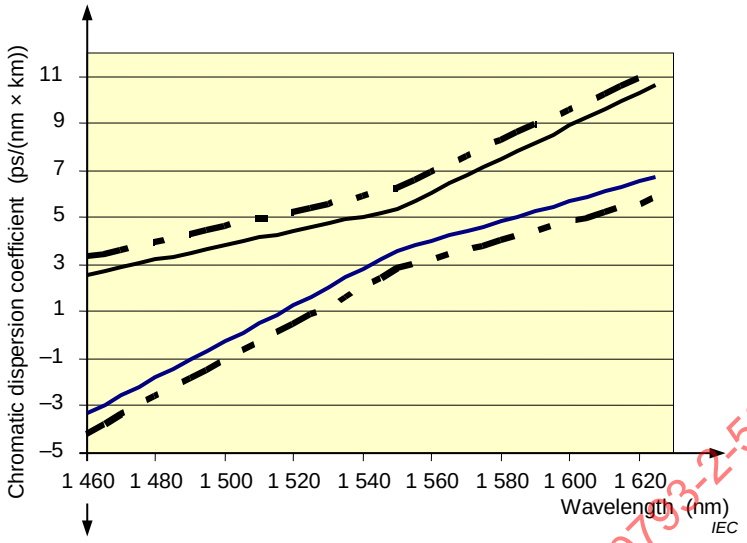

Figure G.1 – Sub-category B-655.D chromatic dispersion coefficient limits

G.3 One standard deviation limits for sub-category B-655.E fibres

The following represent limits derived from considering multiple vendors of sub-category B-655.E fibres and average plus or minus one standard deviation:

$$\frac{5{,}28}{90}(\lambda - 1\,460) + 1{,}68 \le D(\lambda) \le \frac{4{,}56}{90}(\lambda - 1\,460) + 3{,}89 \qquad \text{(G.3)}$$

for 1 460 nm ≤ λ ≤ 1 550 nm

and

$$\frac{3{,}05}{75}(\lambda - 1\,550) + 6{,}96 \le D(\lambda) \le \frac{3{,}96}{75}(\lambda - 1\,550) + 8{,}45 \qquad \text{(G.4)}$$

for 1 500 nm ≤ λ ≤ 1 625 nm

Figure G.2 shows the chromatic dispersion coefficient limits associated with the specification, i.e. three sigma limits, and the values that could be used in system design, i.e. one sigma limit.

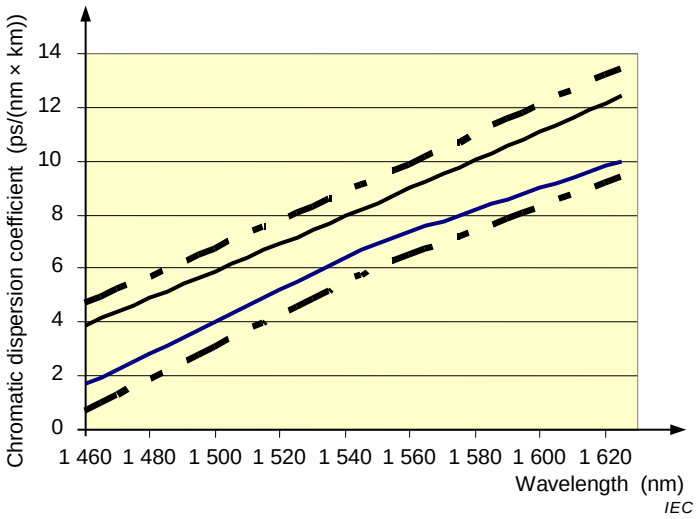

Figure G.2 – Sub-category B-655.E chromatic dispersion coefficient limits

Bibliography

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

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

IEC TR 62048, *Optical fibres – Reliability – Power law theory*

IEC TR 62316, *Guidance for the interpretation of OTDR backscattering traces for single-mode fibres*

ITU-T Rec. G.652, *Characteristics of a single-mode optical fibre and cable*

ITU-T Rec. G.653, *Characteristics of a dispersion-shifted, single-mode optical fibre and cable*

ITU-T Rec. G.654, *Characteristics of a cut-off shifted single-mode optical fibre and cable*

ITU-T Rec. G.655, *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*

ITU-T Rec. G.656, *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*

ITU-T Rec. G.657, *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*

ITU-T G.Sup.59:2018, *Guidance on optical fibre and cable reliability*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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FIBRES OPTIQUES –

Partie 2-50: Spécifications de produits – Spécification intermédiaire pour les fibres unimodales de classe B

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La Norme internationale IEC 60793-2-50 a été établie par le sous-comité 86A: Fibres et câbles, du comité d'études 86 de l'IEC: Fibres optiques.

Cette sixième édition annule et remplace la cinquième édition parue en 2015. Cette édition constitue une révision technique. Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) introduction d'une convention de nommage révisée correspondant mieux à celles figurant dans les Recommandations de l'UIT-T G.652, G.653, G.654, G.655, G.656 et G.657. Ces modifications sont décrites dans le domaine d'application du présent document et accompagnées d'une table de correspondance pour les nouveaux noms. Les annexes ont été réarrangées à partir du nouveau nommage à des fins de lisibilité;
b) plus de détails sur les exigences pour une fibre unimodale à revêtement de 200 microns;

c) harmonisation avec les Recommandations de l'IUT-T G.652, G.654, G.657, consenties en septembre 2016 et comprenant des spécifications révisées de dispersion chromatique, des nouvelles catégories de fibre et les nouveaux lieux d'application correspondants;

d) des descriptions des types de fibre ont été ajoutées aux titres des Annexes A à F.

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

FDIS	Rapport de vote
86A/1884/FDIS	86A/1898/RVD

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 60793, publiées sous le titre général *Fibres optiques*, est disponible 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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FIBRES OPTIQUES –

Partie 2-50: Spécifications de produits – Spécification intermédiaire pour les fibres unimodales de classe B

1 Domaine d'application

La présente partie de l'IEC 60793 est applicable aux fibres optiques des catégories B-652, B-653, B-654, B-655, B-656 et B-657. Une table de correspondance entre les désignations IEC et les désignations UIT-T est représentée dans le Tableau 1. Ces fibres sont utilisées ou peuvent être intégrées dans des équipements destinés à la transmission de l'information et dans des câbles à fibres optiques.

Trois types d'exigences s'appliquent à ces fibres:

- les exigences générales, qui sont définies dans l'IEC 60793-2;
- des exigences spécifiques communes aux fibres unimodales de classe B, couvertes par le présent document, et qui sont données dans l'Article 5;
- des exigences particulières applicables à des catégories particulières de fibres ou à des applications données, qui sont définies dans les Annexes A à F.

Pour certaines catégories de fibres (indiquées dans les spécifications de famille correspondantes), il existe des sous-catégories qui se distinguent les unes des autres par leurs différences de spécifications d'attributs de transmission. Les désignations pour ces sous-catégories sont documentées dans les spécifications de famille individuelles.

Le Tableau 1 représente une table de correspondance entre les désignations IEC et les Recommandations de l'UIT-T. Le tableau fournit également l'annexe normative du présent document contenant la spécification particulière ainsi que le nom utilisé pour décrire ce type de fibre dans l'IEC 60793-2-50:2015. Les Recommandations de l'UIT-T ainsi que les catégories/sous-catégories IEC correspondant à chaque Recommandation sont données. Dans certains cas, comme la Recommandation G.652, une désignation IEC donnée correspond à de multiples catégories dans l'UIT-T car les catégories UIT-T se distinguent par la performance des attributs de fibres câblées (PMD_Q), ce qui n'est pas le cas dans les spécifications de fibres IEC.

Tableau 1 – Table de correspondance de la désignation IEC et des Recommandations ITU-T ainsi que la désignation de l'IEC 60793-2-50:2015

Annexe	Catégorie	Sous-catégorie	Description	IEC 60793-2-50:2015	Rec UIT-T
	B-652		Fibre à dispersion non décalée		G.652
A		B-652.B		B1.1	G.652.B
A		B-652.D		B1.3	G.652.D
	B-653		Fibre à dispersion décalée		G.653
B		B-653.A		B2_a	G.653.A
B		B-653.B		B2_b	G.653.B
	B-654		Fibre à coupure décalée		G.654
C		B-654.A		B1.2_a	G.654.A
C		B-654.B		B1.2_b	G.654.B
C		B-654.C		B1.2_c	G.654.C
C		B-654.D		N/A	G.654.D
C		B-654.E		N/A	G.654.E
C	B-655		Fibre à dispersion décalée non nulle	B4	G.655
D		B-655.C		B4_c	G.655.C
D		B-655.D		B4_d	G.655.D
D		B-655.E		B4_e	G.655.E
E	B-656		Fibre à dispersion décalée non nulle à large bande	B5	G.656
F	B-657		Fibre insensible aux pertes dues aux courbures	B6	G.657
F		B-657.A1		B6_a1	G.657.A1
F		B-657.A2		B6_a2	G.657.A2
F		B-657.B2		B6_b2	G.657.B2
F		B-657.B3		B6_b3	G.657.B3

2 Références normatives

Les documents suivants cités dans le texte 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 60793-1 (toutes les parties), *Fibres optiques*

IEC 60793-1-20, *Fibres optiques – Partie 1-20: Méthodes de mesure et procédures d'essai – Géométrie de la fibre*

IEC 60793-1-21, *Fibres optiques – Partie 1-21: Méthodes de mesure et procédures d'essai – Géométrie du revêtement*

IEC 60793-1-22, *Fibres optiques – Partie 1-22: Méthodes de mesure et procédures d'essai – Mesure de la longueur*

IEC 60793-1-30, *Fibres optiques – Partie 1-30: Méthodes de mesure et procédures d'essai – Essais de sélection*

IEC 60793-1-31, *Fibres optiques – Partie 1-31: Méthodes de mesure et procédures d'essai – Résistance à la traction*

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

IEC 60793-1-33, *Fibres optiques – Partie 1-33: Méthodes de mesures et procédures d'essai – Résistance à la corrosion sous contrainte*

IEC 60793-1-34, *Fibres optiques – Partie 1-34: Méthodes de mesure et procédures d'essai – Ondulation de la fibre*

IEC 60793-1-40, *Fibres optiques – Partie 1-40: Méthodes de mesure et procédures d'essai – Affaiblissement*

IEC 60793-1-42, *Fibres optiques – Partie 1-42: Méthodes de mesure et procédures d'essai – Dispersion chromatique*

IEC 60793-1-44, *Fibres optiques – Partie 1-44: Méthodes de mesure et procédures d'essai – Longueur d'onde de coupure*

IEC 60793-1-45, *Fibres optiques – Partie 1-45 : Méthodes de mesure et procédures d'essai – Diamètre du champ de mode*

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 60793-1-47, *Fibres optiques – Partie 1-47: Méthodes de mesure et procédures d'essai – Pertes par macrocourbures*

IEC 60793-1-48, *Fibres optiques – Partie 1-48: Méthodes de mesure et procédures d'essai – Dispersion de mode de polarisation*

IEC 60793-1-50, *Fibres optiques – Partie 1-50: Méthodes de mesure et procédures d'essai – Essais de chaleur humide (état continu)*

IEC 60793-1-51, *Fibres optiques – Partie 1-51: Méthodes de mesure et procédures d'essai – Essais de chaleur sèche (état continu)*

IEC 60793-1-52, *Fibres optiques – Partie 1-52: Méthodes de mesure et procédures d'essai – Essais de variations de température*

IEC 60793-1-53, *Fibres optiques – Partie 1-53: Méthodes de mesure et procédures d'essai – Essais d'immersion dans l'eau*

IEC 60793-2, *Fibres optiques – Partie 2: Spécifications de produits – Généralités*

IEC 60794-2, *Câbles à fibres optiques – Partie 2: Câbles intérieurs – Spécification intermédiaire*

3 Termes et définitions

Pour les besoins du présent document, les termes et les définitions de l'IEC 60793-2 et la série IEC 60793-1 s'appliquent.

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

NOTE Les définitions générales relatives aux fibres sont données dans l'IEC 60793-2. Les définitions des attributs spécifiés sont données dans la norme sur les méthodes d'essai correspondantes, dans la série IEC 60793-1, tandis que les définitions générales relatives aux essais sont données dans l'IEC 60793-1-1.

4 Termes abrégés et symboles

Pour les besoins du présent document, les termes abrégés et symboles suivants s'appliquent:

F_{avg}	Force de dénudage moyenne
F_{peak}	Force de dénudage maximale
λ_0	Longueur d'onde de dispersion nulle
λ_c	Longueur d'onde de coupure de la fibre
λ_{cc}	Longueur d'onde de coupure du câble
MFD	Diamètre de champ de mode
n_d	Paramètre de corrosion sous contrainte – dynamique
PMD	Dispersion du mode de polarisation
PMD_Q	Valeur de conception de la liaison PMD

5 Spécifications

5.1 Généralités

La fibre doit consister en un cœur en verre et une gaine en verre conformément aux recommandations de construction des fibres optiques de classe B – fibres unimodales – données dans l'IEC 60793-2.

Le terme «verre» se réfère habituellement à des matériaux relatifs à des oxydes non métalliques. La composition de certaines fibres peut être tout verre, ou verre et composite verre/polymère dur.

5.2 Exigences dimensionnelles

Les attributs dimensionnels et les méthodes de mesure applicables sont donnés dans le Tableau 2.

Les exigences communes à toutes les catégories de fibres unimodales de classe B figurent dans le Tableau 3.

Le diamètre de la gaine, la non-circularité de la gaine et l'erreur de concentricité entre le cœur et la gaine doivent être stipulés dans les spécifications de famille.

Tableau 2 – Attributs dimensionnels et méthodes de mesure

Attribut	Méthode de mesure
Diamètre de la gaine	IEC 60793-1-20
Non-circularité de la gaine	IEC 60793-1-20
Erreur de concentricité entre le cœur et la gaine	IEC 60793-1-20
Diamètre du revêtement primaire	IEC 60793-1-21
Non-circularité du revêtement primaire	IEC 60793-1-21
Erreur de concentricité gaine–revêtement primaire	IEC 60793-1-21
Longueur de la fibre	IEC 60793-1-22

Tableau 3 – Exigences dimensionnelles communes à toutes les fibres de classe B

Attribut	Unité	Limite
Diamètre du revêtement primaire – incolore	µm	235 à 255 [a]
Diamètre du revêtement primaire – coloré	µm	235 à 265 [a]
Erreur de concentricité gaine–revêtement primaire	µm	≤ 12,5
Longueur de la fibre	km	[b]

[a] Les limites ci-dessus sur le diamètre du revêtement primaire sont les plus couramment utilisées dans les câbles de télécommunications. Il existe d'autres applications telles que les fibres pour utilisation dans les sous-systèmes optiques, les fibres amorces ou des applications spécifiques telles que les câbles sous-marins ou les câbles FTTH compacts, qui utilisent d'autres diamètres de revêtement primaire, dont plusieurs sont énumérés ci-dessous.

180 µm à 210 µm pour la version incolore; 180 °µm à 220 µm pour la version colorée

400 µm ± 40 µm

500 µm ± 50 µm

700 µm ± 70 µm

900 µm ± 90 µm

D'autres diamètres de revêtement peuvent influer sur la connectivité de la fibre, au niveau des rubans, des connecteurs multifibres, des épissures mécaniques et des protecteurs d'épissures par fusion; ils peuvent également nécessiter des ajustements par rapport aux outils de montage de connexions et/ou des tolérances de revêtement plus serrées.

[b] Les exigences de longueur sont variables et il convient qu'elles fassent l'objet d'un accord entre le fournisseur et le client.

5.3 Exigences mécaniques

Les attributs mécaniques et les méthodes d'essai applicables sont donnés dans le Tableau 4. La relation entre certains de ces attributs et la fiabilité mécanique est décrite dans l'IEC TR 62048 et l'ITU-T G.Sup.59.

Les exigences communes à toutes les catégories de fibres unimodales de classe B figurent dans le Tableau 5.

Tableau 4 – Attributs mécaniques et méthodes d'essai

Attribut	Méthode d'essai
Essai de sélection	IEC 60793-1-30
Résistance à la traction	IEC 60793-1-31
Dénudabilité du revêtement	IEC 60793-1-32
Résistance à la corrosion sous contrainte	IEC 60793-1-33
Ondulation de la fibre	IEC 60793-1-34

Tableau 5 – Exigences mécaniques communes à toutes les fibres de classe B

Attribut	Unité	Limite
Niveau de contrainte de sélection	GPa	≥ 0,69 [a]
Force de dénudage (moyenne) [b, c]	N	$1,0 \leq F_{ave} \leq 5,0$
Force de dénudage (maximale) [b, c]	N	$1,0 \leq F_{peak} \leq 8,9$
Rayon de boucle de la fibre	m	≥ 2 [d]
Résistance à la traction (médiane) pour une longueur de spécimen de 0,5 m	GPa	≥ 3,8
Paramètre de résistance à la corrosion sous contrainte, n_d		≥ 18

[a] La valeur de l'essai de sélection de 0,69 GPa est égale à une déformation d'environ 1 % ou une force d'environ 8,8 N. Pour la relation entre ces différentes unités, voir l'IEC TR 62048:2014, article 8.4.

[b] La force de dénudage moyenne ou la force de dénudage maximale, qui sont toutes deux définies dans le mode opératoire d'essai, peuvent être spécifiées selon accord entre le fournisseur et le client.

[c] Dans le cas d'autres diamètres nominaux de revêtement primaire (voir Tableau 2), les autres valeurs de force de dénudage associées doivent faire l'objet d'un accord entre le fournisseur et le client ou bien être fournies dans les spécifications particulières présentes dans les annexes du présent document.

[d] En fonction des méthodes d'épissurage, une longueur minimale de 4 m peut être spécifiée pour les fibres dont l'utilisation est prévue dans certaines constructions de câbles, telles que les câbles à rubans.

5.4 Exigences de transmission

Les attributs de transmission et les méthodes de mesure applicables sont donnés dans le Tableau 6.

Les exigences communes à toutes les catégories de fibres unimodales de classe B figurent dans le Tableau 7.

Les exigences qui doivent être stipulées dans les spécifications de famille sont énumérées dans le Tableau 8.

Tableau 6 – Attributs de transmission et méthodes de mesure

Attribut	Méthode de mesure
Affaiblissement linéique	IEC 60793-1-40 [a]
Dispersion chromatique	IEC 60793-1-42
Longueur d'onde de coupure [b]	IEC 60793-1-44
Diamètre de champ de mode	IEC 60793-1-45
Variations du facteur de transmission optique	IEC 60793-1-46
Affaiblissement par macrocourbures	IEC 60793-1-47
Dispersion du mode de polarisation	IEC 60793-1-48
Les valeurs d'affaiblissement maximales indiquées s'appliquent aux fibres optiques câblées et non câblées. Des spécifications plus serrées pour la fibre peuvent être demandées pour tenir compte de l'affaiblissement ajouté dans le processus de câblage; pour les valeurs d'affaiblissement maximales de fibres optiques câblées, il est fait référence à l'IEC 60794-2, utilisable conjointement avec le présent document.	
[a] L'affaiblissement linéique à diverses longueurs d'onde peut être calculé en utilisant les valeurs mesurées sur un petit nombre de longueurs d'onde en utilisant un modèle spectral, tel que celui qui est donné dans l'IEC 60793-1-40. Par exemple, l'affaiblissement à 1 480 nm peut être calculé et utilisé pour la conception de systèmes qui emploient le pompage à distance des amplificateurs optiques. Lors de l'utilisation de la méthode C, réflectométrie optique dans le domaine temporel (OTDR, Optical Time Domain Reflectometer), les recommandations supplémentaires de l'IEC TR 62316 doivent être prises en compte. Comme indiqué dans l'IEC 60793-1-40:20xx, le modèle d'affaiblissement spectral a été démontré sur toutes les fibres de classe B.	
[b] Il existe deux façons de mesurer la longueur d'onde de coupure, ce qui conduit à: longueur d'onde de coupure de la fibre λ_c et longueur d'onde de coupure du câble λ_{cc}, respectivement. La corrélation des valeurs mesurées de λ_c et λ_{cc} dépend de la conception spécifique des fibres et câbles et des conditions d'essai. Même si, en général, $\lambda_{cc} < \lambda_c$, une relation quantitative générale ne peut pas être aisément établie, et il est de la première importance de s'assurer de la transmission unimodale dans la longueur de câble minimale entre les jonctions, à la longueur d'onde de fonctionnement minimale. Cela peut être effectué en recommandant que la longueur d'onde de coupure de câble maximale λ_{cc} d'une fibre unimodale câblée soit de 1 260 nm ou pour le cas le plus défavorable de longueur et de courbures, en recommandant une longueur d'onde de coupure de fibre maximale λ_c de 1 260 nm.	

Tableau 7 – Exigences de transmission communes à toutes les fibres de classe B

Attribut	Unité	Limite
Valeur de conception de liaison (PMD_Q) du coefficient de dispersion du mode de polarisation (PMD)	$ps/\sqrt{km}$	[a]
[a] Une valeur maximale de PMD_Q sur une fibre non câblée doit être convenue entre le fournisseur et le client, pour satisfaire à l'exigence primaire de PMD du câble, donnée dans l'IEC 60794-3.		

Tableau 8 – Attributs de transmission supplémentaires exigés dans les spécifications de famille

Attribut
Affaiblissement linéique et longueurs d'onde
Caractéristiques de dispersion chromatique
Plage de diamètres de champ de mode (MFD) nominaux et longueur d'onde
Tolérance de diamètre de champ de mode
Longueur d'onde de coupure du câble, λ_{cc}
Affaiblissement par macrocourbures comprenant: longueur d'onde, taille de mandrin et nombre de tours
Diamètre de la gaine
Non-circularité de la gaine
Erreur de concentricité entre le cœur et la gaine

Pour les fibres de catégorie B-655, l'information relative à la conception du système est donnée dans l'Annexe G.

5.5 Exigences d'environnement

5.5.1 Généralités

Les essais d'exposition à l'environnement et les méthodes de mesure correspondantes sont documentés sous deux formes:

- les attributs d'environnement et les méthodes d'essai applicables sont donnés dans le Tableau 9;
- les mesures des attributs mécaniques ou de transmission particuliers, pouvant varier en fonction de l'environnement, sont énumérées dans le Tableau 10.

Tableau 9 – Essais d'exposition à l'environnement

Attribut	Méthode d'essai
Essais de chaleur humide	IEC 60793-1-50
Essais de chaleur sèche	IEC 60793-1-51
Essais de variations de température	IEC 60793-1-52
Essais d'immersion dans l'eau	IEC 60793-1-53

Tableau 10 – Attributs mesurés dans les essais d'exposition à l'environnement

Attribut	Méthode d'essai
Variations du facteur de transmission optique	IEC 60793-1-46
Affaiblissement	IEC 60793-1-40
Force de dénudage du revêtement	IEC 60793-1-32
Résistance à la traction	IEC 60793-1-31
Résistance à la corrosion sous contrainte	IEC 60793-1-33

Ces essais sont normalement effectués de manière périodique comme essais de type pour une conception de fibre et de revêtement donnée. Sauf indication contraire, la période de rétablissement permise entre la fin de l'exposition à l'environnement et la réalisation des mesures des attributs doit être celle spécifiée dans la méthode d'essai d'environnement spécifique.

5.5.2 Exigences d'environnement optiques – Affaiblissement

La variation d'affaiblissement par rapport à la valeur initiale doit être inférieure aux valeurs du Tableau 11. L'affaiblissement doit être mesuré de manière périodique au cours de toute la durée d'exposition à chaque environnement, et après retrait de cet environnement.

Tableau 11 – Variation d'affaiblissement lors des essais d'environnement

Environnement	Longueur d'onde nm	Augmentation maximale d'affaiblissement dB/km
Chaleur humide	1 550, 1 625	≤ 0,05
Chaleur sèche	1 550, 1 625	≤ 0,05
Variations de température	1 550, 1 625	≤ 0,05
Immersion dans l'eau	1 550, 1 625	≤ 0,05
NOTE Les variations d'affaiblissement à des longueurs d'onde inférieures à la longueur d'onde d'essai sont plus faibles que la variation d'affaiblissement à la longueur d'onde d'essai.		

5.5.3 Exigences d'environnement mécaniques

5.5.3.1 Généralités

Ces essais sont, en pratique, les exigences les plus sévères parmi les environnements définis dans le Tableau 9.

5.5.3.2 Force de dénudage du revêtement

Les attributs donnés dans le Tableau 12 doivent être vérifiés après retrait de la fibre de l'environnement spécifique.

Tableau 12 – Force de dénudage du revêtement pour les essais d'environnement

Environnement	Force de dénudage moyenne N	Force de dénudage maximale N
Chaleur humide	$1,0 \leq F_{avg} \leq 5,0$	$1,0 \leq F_{peak} \leq 8,9$
Immersion dans l'eau	$1,0 \leq F_{avg} \leq 5,0$	$1,0 \leq F_{peak} \leq 8,9$
NOTE Dans le cas d'autres diamètres nominaux de revêtement primaire (voir Tableau 2), les autres valeurs de force de dénudage associées doivent faire l'objet d'un accord entre le fournisseur et le client à moins qu'elles ne soient spécifiées dans les spécifications de produits particulières ou présentes dans les annexes du présent document.		

5.5.3.3 Résistance à la traction

Les attributs donnés dans le Tableau 13 doivent être vérifiés après retrait de la fibre de l'environnement indiqué.

Tableau 13 – Résistance à la traction pour les essais d'environnement

Environnement	Résistance à la traction médiane (GPa), longueur du spécimen: 0,5 m	Distribution de résistance à la traction (GPa) à 15 %, longueur du spécimen: 0,5 m
Chaleur humide	≥ 3,03	≥ 2,76
NOTE Ces exigences ne sont pas applicables aux fibres hermétiquement revêtues. (Un revêtement hermétique consiste en une couche de protection qui isole complètement les fibres en verre de l'humidité, assurant ainsi un niveau élevé de résistance à la corrosion sous contrainte. Un revêtement hermétique typique est constitué d'une couche de carbone de plusieurs microns d'épaisseur appliquée sur la surface en verre.)		

5.5.3.4 Résistance à la corrosion sous contrainte

L'attribut donné dans le Tableau 14 doit être vérifié après retrait de la fibre de l'environnement indiqué.

Tableau 14 – Résistance à la corrosion sous contrainte lors des essais d'environnement

Environnement	Paramètre de résistance à la corrosion sous contrainte, n_d
Chaleur humide	≥ 18
NOTE Cette exigence n'est pas applicable aux fibres hermétiquement revêtues (voir la définition du revêtement hermétique dans le Tableau 13).	

Annex A
(normative)

Spécification de famille pour les fibres unimodales à dispersion non décalée de catégorie B-652

A.1 Généralités

Cette fibre unimodale à dispersion non décalée est spécialement conçue pour une utilisation dans la région de 1 310 nm mais elle peut être utilisée dans les régions de 1 550 nm et 1 625 nm. En fonction de la longueur de la liaison et des débits binaires, la dispersion peut nécessiter un aménagement dans les régions de 1 550 nm et 1 625 nm.

Les articles et tableaux dans l'Annexe A contiennent les exigences particulières applicables aux fibres de catégorie B-652. Les exigences communes, rappelées pour faciliter leur référence à partir de la spécification intermédiaire, sont spécifiées dans la colonne «Référence». Les notes correspondantes de la spécification intermédiaire ne sont pas répétées mais indiquées à l'aide d'un exposant "ss".

A.2 Exigences dimensionnelles

Le Tableau A.1 contient les exigences dimensionnelles spécifiques aux fibres de catégorie B-652.B.

Tableau A.1 – Exigences dimensionnelles spécifiques aux fibres de catégorie B-652.B

Attribut	Unité	Limite (Revêtement de 250 µm)	Limite (Revêtement de 200 µm)	Référence
Diamètre de la gaine	µm	125 ± 1	125 ± 1	5.2
Non-circularité de la gaine	%	≤ 1,0	≤ 1,0	5.2
Erreur de concentricité entre le cœur et la gaine	µm	≤ 0,6	≤ 0,6	5.2
Diamètre du revêtement primaire – incolore [a]	µm	235 à 255	180 à 210	5.2
Diamètre du revêtement primaire – coloré [a]	µm	235 à 265	180 à 220	5.2
Erreur de concentricité gaine– revêtement primaire	µm	≤ 12,5	≤ 10,0	5.2
Longueur de la fibre	km	Voir 5.2	Voir 5.2	5.2

[a] D'autres diamètres nominaux de revêtement primaire peuvent être utilisés (voir Tableau 2), sous réserve d'un accord entre le fournisseur et le client.

Le Tableau A.2 contient les exigences dimensionnelles spécifiques aux fibres de catégorie B-652.D.

Tableau A.2 – Exigences dimensionnelles spécifiques aux fibres de catégorie B-652.D

Attribut	Unité	Limite (Revêtement de 250 µm)	Limite (Revêtement de 200 µm)	Référence
Diamètre de la gaine	µm	125 ± 0,7	125 ± 0,7	5.2
Non-circularité de la gaine	%	≤ 1,0	≤ 1,0	5.2
Erreur de concentricité entre le cœur et la gaine	µm	≤ 0,6	≤ 0,6	5.2
Diamètre du revêtement primaire – incolore [a]	µm	235 à 255	180 à 210	5.2
Diamètre du revêtement primaire – coloré [a]	µm	235 à 265	180 à 220	5.2
Erreur de concentricité gaine–revêtement primaire	µm	≤ 12,5	≤ 10,0	5.2
Longueur de la fibre	km	Voir 5.2	Voir 5.2	5.2
[a] D'autres diamètres nominaux de revêtement primaire peuvent être utilisés (voir Tableau 2), sous réserve d'un accord entre le fournisseur et le client.				

A.3 Exigences mécaniques

Le Tableau A.3 contient les exigences mécaniques spécifiques aux fibres de catégorie B-652.

Tableau A.3 – Exigences mécaniques spécifiques aux fibres de catégorie B-652

Attribut	Unité	Limite (Revêtement de 250 µm)	Limite (Revêtement de 200 µm)	Référence
Niveau de contrainte de sélection	GPa	≥ 0,69 [SS]		5.3
Force de dénudage (moyenne) [SS]	N	$1,0 \leq F_{ave} \leq 5,0$	$0,4 \leq F_{ave} \leq 5,0$	5.3
Force de dénudage (maximale) [SS]	N	$1,0 \leq F_{peak} \leq 8,9$	$0,4 \leq F_{peak} \leq 8,9$	5.3
Rayon de boucle de la fibre	m	≥ 2 [a]		5.3
Résistance à la traction (médiane) pour une longueur de spécimen de 0,5 m	GPa	≥ 3,8		5.3
Paramètre de résistance à la corrosion sous contrainte, n_d	–	≥ 18		5.3
[a] En fonction des méthodes d'épissurage, une longueur minimale de 4 m peut être spécifiée pour les fibres dont l'utilisation est prévue dans certaines constructions de câbles, telles que les câbles à rubans.				

A.4 Exigences de transmission

Le Tableau A.4 contient des exigences de transmission spécifiques aux fibres de sous-catégorie B-652.B et le Tableau A.5 contient des exigences de transmission spécifiques aux fibres de sous-catégorie B-652.D. Le Tableau A.6 fournit des valeurs de la dispersion chromatique pour les fibres de sous-catégorie B-652.D.