International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.12

(03/2008)

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre splices

Recommendation ITU-T L.12

ITU-T

Recommendation ITU-T L.12

Optical fibre splices

Summary

Splices are critical points in the optical fibre network, as they strongly affect not only the quality of the links, but also their lifetime. In fact, the splice shall ensure high quality and stability of performance with time. High quality in splicing is usually defined as low splice loss and tensile strength near that of the fibre proof-test level. Splices shall be stable over the design life of the system under its expected environmental conditions.

At present, two technologies, fusion and mechanical, can be used for splicing glass optical fibres and the choice between them depends upon the expected functional performance and considerations of installation and maintenance. These splices are designed to provide permanent connections.

Source

Recommendation ITU-T L.12 was approved on 8 March 2008 by ITU-T Study Group 6 (2005-2008) under Recommendation ITU-T A.8 procedure.

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.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

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/.

CONTENTS

Recommendation ITU-T L.12

Optical fibre splices

1 Scope

This Recommendation deals with the application of splices of single-mode and multimode optical fibres. It describes a suitable procedure for splicing that shall be carefully followed in order to obtain reliable splices between optical fibres or ribbons. This procedure applies both to single fibres or ribbons (mass splicing). In addition, this Recommendation advises on the optical, mechanical and environmental testing methods required for the splice system design and equipment qualification. Further information is provided in [b-ITU-T Handbook].

The fibres shall be in accordance with [ITU-T G.651.1], [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656] and [ITU-T G.657].

2 Normative 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.651.1] Recommendation ITU-T G.651.1 (2007), *Characteristics of a 50/125 µm multimode graded index optical fibre cable for the optical access network*.

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

[ITU-T G.653] Recommendation ITU-T G.653 (2003), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2004), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] Recommendation ITU-T G.656 (2006), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.657] Recommendation ITU-T G.657 (2006), *Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network*.

[IEC 61300] IEC 61300-x-series (in force), *Fibre optic interconnecting devices and passive components - Basic test and measurement procedures.* <http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwprog=sea22.p&search=iecnumber&header=IEC&pubno=61300>

[IEC 61755-2-x] IEC 61755-2-series (2006), *Fibre optic connector optical interfaces*. <http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwprog=sea22.p&search=iecnumber&header=IEC&pubno=61755&part=2>

[IEC/TR 62316] IEC/TR 62316 (2007), *Guidance for the interpretation of OTDR backscattering traces*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/037447>

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

IL	Insertion Loss or attenuation
MFD	Mode Field Diameter
RH	Relative Humidity
OTDR	Optical Time Domain Reflectometer
RL	Return Loss

4 Types of splices: General description

All optical fibre splices as mentioned in this Recommendation should be suitable for indoor applications as well as for outdoor environments when stored in an appropriate enclosure.

4.1 Fusion splices

Different methods exist to obtain a fusion splice of fibres or ribbons. Electric arc-fusion is the most widely used method to make reliable single or mass optical splices in the field. The fusion process is realized by using specially-developed splicing machines.

To make a fusion splice, all the protective coatings are removed from the fibre, the fibres are cleaved and then positioned and aligned between two electrodes in the splicing machine. An electric arc heats the silica glass until the "melting" or softening point is reached and at the same time the fibres are brought together longitudinally in such a way that a geometrically continuous splice is obtained. This process produces a continuous glass filament. The fibre alignment in these machines can be passive (v-groove alignment) or active (light injection and detection system or core/cladding profile monitoring and alignment system). A suitable protection device is then applied to the splice to protect the bare fibre and to allow handling and storage without adversely affecting the physical integrity of the splice. The cleave quality and the intensity and the duration of the arc as well as the differences between the two fibres to be spliced determine the splice loss. In addition, the quality of coating removal, fibre cleaving and splice protection contribute to the long-term mechanical reliability in the field.

4.2 Mechanical splices

Mechanical splices have different structures and physical designs, and usually include the following basic components:

- surface for aligning mating fibre ends;
- a retainer to keep the fibres in alignment;
- an index matching material (gel, grease, adhesive, etc.) placed between the fibre ends.

They can be used for single fibres or ribbons. Some designs allow installation on the fibres at the end of a cable in the factory for faster jointing in the field.

An optical matching material between the ends of the fibres can be used to reduce Fresnel reflections. This material shall be chosen to match the optical properties of the fibre. Common index matching materials include silicon gels, UV-curable adhesive, epoxy resins and optical greases. The index of refraction of these materials each has a different temperature dependence to the fibre.

More detailed information on index matching materials can be found in Appendix I.

5 Splicing procedure steps

5.1 Fibre cleaning and end preparation

For jelly-filled cables, the fibres shall be mechanically cleaned of the water-blocking jelly of the cable using lint-free paper tissue or cotton cloth. Commercial solvents are available that can be used to assist in this cleaning. Care shall be taken so that the ribbon matrix material and fibre coatings are not damaged either mechanically or chemically. Long-term soaking in solvents can damage the fibre coating. In addition, all the safety-related information of these products shall be declared by the solvent supplier.

The fusion splicing machine or mechanical splice assembly tool shall be close to the joint closure, so that the fibres are not subjected to excessive bending, tensile or pressure stresses.

The ends to be spliced shall be identified on the basis of the cable identification system which denotes the fibres in the cable.

If tube-type protection devices are used, they shall be placed over one end of the fibres or ribbons to be spliced before splicing. Clamshell-type protectors can be fitted after splicing is complete.

5.2 Coating stripping

Where applicable, secondary coatings (tight buffer or loose tube constructions) shall be removed to the distance recommended by the splice protector manufacturer using an appropriate tool in order to expose the primary coating.

Enough coating shall be removed from the ends so that, after cleaving and splicing, all bare fibre shall be covered by the protection device or mechanical splice. Coating removal could be the most critical operation in the splicing procedure, especially if it has to be performed on fibres that have been in the field for many years, because strippability may get worse due to ageing. Therefore, this step must be performed carefully because the final strength of the completed splice depends on minimizing the exposure that can cause flaws on the bare fibre.

The stripping method could be chemical, thermal or mechanical, depending on the applications and on the desired performance. In the case of a chemical method, all safety-related information of the product shall be supplied by the manufacturer. Typically, for underground, directly buried or aerial applications mechanical stripping is used. The blade separation and alignment of the semi-circular or v-groove openings shall be controlled to penetrate into the soft inner coating layer without scratching the fibre surface. The blades shall be examined carefully and frequently. The blades shall be well aligned, clean at all times and replaced if damaged or worn. Where the blades are an integral part of the stripper, the tool shall be replaced. When thermal stripping methods are used, especially for ribbons, the coating shall be heated to the temperature recommended by the ribbon manufacturer, and then removed by a blade. For submarine applications, the chemical method is more suitable for the higher proof-test levels required.

Holders are always used for stripping, cleaving and splicing fibre ribbons and are sometimes used for single fibre splicing systems. The ribbons are held in a holder prior to stripping and cleaving, and during the fusion process. The holder shall ensure a good alignment of the fibres without damaging them. Only the coated part of the fibre or ribbon shall be put into the holder, so that clamping does not cause damage. The holders shall be kept clean and free of debris.

5.3 Cleaning of the bare fibre ends

When fibre end cleaning is needed, the bare ends shall be cleaned with paper tissue soaked with reagent grade alcohol to eliminate residual coating, paying attention not to break them. Avoid wiping the fibre more than necessary to clean off debris.

5.4 Fibre cleaving

The bare fibre ends shall be cleaved perpendicularly to the longitudinal axis; the cut surface shall be mirror-like without chips or hackle.

For fusion splices, end angles shall be typically less than 1° from perpendicular for single fibres and less than 3° to 4° for ribbons (depending on the fibre type) to achieve a satisfactory splice. The cleaving tool shall be capable of achieving these values with a controlled length of bare fibre, compatible with the splicing system and protection device.

For mechanical splices, two types can be identified: perpendicular cleaved, with typically the same cleave angle as fusion splices; and angle cleaved, with a cleave angle of at least 4°. This is done to eliminate reflected light due to the mismatch between fibre glass and index matching material at extreme temperature. When splices are assembled with angled cleaves instead of perpendicular cleaves, the reflected light is no longer completely captured and guided by the fibre core, but is directed to the fibre cladding where it is attenuated.

The cleaving tool shall be clean and properly adjusted to produce consistent fibre ends with the appropriate cleaving angle. Dirty cleaving tool clamping pads can cause flaws that make the fibre break at the wrong location or reduce the strength of the completed splice. The blade shall score the fibre sufficiently to produce a clean break, but should not impact so hard on the fibre that it shatters it. Cleaving tools that use bending to stress the fibres shall be limited in their travel to avoid over-bending the fibres. For mass fusion, the cleaved bare fibre lengths shall be approximately equal across the ribbon to provide uniform overlap on all of the fibres during fusion. The off-cuts cleaved from the fibre shall be collected and disposed of carefully to prevent injury.

5.5 Splicing

5.5.1 Electric arc-fusion splicing

5.5.1.1 Control of the splicing parameters and conditions

Before using the splicing machine, it is fundamental to check its performance. The condition of the electrodes is a critical factor determining whether fusion splicing will proceed normally, especially when working at environmental extremes.

A good indicator of the electrode condition and whether or not the machine parameters are set correctly for the type of fibre and environmental conditions is the degree to which fibres "melt back" when subjected to the fusion arc but with the fibre feed turned off. Alternatively, some other substitute tests can be used to check the equipment. Some machines can automatically optimize the arc parameters; otherwise, manual adjustments will be needed.

Machine performance is sensitive to atmospheric variations. Either automatic or manual adjustment of arc parameters shall be made to optimize for the existing conditions.

The splicing machine shall have the facility to count and indicate the arc number and the manufacturer shall provide the number after which the electrodes shall be replaced. The replacement shall be in accordance with the instructions of the manufacturer.

Since the optimal splice conditions (arc current, arc time, etc.) may depend on both the characteristics of the type of fibre as well as the characteristics of the splicing machine, it is recommended to use an arc test procedure, available in many splicing machines.

NOTE 1 – Some splicing machines can also optimize the arc position asymmetrically between the fibre ends of dissimilar fibres. When working under these settings, attention should be paid to always place the proper fibre at the proper side of the fibre holder.

NOTE 2 – Some splicing machines offer fibre type recognition algorithms, based on particular (non-standardized) interpretation of the fibre index profile. Care should be taken with these algorithms, since index profiles have not been standardized. At least a check per commercial fibre type is recommended.

5.5.1.2 Fusion splicing

When testing of the arc condition is completed, splicing can commence. The fibre shall be positioned in the v-grooves of the splicing machine.

Fusion splicing machines, in general, are divided into two types: active or passive alignment. The use of either type depends on how the fibres are aligned. Active alignment machines use either a vision system or local injection/local detection system and three-dimensional movement of the fibres to actively align the cores or the outside diameters of the two fibres being spliced. The splicing machine minimizes the splice attenuation by either focusing on the core or cladding of the fibres with its vision system to directly align them or optimizing the transmitted light through the fibres and providing an estimate of the splice attenuation after the splice is complete.

Those systems which compensate for core concentricity errors provide better results in terms of splice attenuation. Splicing machines that use active alignment systems are only suitable for single fibre splicing at this time.

Passive alignment machines use only fibre longitudinal movement so accurate core alignment depends on good fibre geometry. The passive alignment system is currently used to splice ribbons and is also used in single fibre splicing machines where an estimate of splice attenuation may also be provided. For ribbon cables, however, all of the current mass fusion machines estimate splice attenuation by observing fibre alignment before and/or after splicing.

5.5.1.3 Proof-test

After the splice is completed, it is recommended to check its minimum strength. It is very important to establish a defined level of mechanical strength for the splice that is related to its expected lifetime. As performed for optical fibres just after manufacturing, the splice is subjected to a tensile proof-test for a short period of time. Some splicing machines perform this test with the spliced fibres in the splicing chucks and some perform it after placing the spliced fibres in the holders for heat-shrink protector application. Splices which have their strength below the proof-test level will be eliminated.

The splicing machine shall be able to perform the proof-test automatically or manually. The unloading time shall be short in order to minimize the strength reduction during the unloading. Typical values for proof-testing range from 2N up to 20N, depending on the type of equipment and desired strength.

5.5.1.4 Splice protection

After the proof-test, the protector shall be positioned over the spliced point. The "protector" is a mechanical device or restored coating, that provides both mechanical and environmental protection to the single or multiple splices. In all cases, the protection device shall affect neither the attenuation of the splice nor its functional properties.

The characteristics of the completed fusion splice can be verified using the test methods reported in clause 6.

Protector designs may include heat-shrink sleeve, "clam-shell", fibre re-coating and encapsulating protectors. The protectors for single fibre fusion splices shall be capable of accepting either 250 µm (nominal) diameter coated fibres, 900 µm (nominal) diameter buffered fibres, or 250 µm/900 µm combinations. Typically, these protectors require tools or equipment to install or make.

The protector designs shall be suitable for either aerial, underground or buried applications while stored inside an appropriate enclosure. The manufacturer shall provide information on the compatibility with the splice organizer trays and on the tools or equipment for its application. In particular, the manufacturer shall provide information on the minimum/maximum fibre strip lengths that the protector will accommodate and on the storage dimensions for the completed protector (length, width and height) and on the application details.

For heat-shrink sleeve protectors, the manufacturer shall specify the time and the temperature required to complete the shrinkage, which shall be taken into account by the oven settings. The function of the strength member, if present, is to improve the mechanical strength of the splice without affecting it, both from an optical and mechanical point of view. It shall be straight and free from burrs and sharp edges. During cool-down, care shall be taken to prevent deformations that cause bending attenuation.

For UV-curable resin-filled protectors, the manufacturer shall specify the total energy (time exposure and the power) applied by the UV lamp.

The complete documentation containing all the details, such as the manufacturer's references, the product code and the order mode, the use and application, the repair and maintenance procedures shall be available with the product. The constituting materials shall be compatible with the jelly inside the cables and the protectors shall be supplied with safety and operational instructions.

A schematic representation of the fusion splicing procedure is shown in Figure 1.

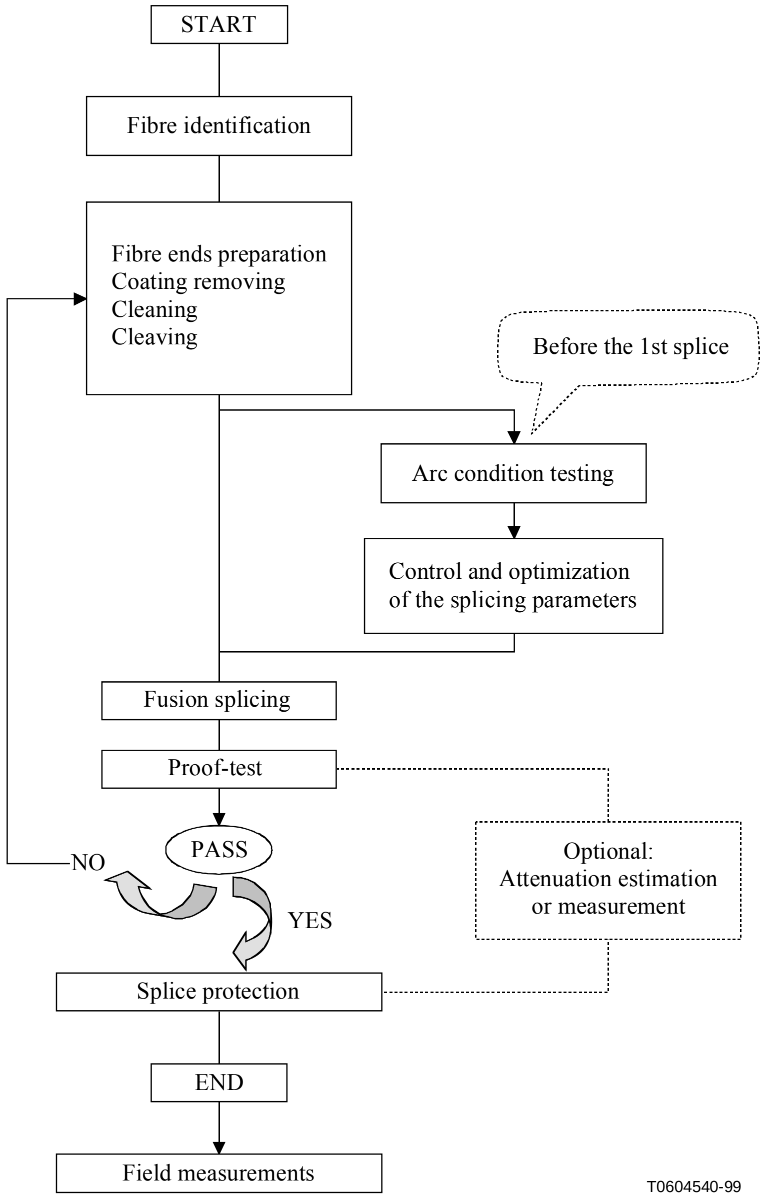

Figure 1 – Schematic representation of the fusion splicing procedure

5.5.2 Mechanical splicing

The mechanical method allows fixing the fibres in a splice-protective housing, generally without the need of electrical power. Some mechanical splices can be tuned by hand for minimum splice loss.

After stripping and cleaving operations, described in clauses 5.1 to 5.4, the fibre bare ends are inserted in the mechanical housing (in a guiding structure, for instance a v-groove) and checked for their physical contact. For angle-cleaved splices, it is recommended to maintain the relative orientation of the angled end faces of the fibres during installation in order to obtain optimal optical performance.

For mechanical splices, proof-test is generally not a part of the installation sequence as it is for fusion splices.

Sometimes, the fibre ends are prepared for splicing by grinding and polishing procedures, especially in factory pre-terminated mass splices.

The mechanical splices shall be versatile, allowing the splicing of different types of fibres, for example, 250 µm with 900 µm diameter buffered fibres.

The integral housing of the splice (different for single or multiple splices) provides mechanical and environmental protection. They shall be suitable either for aerial, underground or buried applications. The manufacturer shall provide information on the compatibility with the splice organizer trays and on the tools or equipment for their application.

The index matching material used between the ends of the mating fibres shall be chosen to match the optical properties of the glass. The supplier of the index matching material shall provide complete information about its behaviour at different temperatures (especially the extremes) and its estimated lifetime in terms of maintaining the initial optical performance.

The characteristics of the completed mechanical splice can be verified using the test methods reported in clause 6.

In mechanical splicing, the splice protection is built into the splice design and separate protectors are not required.

A schematic representation of the mechanical splicing procedure is shown in Figure 2:

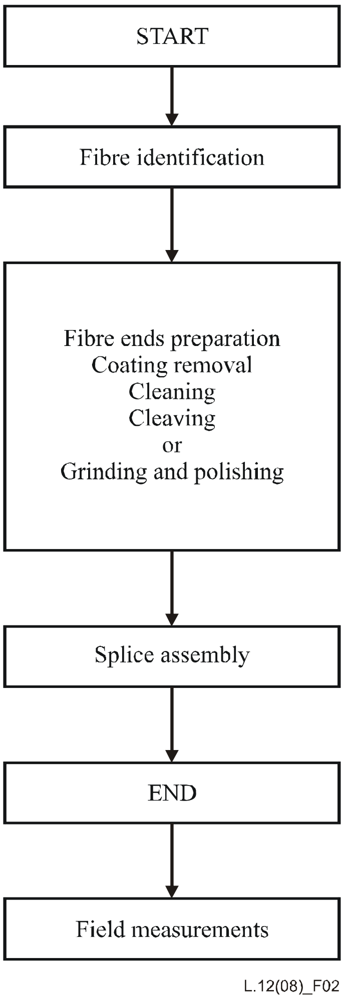

Figure 2 – Schematic representation of the mechanical splicing procedure

5.6 Field splice loss measurements

One critical requirement for an optical fibre communication system is the total end-to-end loss of each link. Considering the number of splices in a link, a realistic maximum splice loss should be set.

In practice, the field measurement of each splice loss during construction of a fibre route is usually indicated by the fusion splicing machine (when loss estimation is a facility) and/or by a one-way

OTDR measurement. Either of these techniques can be used to evaluate gross high splice losses so that the splice may be remade if necessary. After construction is complete, the actual splice loss in the field can be determined by bidirectional OTDR if necessary.

For single-mode fibre the true splice loss is determined by the bidirectional average of the OTDR readings at a splice. A one-way OTDR measurement should not be used as actual splice loss because MFD tolerances and other intrinsic parameter differences in fibres can cause errors. In case of single-mode fibres, OTDR single direction readings can be high, being either positive or negative. In addition, any measurable spike from a fusion splice requires that the splice be remade. Acceptance levels for splice loss before remake depend on the loss budget of the link.

More guidance on the interpretation of OTDR backscattering traces of splices can be found in [IEC/TR 62316].

6 Functional properties of the splices

The aim of this clause is to prescribe a number of tests and criteria, necessary to validate and qualify a splicing system or equipment. For the validation of a splicing system or equipment, single-mode fibres with the same nominal mode field diameter or multimode fibres with the same nominal numerical aperture should be used, in order to avoid incorrect results due to mismatches between different fibres. More details on single-mode fibre mode field diameter range can be found in [IEC 61755-2-x].

These tests are to be executed in laboratory conditions according to IEC definition:

Temperature (°C)	18-28
Relative humidity (%)	25-75
Air pressure (hPa):	860-1060

6.1 Recommended characteristics for single-mode fibre splices

Table 1 – Recommended characteristics for single-mode fibre splices

Nº	Test	Method	Severity	Mechanical splice (single fibre) (Note 3)	Fusion splice with protector (single fibre) (Note 3)
6.1.1	Attenuation/ Insertion loss (IL)	IEC 61300-3-7	IL at 1310 nm, 1550 nm and 1625 nm	≤ 0.2 dB average ≤ 0.5 dB max in 97%	≤ 0.1 dB average ≤ 0.2 dB max in 97%
6.1.2	Return loss (RL)	IEC 61300-3-6 method 1 or 2	RL at 1310 nm, 1550 nm and 1625 nm	When straight cleaved: ≥ 35 dB (grade 3) ≥ 45 dB (grade 2) When angle cleaved: ≥ 60 dB (grade 1)	≥ 60 dB
6.1.3	Vibration (sinusoidal)	IEC 61300-2-1	Sweep 10-55 Hz Amplitude 0.75 mm 15 cycles 3 directions X-Y-Z	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.4	Shock	IEC 61300-2-9	500 g 1 ms pulse 3 axes	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.5	Torsion	IEC 61300-2-5	Load 2N ± 180° 10 cycles	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met

Table 1 – Recommended characteristics for single-mode fibre splices

Nº	Test	Method	Severity	Mechanical splice (single fibre) (Note 3)	Fusion splice with protector (single fibre) (Note 3)
6.1.6	Fibre retention	IEC 61300-2-4	Load: 2 N primary 5 N secondary at 0.3 metre for 60 seconds	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.7	Cold (Note 2)	IEC 61300-2-17	–40°C, 96 hrs	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.8	Dry heat (Note 2)	IEC 61300-2-18	+70°C, 96 hrs	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.9	Condensation	IEC 61300-2-21	–10/+65°C 93% RH at Tmax Dwell time at extreme temperatures: 3 hr (24 hr/cycle) 10 cycles	During and after test, the IL and RL values specified in 6.1.1 and 6.12 shall be met	During and after test, the IL and RL values specified in 6.1.1 and 6.12 shall be met
6.1.10	Change of temperature	IEC 61300-2-22	–40°C/+70°C 12 cycles	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	During and after test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met
6.1.11	Dust – Laminar flow	IEC 61300-2-27	+35°C/60%R <150 µm 25 g/m^3	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	Not applicable
6.1.12	Salt mist (Note 1)	IEC 61300-2-26	5% NaCl solution at 35°C for 96 hrs	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met No visual evidence of corrosion	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met No visual evidence of corrosion
6.1.13	Water immersion (Note 4)	IEC 61300-2-45	5 cm below the surface of the water +25°C Duration: 1 hr Immersion: 1 cycle	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met	After test, the IL and RL values specified in 6.1.1 and 6.1.2 shall be met

NOTE 1 – Only recommended when the splice or splice protector contains metallic component(s).

NOTE 2 – Cold and dry heat optional as temperature effects are already assessed during temperature cycling test.

NOTE 3 – Internationally accepted values for performance criteria for multi-fibre splices are not yet defined: for further study.

NOTE 4 – Only recommended for splices that may be subject to occasional immersion in water, e.g., due to flooding of pedestals, basements, vaults, etc. To be agreed between supplier and customer.

6.2 Performance criteria for multimode fibre splices

For further study: definition of launch conditions and related performance requirements to be finalized in collaboration with IEC.

Appendix I

Index of refraction matching materials for mechanical optical fibre splices

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

The most common index matching materials are silicon gels and silicon greases. UV-curable adhesives and epoxies are also sometimes used as matching materials.

Gels and greases are used more often because they provide superior strain relief and viscoelasticity in the fibre-to-fibre gap. This allows them to accommodate differential thermal expansion and mechanical stresses without causing delamination in the gap or inducing excessive stress in the fibre.

Curing silicone gels, UV-curable adhesives and epoxies are cross-linked, cured materials. As such, they are chemically active until they are cured and they have limited shelf life in their uncured state (6 months is typical). Curing gels must be cured at the time of splicing by means of mixing two component fluids or by exposure of an uncured fluid to elevated temperature. They should be chemically and physically stable once cured.

Non-curing silicone and other greases are suspensions of a microscopic powder thickener in an optical fluid and are sometimes also called gels, optical coupling compounds or optical couplants. They are non-curing, ready-to-use, single component materials, with no intrinsic shelf life limit due to cure reaction components. Their physical consistency is that of a grease – while they will flow from a dispensing syringe under pressure, they do not migrate when at rest in the fibre splice.

Most pre-index-matched mechanical splices use non-curing index matching grease. Some optical greases have been shown to separate into their constituent fluid and thickener after long periods at elevated temperature ("oil separation"). Some materials have exhibited a tendency to dry out over many months or to evolve gas micro-bubbles which introduce a hazy appearance ("evaporation", "appearance"). If the materials are not properly filtered, de-aerated and packaged they will contain entrained microscopic air bubbles, dust, fibres and other particles which can degrade return loss and insertion loss in the splice ("colour", "appearance", "particulate contamination"). The long-term environmental stability of index matching greases should be confirmed before use in applications with a wide temperature range, or other severe or unusual environmental conditions. Lot test requirements for these materials is recommended as shown in Table I.1. Other requirements should be added to suit the particular splice design and environmental conditions.

Table I.1 – Recommended specifications for index matching greases in fibre splices

Property	Method	Requirement
Colour	Visual	Water white, non-yellowing
Appearance	Visual	No bubbles, voids or visible particles
Refractive index @ 25°C, 589 nm	See [b-ASTM D1218-99]	1.463 ± 0.003 (for silica fibre)
Evaporation, 24h @ 100°C	See [b-ASTM D972-97]	0.2%, max
Oil separation, 24h @ 100°C	See [b-Mellqvist] FTM 791, method 321.2	0.2%, max
Particulate contamination	See [b-Mellqvist] FTM 791B, method 3005	<300 particles/cc, 10 to 34 μm No particles above 35 μm

Appendix II

Japanese experience on optical fibre splicing

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

See Tables II.1 to II.3.

Table II.1 – Optical performance of fibre splice

Test	Type of splice	Test method	Condition	Performance
Insertion loss	Single or multiple fibre fusion splice	IEC 61300-3-4		Attenuation: GI: 90% = 0.1 dB 100% = 0.3 dB SM: 90% = 0.2 dB 100% = 0.3 dB DSM: 90% = 0.2 dB 100% = 0.3 dB @1.31 ± 0.1 µm
Insertion loss	Single fibre mechanical splice (access)	IEC 61300-3-4		Attenuation: Mechanical splice SM: 90% = 0.4 dB 100% = 0.5 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Insertion loss	Multiple fibre mechanical splice (access)	IEC 61300-3-4		Attenuation: Mechanical splice SM: 90% = 0.4 dB 100% = 0.5 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Return loss	Single or multiple fibre mechanical splices	IEC 61300-3-6		Return loss: Mechanical splice SM: > 40 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
NOTE – In Japan, fusion splice covers [ITU-T G.651.1], [ITU-T G.652] and [ITU-T G.653] and mechanical splice covers only [ITU-T G.652].				

Table II.2 – Mechanical performance of fibre splice

Test	Type of splice	Test method	Condition	Performance
Tensile strength	Single or multiple fibre fusion splices	IEC 61300-2-4	Load: Single: <8.9 N Multiple: <21.6 N	Not break
Fibre retention	Single or multiple fibre mechanical splices	IEC 61300-2-4	Load: Mechanical splice Single: 3 N Multiple: 8.5 N	Attenuation change: Mechanical splice Single: <0.2 dB Multiple: <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Vibration (sinusoidal)	Single or multiple fibre mechanical splices	IEC 61300-2-1	Amplitude: 0.75 mm Frequency: 10-55 Hz Duration: 24 cycles (2 hr) Direction: 3	Attenuation change: Mechanical splice <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Shock	Single or multiple fibre mechanical splices	IEC 61300-2-9	100G, 6 ms, 3 directions, 3 times/direction	Attenuation change: Mechanical splice <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Side pull	Single or multiple fibre mechanical splices	IEC 61300-2-42	0.05 N, 10 times	Attenuation change: Mechanical splice <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
NOTE – In Japan, fusion splice covers [ITU-T G.651.1], [ITU-T G.652] and [ITU-T G.653] and mechanical splice covers only [ITU-T G.652].				

Table II.3 – Environmental performance of fibre fusion or mechanical splice

Test	Test method	Condition	Performance
Change of temperature	IEC 61300-2-22	Temperature range: –40 ~ +70°C Duration: 10 cycles (60 hr)	Attenuation change: Mechanical splice <0.3 dB @1.31 ± 0.1, 1.55 ± 0.2 µm Fusion splice <0.2 dB @1.31 ± 0.1 µm
Dry heat	IEC 61300-2-18	Temperature: +70°C Duration: 240 hr	Attenuation change: Mechanical splice <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm Fusion splice <0.2 dB @1.31 ± 0.1 µm
Cold	IEC 61300-2-17	Temperature: –40°C Duration: 240 hr	Attenuation change: Mechanical splice <0.3 dB @1.31 ± 0.1, 1.55 ± 0.2 µm Fusion splice <0.2 dB @1.31 ± 0.1 µm
Cyclic damp heat (condensation)	IEC 61300-2-21	Temperature range: –10 ~ +25 ~ +65°C Humidity: 93% at 60 °C Duration: 10 cycles (240 hr)	Attenuation change: Mechanical splice <0.3 dB @1.31 ± 0.1, 1.55 ± 0.2 µm Fusion splice <0.2 dB @1.31 ± 0.1µm
Corrosive atmosphere	IEC 61300-2-26	Temperature: +35°C Salt content: 5% Duration: 24 hr	Attenuation change: Mechanical splice <0.2 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
Continual humidity – aging cycle		+85°C: 336 hr +60°C, 90% RH: 336 hr –40/23/75°C: 42 cycles (336 hr)	Attenuation change: Mechanical splice <0.3 dB @1.31 ± 0.1, 1.55 ± 0.2 µm
NOTE – In Japan, fusion splice covers [ITU-T G.651.1], [ITU-T G.652] and [ITU-T G.653] and mechanical splice covers only [ITU-T G.652].			

Bibliography

[b-ITU-T Handbook] ITU-T Handbook (1994), *Construction, installation, jointing and protection of optical fibre cables*, ITU-T, Geneva.

[b-ASTM D1218-99] ASTM D1218-99, *Standard Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids*.
<http://www.astm.org/DATABASE.CART/HISTORICAL/D1218-99.htm>

[b-ASTM D972-97] ASTM D972-97, *Standard Test Method for Evaporation Loss of Lubricating Greases and Oils*.
<http://www.astm.org/DATABASE.CART/HISTORICAL/D972-97.htm>

[b-Mellqvist] Mellqvist, J., Arlander, B., Galle, B., Bergqvist, B., (1996), *Measurements of industrial fugitive emissions by the FTIR tracer method (FTM) – FTM 791, Method 321.2*; FTM 791B, method 3005.
<http://www.fao.org/agris/search/display.do?f=./1996/v2217/SE9610988.xml;SE9610988>

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2009