International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.657

Amendment 1

(06/2010)

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

Amendment 1: Revised Appendix I – Lifetime expectation in case of small radius bending of single-mode fibre

Recommendation ITU-T G.657 (2009) – Amendment 1

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Recommendation ITU-T G.657

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

Amendment 1

Revised Appendix I – Lifetime expectation in case of small radius bending of single-mode fibre

Summary

Amendment 1 to Recommendation ITU-T G.657 is aimed to provide information on reliability of optical fibre with small bending radius.

Clause I.2 is inserted to describe general aspects on failure characteristics under small radius bending. The following figures and tables are also introduced in this amendment.

– Figure I.1 Example of calculated relationship between failure probability and bending radius for uniformly bent one-turn fibres.

– Figure I.2 Example of time to failure under ultra-small bending radius.

– Table I.1 Example of failure probability for fibre stored in loose coils.

– Table I.3 Example of failure probabilities with bend only and bend + tension.

Reliability of small bending radius is an ongoing topic under study in ITU-T and IEC.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.657	2006-12-14	15
2.0	ITU-T G.657	2009-11-13	15
2.1	ITU-T G.657 (2009) Amend. 1	2010-06-11	15

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Amendment 1

Revised Appendix I – Lifetime expectation in case of small radius bending of single-mode fibre

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

(Reliability of small bending radius is an ongoing topic under ITU-T and IEC study.)

Replace clauses I.1, I.2, I.3 and I.4 with the following ones:

I.1 Introduction

Fibres under installation at reduced bending radius including multi dwelling units (MDUs) and closures may impose concerns with respect to the fibre lifetime expectation. Important parameters that determine the expected lifetime are the extrinsic strength and intrinsic strength in a 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 General aspects on failure characteristics under small radius bending

In general, the estimation of mechanical failure probability or lifetime of a bent fibre is done using power law theory. Details of power law theory are described in [b-IEC/TR 62048]. IEC document describes two strength regions, intrinsic and extrinsic. The intrinsic strength region is length independent and dominant for small radius bending. In the extrinsic region, the mechanical failure probability of bend fibre increases proportionally with fibre length if bending radius is constant. Transition between these regions is hard to determine and depends on many variables.

It is desirable that bent region in a fibre link is as short as possible. The failure probability of various bend radii can be estimated by using power law theory. An example image of failure probabilities with respect to bending radius for 1% proof test level is shown in Figure I.1. In this calculation, the static stress corrosion susceptibility coefficient n (fatigue parameter) of 18 and the mean number of break Np per length during proof test of 0.01 km^{-1} are used as example. In the figure, the values of mechanical failure probability within 20 years are plotted for a fibre with 1 turn bend length for each bend radius. From Figure I.1, two regions are observed: an intrinsic region and an extrinsic region tail. The failure probability in extrinsic region is affected by means of the proof strain level. On the other hand, the failure probability in the intrinsic region depends on the intrinsic strength of the fibre, and is close to the theoretical strength of the glass.

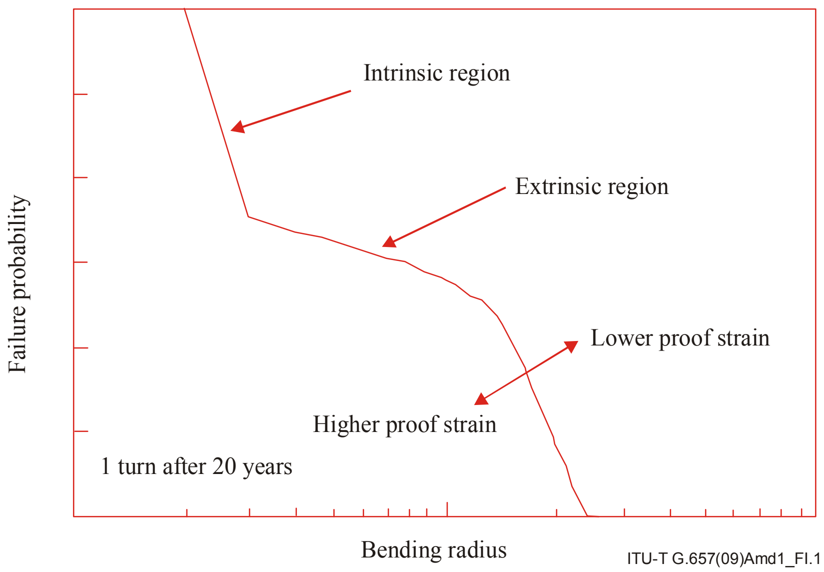

Figure I.1 – Example of calculated relationship between failure probability and bending radius for uniformly bent one-turn fibres after 20 years

Figure I.2 shows the dependence of time to failure on the bending radius. These experimental results show that very small radii cause the reliability degradation.

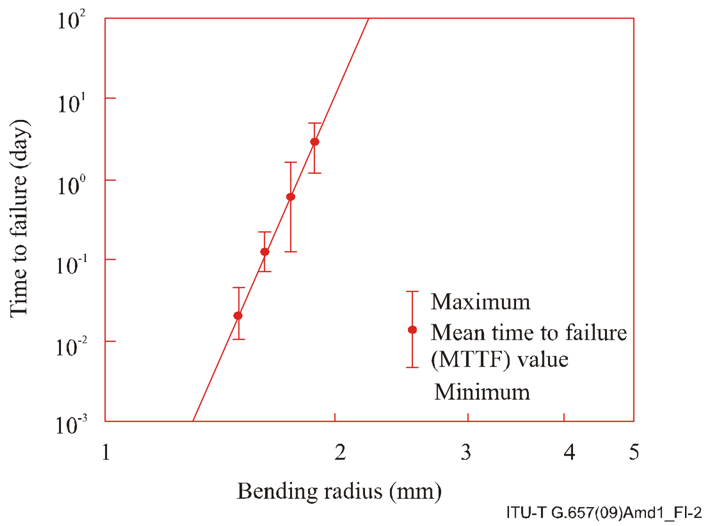

Figure I.2 – Example of time to failure under ultra-small bending radius

The fibre storage at reduced radius in fibre management systems and in closures may impose concerns with respect to the fibre lifetime. For these applications, the loop size should be chosen to be large enough that fibres are in the extrinsic region.

In many applications, loose fibre storage loops are 30 mm radius with approximately 1-10 m of fibre stored at a splice point. With improved macrobend fibre, the size of these loops could be reduced resulting in smaller enclosures but the amount of fibre required, 1-10 m, for splicing will likely remain the same. Smaller loop results in more stress on the fibre and thus a greater risk of mechanical failure. Table I.1 below uses the well-known power law theory of optical fibre reliability (see [b-IEC/TR 62048]) to show 25-year failure probability as a function of loop size and fibre length.

Table I.1 – Twenty-five year failure probability for fibre stored in loose coils, proof tested at 1%

Length	15 mm radius	20 mm radius	25 mm radius	30 mm radius
1 m	5.0×10^{-6}	4.7×10^{-7}	7.9×10^{-9}	1.9×10^{-10}
10 m	5.0×10^{-5}	4.7×10^{-6}	7.9×10^{-8}	1.9×10^{-9}

One can see from this example that using smaller coils will increase the failure probability. This failure probability would improve with increased proof stress.

I.3 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.3. 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.

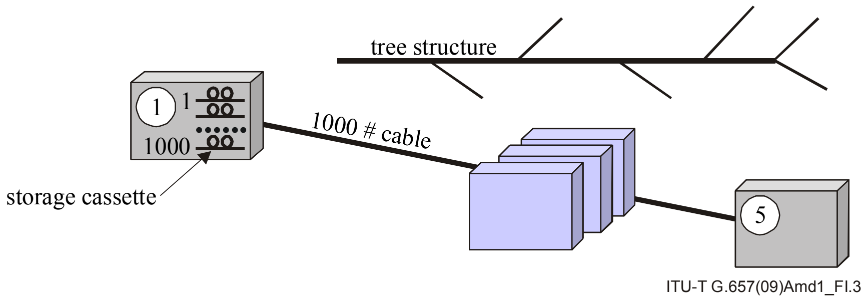

Figure I.3 – Simplified network structure

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-year 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.4 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. Shorter storage length will have a positive influence, whereas 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 Figure I.4 for different values of the dynamic stress corrosion susceptibility coefficient, *n* (fatigue parameter).

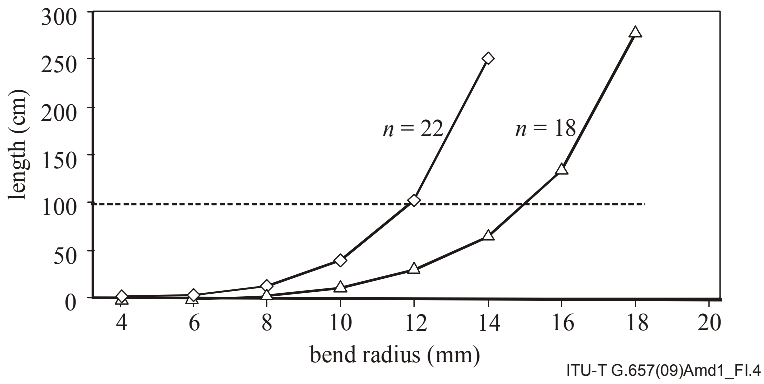

Figure I.4 – Maximum storage length for a bent fibre and different values of the fatigue parameter *n*

Note that a value of $n = 18$ is the minimum value as stated in [b-IEC 60793-2-50] and in Telcordia Generic Requirements for Optical Fiber and Optical Fiber Cable (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-degree bends 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.2.

Table I.2 – 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

In the right column, the minimum radius in case of a single 180-degree 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 two different values of the fatigue parameter, *n*.

Optical cables are traditionally designed to separate bending forces from axial tension. This assumption is not valid for drop cables used in building applications. These new cables may be subject to bends and tension simultaneously. In these conditions, the strain from all sources should be taken into account to accurately predict mechanical life time at the bend. The resulting failure probability when bends and tension are present can be calculated using the strip calculation found in [b-IEC/TR 62048].

An example of the data regarding mechanical failure rate under tension is described in Table I.3.

Table I.3 – Failure probabilities (F) with bend only and bend + tension (30% of proof test tension for 30 years)

Bend radius	Bend only		Bend + tension	
	(F/m)	ppm (turn)	(F/m)	ppm (turn)
5	1.02E-04	~ 3.2	1.87E-04	~ 5.5
7.5	3.54E-05	~ 1.7	9.00E-05	~ 4.2
10	1.49E-05	~ 0.9	5.53E-05	~ 3.5
15	2.64E-06	~ 0.3	2.90E-05	~ 2.7

I.5 Conclusions

The examples given support a 20-year operational lifetime for an appropriately installed network with bend radii less than 30 mm.

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