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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Transmission media and optical systems characteristics – Optical fibre cables

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Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network

ITU-T Recommendation G.657

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ITU-T Recommendation G.657

Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network

Summary

Worldwide, technologies for broadband access networks are advancing rapidly. Among these, the technology applying *single mode fibre* provides for a high-capacity transmission medium which can answer the growing demand for broadband services.

The experience with the installation and operation of single mode fibre and cable based networks is huge, and ITU-T Recommendation G.652 describing its characteristics has been adapted to this experience. Nevertheless, the specific use in an optical access network puts different demands on the fibre and cable which impacts its optimal performance characteristics. Differences with respect to the use in the general transport network are mainly due to the high density network of distribution and drop-cables in the access network. The limited space and the many manipulations ask for operator friendly fibre performance and low bending sensitivity. In addition, the cabling in the crowded telecom offices where space is a limiting factor has to be improved accordingly.

It is the aim of ITU-T Recommendation G.657 to support this optimization by recommending strongly improved bending performance compared with the existing G.652 single mode fibre and cables. This is done by means of introducing two classes of single mode fibres, one of which, class A, is fully compliant with the G.652 single mode fibres and can also be used in other parts of the network. The other class, class B, is not necessarily compliant with G.652 but is capable of low values of macrobending losses at very low bend radii and is pre-dominantly intended for in-building use.

Source

ITU-T Recommendation G.657 was approved on 14 December 2006 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

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Introduction

Worldwide, technologies for broadband access networks are advancing rapidly. Among these, the technology applying *single mode fibre* provides for a high-capacity transmission medium which can answer the growing demand for broadband services.

The experience with the installation and operation of single mode fibre and cable based networks is huge, and [ITU-T G.652] describing its characteristics has been adapted to this experience. Nevertheless, the specific use in an optical access network puts different demands on the fibre and cable. Due to the dense distribution and drop-cable network, the limited space and the many manipulations in this part of the network, fibre and cable requirements may be optimized differently from the use in a general transport network. It is the aim of this Recommendation to support this optimization by recommending different attribute values for the existing G.652 single mode fibre and cables and by recommending other classes of single mode fibre types.

As for the network structures in which the single mode optical fibre cable is used, the reader is referred to the extensive information that is available in the references listed in the bibliography.

ITU-T Recommendation G.657

Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network

1 Scope

This Recommendation describes two categories of single-mode optical fibre cable which are suitable for use in the access networks, including inside buildings at the end of these networks.

Category A fibres are suitable to be used in the O, E, S, C and L-band (i.e., throughout the 1260 to 1625 nm range). Fibres and requirements in this category are a subset of G.652.D fibres and have the same transmission and interconnection properties. The main improvements are improved bending loss and tighter dimensional specifications, both for improved connectivity.

Category B fibres are suitable for transmission at 1310, 1550 and 1625 nm for restricted distances that are associated with in-building transport of signals. These fibres have different splicing and connection properties than G.652 fibres, but are capable at very low values of bend radius.

The meaning of the terms used in this Recommendation and the guidelines to be followed in the measurement to verify the various characteristics are given in [ITU-T G.650.1] and [ITU-T G.650.2]. The characteristics of these fibre categories, including the definitions of the relevant parameters, their test methods and relevant values, will be refined as studies and experience progress.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.650.1] ITU-T Recommendation G.650.1 (2004), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[ITU-T G.650.2] ITU-T Recommendation G.650.2 (2005), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.652] ITU-T Recommendation G.652 (2005), *Characteristics of a single-mode optical fibre and cable*.

[IEC 60793-1-47] IEC 60793-1-47 (2006), *Optical fibres – Part 1-47; Measurement methods and test procedures – Macrobending loss*.

3 Terms and definitions

For the purposes of this Recommendation, the definitions and the guidelines to be followed in the measurement to verify the various characteristics are given in [ITU-T G.650.1] and [ITU-T G.650.2]. Values shall be rounded to the number of digits given in the Tables of Recommended values before conformance is evaluated.

4 Abbreviations

This Recommendation uses the following abbreviations:

DGD Differential Group Delay

PMD Polarization Mode Dispersion

5 Fibre attributes

The optical fibre characteristics that provide the essential design framework for fibre manufacture, system design and use in outside plant networks have been recommended in [ITU-T G.652]. In this clause, the emphasis is on attributes that optimize the fibre and cable for its use in broadband optical access networks, especially its *improved macro bending* behaviour which supports small volume fibre managements systems and low radius mounting in telecom offices and customer premises in apartment buildings and single dwelling houses.

For completeness, also those characteristics of the fibre that provide a minimum essential design framework for fibre manufacture are recommended in this clause. Ranges or limits on values are presented in the tables of clause 7. Of these, cable manufacture or installation may significantly affect the cabled fibre cut-off wavelength and PMD. Otherwise, the recommended characteristics will apply equally to individual fibres, fibres incorporated into a cable wound on a drum, and fibres in an installed cable.

5.1 Mode field diameter

Both a nominal value and tolerance about that nominal value shall be specified at 1310 nm. The nominal that is specified shall be within the range found in clause 7. The specified tolerance shall not exceed the value in clause 7. The deviation from nominal shall not exceed the specified tolerance.

5.2 Cladding diameter

The recommended nominal value of the cladding diameter is 125 µm. A tolerance is also specified and shall not exceed the value in clause 7. The cladding deviation from nominal shall not exceed the specified tolerance.

5.3 Core concentricity error

The core concentricity error shall not exceed the value specified in clause 7.

5.4 Non-circularity

5.4.1 Mode field non-circularity

In practice, the mode field non-circularity of fibres having nominally circular mode fields is found to be sufficiently low that propagation and jointing are not affected. It is therefore not considered necessary to recommend a particular value for the mode field non-circularity. It is not normally necessary to measure the mode field non-circularity for acceptance purposes.

5.4.2 Cladding non-circularity

The cladding non-circularity shall not exceed the value found in clause 7.

5.5 Cut-off wavelength

Three useful types of cut-off wavelength can be distinguished:

a) cable cut-off wavelength λ_{cc};

b) fibre cut-off wavelength λ_c;

c) jumper cable cut-off wavelength λ_{cj}.

The correlation of the measured values of λ_c, λ_{cc} and λ_{cj} depends on the specific fibre and cable design and the test conditions. While in general $\lambda_{cc} < \lambda_{cj} < \lambda_c$, 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 1260 nm, or for typical jumpers by recommending a maximum jumper cable cut-off to be 1250 nm, or for worst-case length and bends by recommending a maximum fibre cut-off wavelength to be 1250 nm.

The cable cut-off wavelength, λ_{cc}, shall be less than the maximum specified in clause 7.

5.6 Macrobending loss

Macrobending loss varies with wavelength, bend radius and number of turns about a mandrel with a specified radius. Macrobending loss shall not exceed the maximum value given in clause 7 for the specified wavelength(s), bend radii, and number of turns.

The actual low radius exposure of the fibre is on relatively short lengths only. As the typical choice of the bending radius and the length of the bent fibre may vary depending upon the design of the fibre management system and the installation practice, a specification at one single bending radius is not sufficient anymore. Although modelling results on various fibre types have been published, no general applicable bending loss model is available to describe the loss versus bend radius behaviour. For this reason, the recommended maximum macrobending loss is specified at different bend radii in the tables in clause 7.

As optical bending losses increase with wavelengths, a loss specification at the highest envisioned wavelength, i.e., either 1550 or 1625 nm, suffices. If required, a customer and supplier can agree on a lower or higher specification wavelength.

NOTE 1 – A qualification test may be sufficient to ensure that this requirement is being met.

NOTE 2 – In case another number of turns than the recommended number of turns is chosen to be implemented, it is assumed that the maximum loss that occurs in that deployment is proportional to the specified number of turns.

NOTE 3 – In the event that routine tests are required, deviating loop diameters can be used instead of the recommended test, for accuracy and measurement ease. In this case, the loop diameter, number of turns, and the maximum permissible bend loss for the several-turn test should be chosen so as to correlate with the recommended test and allowed loss.

NOTE 4 – In general, the macrobending loss is influenced by the choice of the values for other fibre attributes as the mode field diameter, chromatic dispersion coefficient and the fibre cut-off wavelength. Optimization with respect to macrobending losses usually involves a trade-off between the values of these fibre attributes.

NOTE 5 – A mandrel winding method (Method A), which is described in [IEC 60793-1-47], can be utilized as a measurement method for macrobending loss by substituting the bending radius and number of turns specified in Tables 7-1 and 7-2.

5.7 Material properties of the fibre

5.7.1 Fibre materials

The substances of which the fibres are made should be indicated.

NOTE – Care may be needed in fusion splicing fibres of different substances. Provisional results indicate that adequate splice loss and strength can be achieved when splicing different high-silica fibres.

5.7.2 Protective materials

The physical and chemical properties of the material used for the fibre primary coating and the best way of removing it (if necessary) should be indicated. In the case of single jacketed fibre, similar indications shall be given.

5.7.3 Proof stress level

The specified proof stress σ_p shall not be less than the minimum specified in clause 7.

NOTE 1 – The definitions of the mechanical parameters are contained in clauses 3.2 and 5.6 of [ITU-T G.650.1].

NOTE 2 – See also the informative Appendix I on this subject.

5.8 Refractive index profile

The refractive index profile of the fibre does not generally need to be known.

5.9 Longitudinal uniformity of chromatic dispersion

This attribute is usually less relevant for applications in the access network. For more details, see [ITU-T G.652].

5.10 Chromatic dispersion coefficient for class A fibres

The measured group delay or chromatic dispersion coefficient versus wavelength shall be fitted by the three-term Sellmeier equation as defined in Annex A of [ITU-T G.650.1]. (See clause 5.5 of [ITU-T G.650.1] for guidance on the interpolation of dispersion values to unmeasured wavelengths.)

The Sellmeier equation can be used to fit the data in each range (1310 nm and 1550 nm) separately in two fits or as one common fit with data from both ranges.

The Sellmeier fit in the 1310 nm region may not be sufficiently accurate when extrapolated to the 1550 nm region. Because the chromatic dispersion in the latter region is large, the reduced accuracy may be acceptable; if not, it can be improved by including data from the 1550 nm region when performing the common fit, or by using a separate fit for the 1550 nm region. It should be noted that a common fit may reduce the accuracy in the 1310 nm region.

The chromatic dispersion coefficient, D, is specified by putting limits on the parameters of a chromatic dispersion curve that is a function of wavelength in the 1310 nm region. The chromatic dispersion coefficient limit for any wavelength, λ, is calculated with the minimum zero-dispersion wavelength, λ_{0min}, the maximum zero-dispersion wavelength, λ_{0max}, and the maximum zero-dispersion slope coefficient, S_{0max}, according to:

$$\frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\max}}{\lambda}\right)^4\right] \le D(\lambda) \le \frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right]$$

The values of λ_{0min}, λ_{0max}, and S_{0max} shall be within the limits indicated in the tables of clause 7.

NOTE 1 – It is not necessary to measure the chromatic dispersion coefficient of single-mode fibre on a routine basis.

NOTE 2 – The chromatic dispersion for class B fibres is generally not critical for the application of this class of fibres, and therefore its value is not included in the attributes listed in Table 7-2 class B.

6 Cable attributes

Since the geometrical and optical characteristics of fibres given in clause 5 are barely affected by the cabling process, this clause gives recommendations mainly relevant to transmission characteristics of cabled factory lengths.

Environmental and test conditions are paramount and are described in the guidelines for test methods.

6.1 Attenuation coefficient

The attenuation coefficient is specified with a maximum value at one or more wavelengths in both the 1310 nm and 1550 nm regions. The optical fibre cable attenuation coefficient values shall not exceed the values found in clause 7.

NOTE – The attenuation coefficient may be calculated across a spectrum of wavelengths, based on measurements at a few (3 to 4) predictor wavelengths. This procedure is described in clause 5.4.4 of [ITU-T G.650.1] and an example is given in Appendix III of [ITU-T G.650.1].

6.2 Polarization mode dispersion coefficient for class A fibres

When required, cabled fibre polarization mode dispersion shall be specified on a statistical basis, not on an individual fibre basis. The requirements pertain only to the aspect of the link calculated from cable information. The metrics of the statistical specification are found below. Methods of calculations are found in IEC/TR 61282-3, and are summarized in Appendix IV of [ITU-T G.650.2].

The manufacturer shall supply a PMD link design value, PMD_Q, that serves as a statistical upper bound for the PMD coefficient of the concatenated optical fibre cables within a defined possible link of M cable sections. The upper bound is defined in terms of a small probability level, Q, which is the probability that a concatenated PMD coefficient value exceeds PMD_Q. For the values of M and Q given in clause 7, the value of PMD_Q shall not exceed the maximum PMD coefficient specified in clause 7.

Measurements and specifications on uncabled fibre are necessary, but not sufficient to ensure the cabled fibre specification. The maximum link design value specified on uncabled fibre shall be less than or equal to that specified for the cabled fibre. The ratio of PMD values for uncabled fibre to cabled fibre depends on the details of the cable construction and processing, as well as on the mode coupling condition of the uncabled fibre. [ITU-T G.650.2] recommends a low mode coupling deployment requiring a low tension wrap on a large diameter spool for uncabled fibre PMD measurements.

The limits on the distribution of PMD coefficient values can be interpreted as being nearly equivalent to limits on the statistical variation of the differential group delay (DGD), that varies randomly with time and wavelength. When the PMD coefficient distribution is specified for optical fibre cable, equivalent limits on the variation of DGD can be determined. The metrics and values for link DGD distribution limits are found in Appendix I of [ITU-T G.652].

NOTE 1 – PMD_Q specification would be required only where cables are employed for systems that have the specification of the max DGD, i.e., for example, PMD_Q specification would not be applied to systems recommended in ITU-T Rec. G.957.

NOTE 2 – PMD_Q should be calculated for various types of cables, and they should usually be calculated using sampled PMD values. The samples would be taken from cables of similar construction.

NOTE 3 – The PMD_Q specification should not be applied to short cables such as jumper cables, indoor cables and drop cables.

NOTE 4 – The PMD coefficient for class B fibres is generally not critical for the application of this class of fibres and therefore its value is not included in the attributes listed in Table 7-2 class B.

7 Tables of recommended values

The following tables summarize the recommended values for the categories of fibres that satisfy the objectives of this Recommendation.

Table 7-1 class A Attributes contains the recommended attributes and values needed to support optimized access network installation with respect to macrobending loss, while the recommended values for the other attributes still remain within the range recommended in G.652.D.

Table 7-2 class B Attributes contains the recommended attributes and values needed to support optimized access network installation with very short bending radii applied in fibre management systems and particularly for in- and outdoor installation. For the mode-field diameter and chromatic dispersion coefficients, the recommended range of value might be outside of the range of values recommended in [ITU-T G.652].

Table 7-1 – G.657 class A attributes

Fibre attributes			
Attribute	**Detail**	**Value**	
Mode field diameter	Wavelength	1310 nm	
	Range of nominal values	8.6-9.5 µm	
	Tolerance	±0.4 µm	
Cladding diameter	Nominal	125.0 µm	
	Tolerance	±0.7 µm	
Core concentricity error	Maximum	0.5 µm	
Cladding non-circularity	Maximum	1.0%	
Cable cut-off wavelength	Maximum	1260 nm	
Macrobending loss (Notes 1, 2)	Radius (mm)	15	10
	Number of turns	10	1
	Max. at 1550 nm (dB)	0.25	0.75
	Max. at 1625 nm (dB)	1.0	1.5
Proof stress	Minimum	0.69 GPa	
Chromatic dispersion coefficient	λ_{0min}	1300 nm	
	λ_{0max}	1324 nm	
	S_{0max}	0.092 ps/nm^2 × km	
Cable attributes			
Attenuation coefficient	Maximum from 1310 nm to 1625 nm (Note 3)	0.4 dB/km	
	Maximum at 1383 nm ±3 nm	(Note 4)	
	Maximum at 1550 nm	0.3 dB/km	
PMD coefficient	M	20 cables	
	Q	0.01%	
	Maximum PMD_Q	0.20 ps/$\sqrt{km}$	

NOTE 1 – G.652 fibres deployed at a radius of 15 mm generally can have macrobending losses of several dBs per 10 turns at 1625 nm.

NOTE 2 – The macrobending loss can be evaluated using a mandrel winding method (Method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table.

NOTE 3 – This wavelength region can be extended to 1260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1310 nm. In this case, the cable cut-off wavelength should not exceed 1250 nm.

NOTE 4 – The sampled attenuation average at this wavelength shall be less than or equal to the maximum value specified for the range, 1310 nm to 1625 nm, after hydrogen ageing according to [b-IEC 60793-2-50] regarding the B1.3 fibre category.

Table 7-2 – G.657 class B attributes

Fibre attributes				
Attribute	**Detail**	**Value**		
Mode field diameter	Wavelength	1310 nm		
	Range of nominal values	6.3-9.5 μm		
	Tolerance	±0.4 μm		
Cladding diameter	Nominal	125.0 μm		
	Tolerance	±0.7 μm		
Core concentricity error	Maximum	0.5 μm		
Cladding non-circularity	Maximum	1.0%		
Cable cut-off wavelength	Maximum	1260 nm		
Macrobending loss (Note 1)	Radius	15	10	7.5
	Number of turns	10	1	1
	Max. at 1550 nm (dB)	0.03	0.1	0.5
	Max. at 1625 nm (dB)	0.1	0.2	1.0
Proof stress	Minimum	0.69 GPa		
Chromatic dispersion coefficient (Note 2)		TBD		
Cable attributes				
Attenuation coefficient	Maximum at 1310 nm	0.5 dB/km		
	Maximum at 1550 nm	0.3 dB/km		
	Maximum at 1625 nm	0.4 dB/km		
PMD coefficient (Note 3)		TBD		

NOTE 1 – The macrobending loss can be evaluated using a mandrel winding method (Method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table.

NOTE 2 – Chromatic dispersion coefficients are not essential because the class B fibre supports a part of optimized access network installation with very small bending radii. The minimum and maximum zero-dispersion wavelength can be considered as λ_{0min} = 1300 nm and λ_{0max} = 1420 nm, respectively, with the maximum dispersion slope S_{0max} = 0.10 ps/nm^2· km.

NOTE 3 – PMD coefficients are not essential because the class B fibre supports a part of optimized access network installation with very small bending radii.

To illustrate the different macrobending specifications of the various classes defined in this clause, the recommended values have been represented in Figure 7-1 .

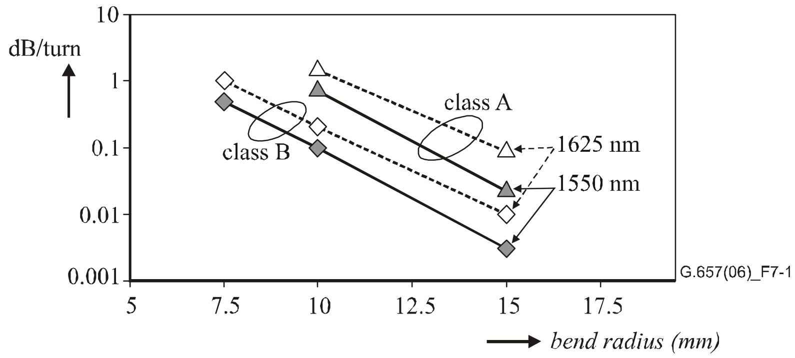

Figure 7-1 – Macrobending loss data from Tables 7-1 and 7-2, class A and B

Appendix I

Lifetime expectation in case of small radius storage of single mode fibre

(This appendix does not form an integral part of this Recommendation)

I.1 Introduction

Fibre storage at reduced radius in fibre management systems and in closures may impose concerns with respect to the fibre lifetime expectation. Important parameters that determine the expected lifetime are the applied proof stress level when producing the fibre and the intrinsic strength of the fibre. The required values of these parameters have to be offset against the accepted failure rate in the network. In assessing the result of this, the major question is whether the single mode fibres as specified in this Recommendation fulfil the requirements for a sufficiently long lifetime expectation. In this appendix, more background is given on this question.

I.2 Network and network failure

For the lifetime calculations, a simple network is considered to be consisting of a 1000 fibre distribution cable with a tree structure as indicated in Figure I.1. Depending upon the installation and customer connection procedures of the operator, the individual fibres or groups of fibres are stored in cassettes in the main distribution cable or in the branches. For simplicity and as a worst-case situation, it is assumed that all 1000 fibres are passing 5 cabinets or enclosures with a storage cassette in every individual fibre link and in every cabinet or enclosure.

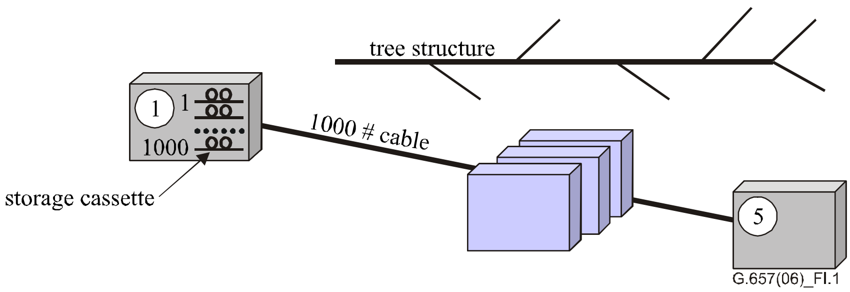

Figure I.1 – Simplified network structure

In this particular network structure, a failure rate *per individual single fibre cassette of 0.001% in 20 years*, results in a 5% probability that in 20 years one single spontaneous break in the total network. This probability has to be compared with the probability of other failures that may occur in the distribution network during the 20 years operational lifetime. Causes for this are in the failures due to re-work or re-configuration in the link or due to other causes of cable or cabinet damage. For most access network situations, it may be assumed that the stated failure probability due to spontaneous fibre breakage is much lower than the failure probability due to other causes. Each operator has to determine the accepted failure rate based on more precise data on the outside plant failure rate statistics.

I.3 Fibre lifetime considerations

Apart from the intrinsic fibre strength characteristics and the fibre environment, the main parameters that determine the failure rate per cassette are the *length* of the stored fibre and the *bending radius R* of the storage. The shorter storage length will have a positive influence, whereas the reduced bending radius will have a negative influence. Applying [b-IEC/TR 62048] lifetime model with more details in [b-OFT] on current fibres with standard setting of the proof stress and normal proof-test performance, the resulting maximum storage length for a 20-year lifetime as a function of the fibre bend radius is indicated in I.2 for different values of the static stress corrosion susceptibility coefficient n (fatigue parameter).

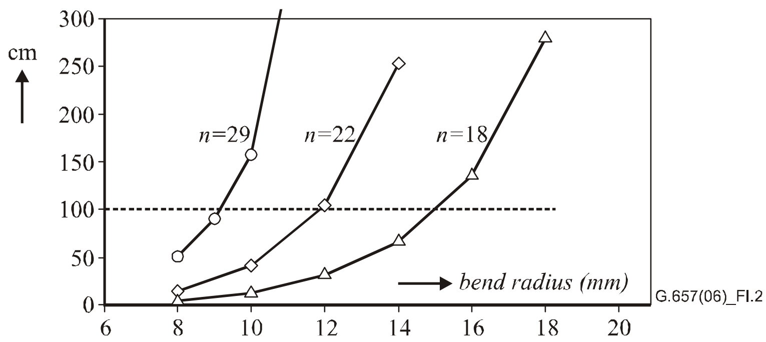

Figure I.2 – Maximum storage length for a bent fibre and different values of the fatigue parameter n

Note that a value of n = 18 is the minimum value as stated in [b-IEC 60793-2-50] and in Telcordia Generic Requirements GR-20-CORE. For a storage length per cassette of, for example, 100 cm, i.e., 2 × 50 cm for one single fibre, the bend radius can be lowered from the current 30 mm value down to 15 or even 9 mm depending upon the guaranteed n-value without violating the 0.001% failure rate per cassette in 20 years.

A second storage issue is at the entrance and exit ports in the fibre management system. The required small volume for optical access network components is not only dependent upon the storage area, but also on the minimum bend radius of the input and exit ports. The effect of this can be taken into account in several ways. For the purpose of this appendix, it is assumed that in every storage cassette ***four*** additional 90 degrees bend are required for guiding the fibres into and out of the storage areas. It is also assumed that the additional failure rate due to these additional bends should be limited to less than 10% of the accepted failure rate of 0.001% per cassette. This results in the minimum values as indicated in the middle column of Table I.1.

Table I.1 – Minimum value of non-storage bend radii

n-value	four 90° bends	single 180° bend
18	R_{min} = 15.0 mm	R_{min} = 12.6 mm
22	R_{min} = 11.1 mm	R_{min} = 9.2 mm
29	R_{min} = 8.0 mm	R_{min} = 6.6 mm

In the right column, the minimum radius in case of a single 180 degrees erroneous bend is given. Also for this situation, a maximum *additional* failure rate per individual cassette of 0.1 × 0.001% is assumed. All figures relate to single fibre management and are given for three different values of the fatigue parameter n.

I.4 Conclusions

The examples given in clause I.3 show that rather detailed knowledge on a realistic deployment of the fibre in a real-life distribution network is required to perform a reliable prediction of the operational lifetime. But even under the rather severe assumptions used in these examples, it also shows that for the reduction of the fibre storage radii into a much lower range than the currently applied 30 mm, the current lifetime characteristics of the single mode fibre as specified in [ITU-T G.652] are sufficient to support a 20-year operational lifetime.

Bibliography

[b-ITU-T ANT] Access Network Transport Standards Overview, Issue 14, June 2007, http://www.itu.int/ITU-T/studygroups/Com15/ant/

[b-ITU-T G.671] ITU-T Recommendation G.671 (2005), *Transmission characteristics of optical components and subsystems*.

[b-ITU-T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2006), *Optical system design and engineering considerations*.

[b-ITU-T L.13] ITU-T Recommendation L.13 (2003), *Performance requirements for passive optical nodes: Sealed closures for outdoor environments*.

[b-ITU-T L.42] ITU-T Recommendation L.42 (2003), *Extending optical fibre solutions into the access network*.

[b-ITU-T L.65] ITU-T Recommendation L.65 (2006), *Optical fibre distribution of access networks*.

[b-ITU-T L.66] ITU-T Recommendation L.66 (2007), *Optical fibre cable maintenance criteria for in-service fibre testing in access networks*.

[b-IEC 60793-2-50] IEC 60793-2-50 (2004), *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*.

[b-IEC/TR 62048] IEC 62048 (2002), *Optical fibres – Reliability – Power law theory*.

[b-OFT] Matching Optical Fibre Lifetime and Bend-loss Limits for Optimized Local Loop Fibre Storage, *Optical Fibre Technology*, Vol. 11, pp. 92-99, 2005.

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