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

Optical fibre joints

ITU-T Recommendation L.12

(Formerly CCITT Recommendation)

ITU-T Recommendation L.12

Optical fibre joints

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

ITU-T Recommendation L.12 was prepared by ITU-T Study Group 6 (1997-2000) and approved under the WTSC Resolution 1 procedure on 12 May 2000.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. 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 Conference (WTSC), 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 WTSC 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.

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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, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation L.12

Optical fibre joints

1 Scope

This Recommendation deals with the manufacture 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 characteristics of the splices and advises on suitable testing methods. Further information is provided in the CCITT Manual "Construction, installation, jointing and protection of optical fibre cables".

The fibres shall be in accordance with ITU-T Recommendations [1], [2], [3], [4] and [5].

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 published regularly.

[1] ITU-T G.651 (1998), *Characteristics of a 50/125 µm multimode graded index optical fibre cable.*

[2] ITU-T G.652 (2000), *Characteristics of a single-mode optical fibre cable.*

[3] ITU-T G.653 (2000), *Characteristics of a dispersion-shifted single-mode optical fibre cable.*

[4] ITU-T G.654 (2000), *Characteristics of a cut-off shifted single-mode optical fibre cable.*

[5] ITU-T G.655 (2000), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre cable.*

[6] IEC 61300 series, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures.*

[7] IEC 61073 series, *Mechanical splices and fusion splice protectors for optical fibres and cables.*

3 Types of splices: General description

3.1 Fusion splices

Different methods exist to obtain a fusion splice of fibres or ribbons. At the moment, 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 in which the reproducibility and simplicity of operation have been continuously improved over the last decade.

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.

3.2 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 has a different temperature dependence.

4 Splicing procedure steps

4.1 Fibres cleaning and ends 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 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.

4.2 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. 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 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 hot mechanical 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 sometimes are used with 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. For mechanical splices, holders may or may not be necessary during stripping and/or during cleaving.

4.3 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. Wiping more than two or three times shall be avoided.

4.4 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, specific devices exist that modify the cleaving tool in order to get an oblique fibre end faces with a consistent 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, low angle fibre ends. 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 keep from 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 disposed of carefully to prevent injury.

4.5 Splicing

4.5.1 Electric arc-fusion splicing

4.5.1.1 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.

4.5.1.2 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 provides 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.

The manufacturers shall provide the default settings for the splicing machine parameters (arc current, arc time, etc.) which are dependent on the type of fibre being spliced.

4.5.1.3 Proof-test

After the splice is completed, its minimum strength shall be checked. 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.

Proof-tests are usually not performed on mechanical splices.

4.5.1.4 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 5.

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 them.

The protector designs shall be suitable for either aerial, underground or buried applications and 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.

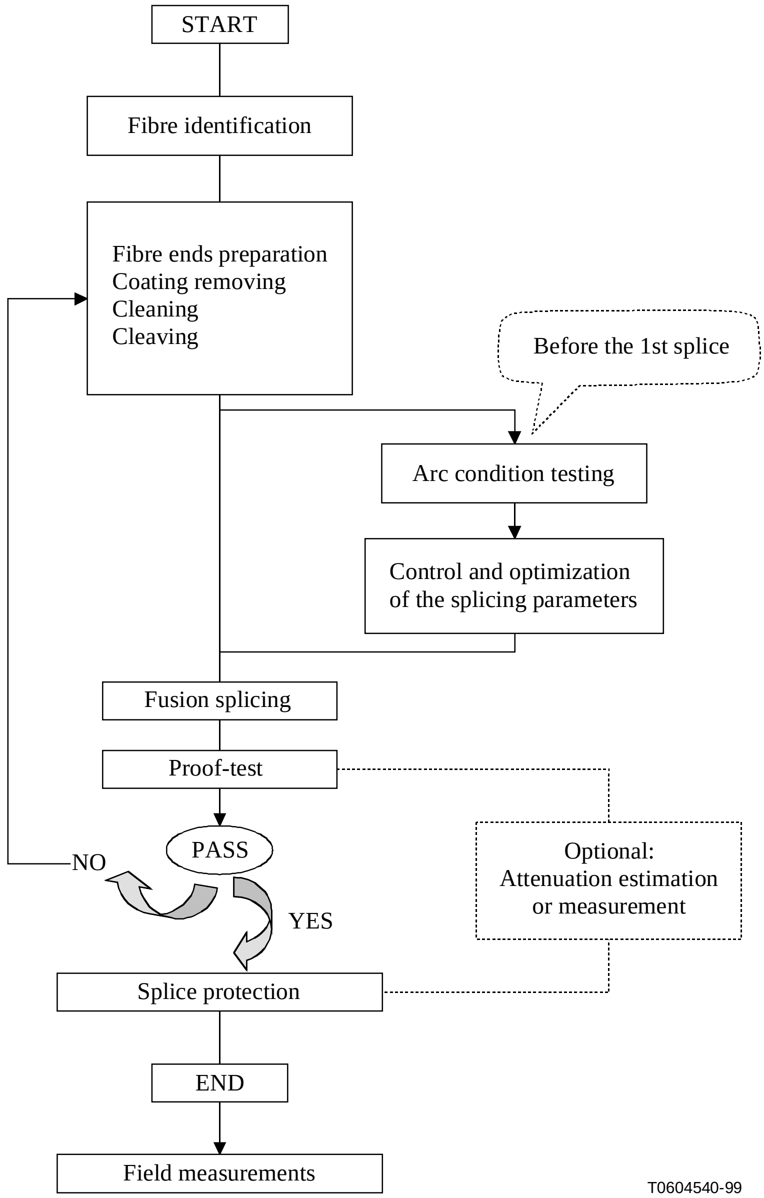

Figure 1/L.12 – Schematic representation of the fusion splicing procedure

4.5.2 Mechanical splicing

The mechanical method does not require the use of a special splicing machine. The installation tools are very simple and allow 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 4.1 to 4.4, 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.

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 5.

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

In Figure 2, a schematic representation of the mechanical splicing procedure is shown:

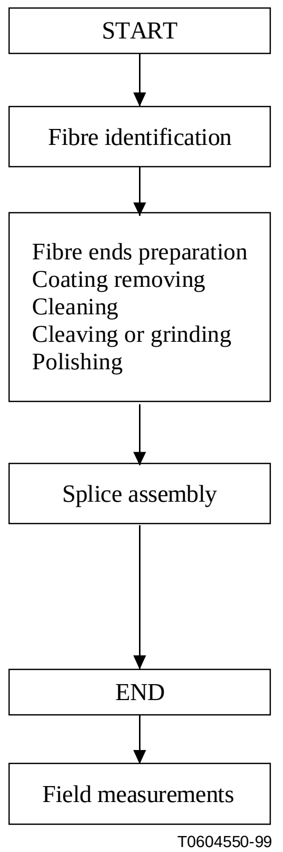

Figure 2/L.12 – Schematic representation of the mechanical splicing procedure

4.6 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 bi-directional OTDR if necessary.

The true splice loss is determined by the bi-directional 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. 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.

5 Functional properties of the splices

The aim of Tables 1 to 4 is to prescribe a number of tests with which the functional properties of the complete splice are verified and the long-term reliability is estimated. These tests are normally done in laboratories for qualification purposes and shall be carried out at standard conditions according to IEC definition [6]:

Temperature (°C)	18-28
Relative humidity (%)	25-75
Air pressure (KPa):	86-106

All the tests reported in the following clauses have to be performed according to IEC test methods [6], [7].

5.1 Optical performance

Table 1/L.12 – Optical performance of single-mode fibre splices

Test	Type of splice	Test method
Insertion loss	Single fibre fusion splice	IEC 61300-3-4; IEC 61073-1, Clause 4.4.4, Method 1 or 2.2
	Multiple fibre fusion splice	
	Single fibre mechanical splice	
	Multiple fibre mechanical splice	
Return loss	Single or multiple fibre mechanical splice	IEC 61300-3-6; IEC 61073-1, Clause 4.4.5, Method 1

Table 2/L.12 – Optical performance of multimode fibre splices

Test	Type of splice	Test method
For further study.		

5.2 Mechanical performance

Table 3/L.12 – Mechanical performance of single-mode and multimode fibre splices

Test	Type of splice	Test method
Fibre retention	Single or multiple fusion or mechanical splice	IEC 61300-2-4; IEC 61073 -1, Clause 4.5.2
Vibration (sinusoidal)	Single or multiple mechanical splice	IEC 61300-2-1; IEC 61073-1, Clause 4.5.1

5.3 Environmental performance

Table 4/L.12 – Environmental performance of single-mode and multimode fibre splices

Test	Type of splice	Test method
Change of temperature	Single or multiple fusion or mechanical splice	IEC 61300-2-22
Water immersion	Single or multiple fusion or mechanical splice	IEC 61300-2-45
Cold	Single or multiple fusion or mechanical splice	IEC 61300-2-17
Condensation	Single or multiple fusion or mechanical splice	IEC 61300-2-21
Damp heat	Single or multiple fusion or mechanical splice	IEC 61300-2-19
Corrosive atmosphere (salt mist)	Mechanical splices (single and multiple) only	IEC 61300-2-26

APPENDIX I

Index of refraction matching materials for mechanical optical fibre splices

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 fiber.

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 fiber splice joint.

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 microbubbles which introduce a hazy appearance ("evaporation", "appearance"). If the materials are not properly filtered, deaerated, and packaged they will contain entrained microscopic air bubbles, dust, fibers, 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 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/L.12 – Recommended specifications for index-matching greases in fiber splices

Property	Method	Requirement
Color	Visual	Water white, non-yellowing
Appearance	Visual	No bubbles, voids, or visible particles
Refractive index @ 25 °C, 589 nm	See Appendix IV [B1]	1.463 ± 0.003 (for silica fiber)
Evaporation, 24h @ 100 °C	See Appendix IV [B2]	0.2%, max
Oil separation, 24h @ 100 °C	See Appendix IV [B3]	0.2%, max
Particulate contamination	See Appendix IV [B4]	<300 particles/cc, 10 to 34 μm No particles above 35 μm

APPENDIX II

Italian experience on optical fibres splicing

Telecom Italia optical network involves several kilometres of optical cables (more than 60 000 kilometres) made of different type of fibres (ITU-T G.651 [1] and ITU-T G.653 [3]) and fibres organizations (single fibres and ribbons). That means Italian experience concerning optical fibre splicing technique (above all the fusion one) is very deep.

The goal of this appendix is to show the results collected during field installation of Dispersion Shifted and Reduced Single Mode fibres both single and ribbon splices and to list a number of tests suitable to check the performances of both mechanical and fusion splices.

Table II.1 reports the statistical behaviour of splices for three different types of fibre, whereas Figures II.1 to II.3 show the measured values as a bar graph. The number of the measured splices is not representative of the number of the installed splices in Italy.

Table II.1/L.12 – Mean values of attenuation calculated on installed splices

Parameter	SM	SM-DS	SM ribbons
Number of splices	1374	12 490	1680
Attenuation max (dB)	0.30	0.30	0.30
Attenuation mean (dB)	0.07	0.07	0.09
Standard deviation (dB)	0.11	0.04	0.08

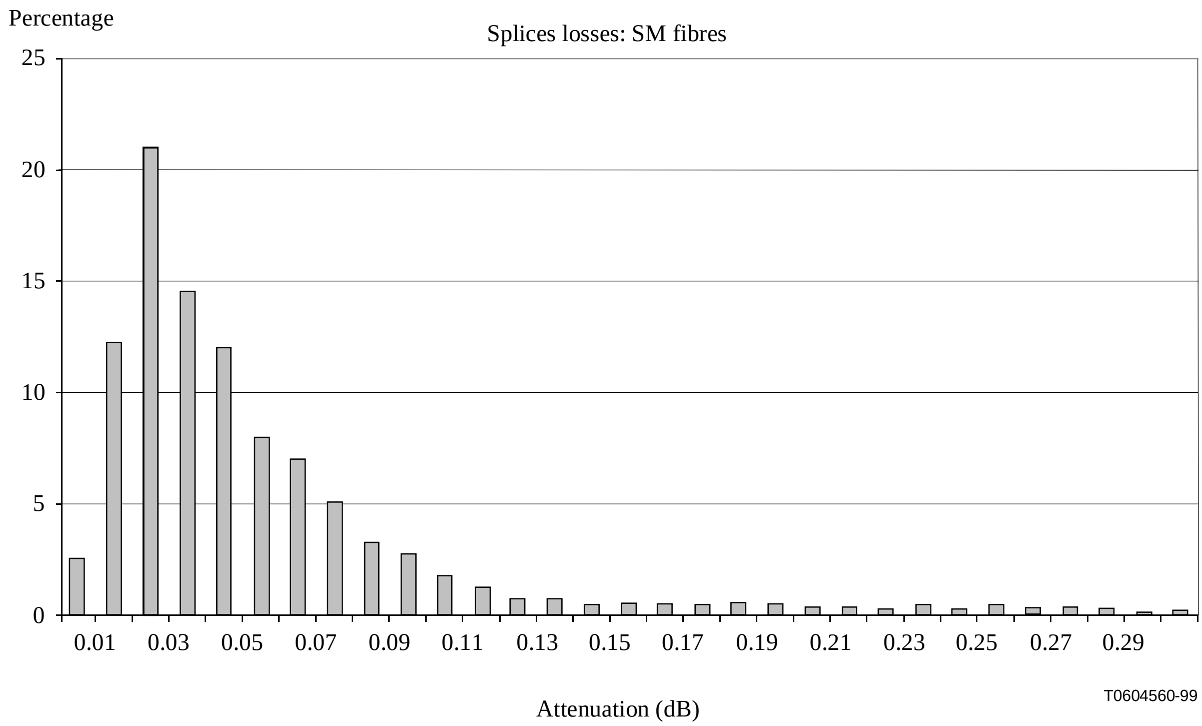

Figure II.1/L.12 – Bar graph of SM single splices attenuation distribution

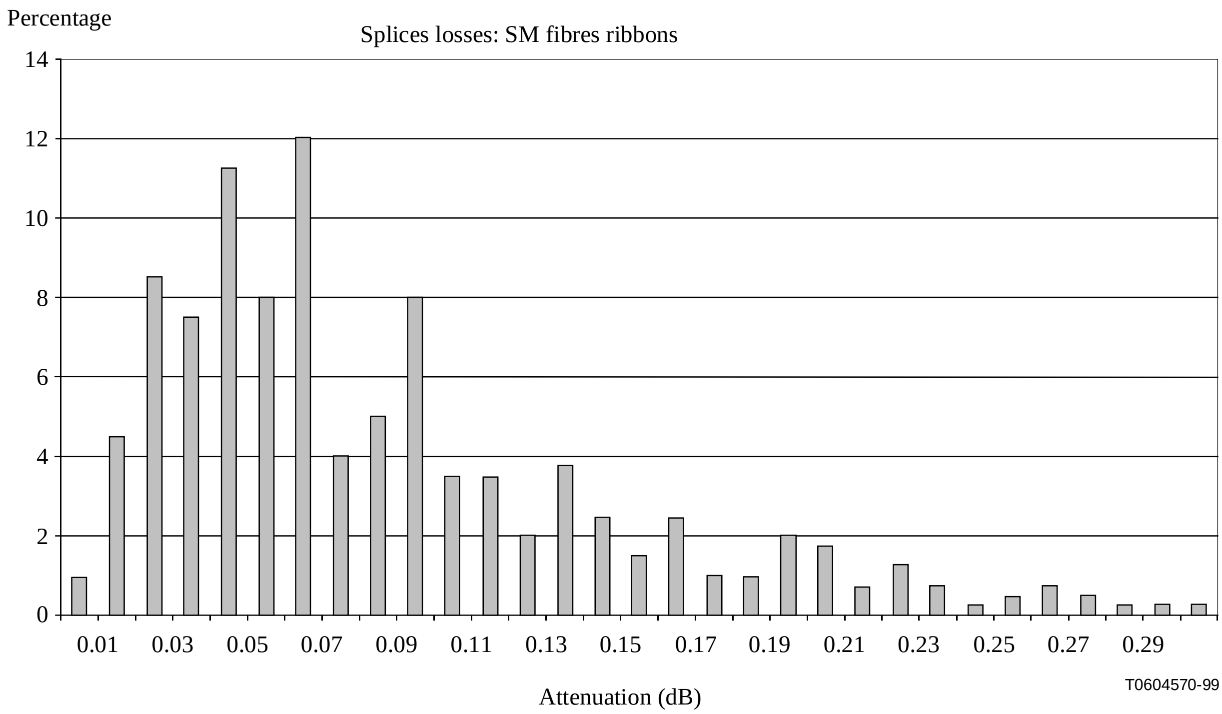

Figure II.2/L.12 – Bar graph of SM 4-fibre splices attenuation distribution

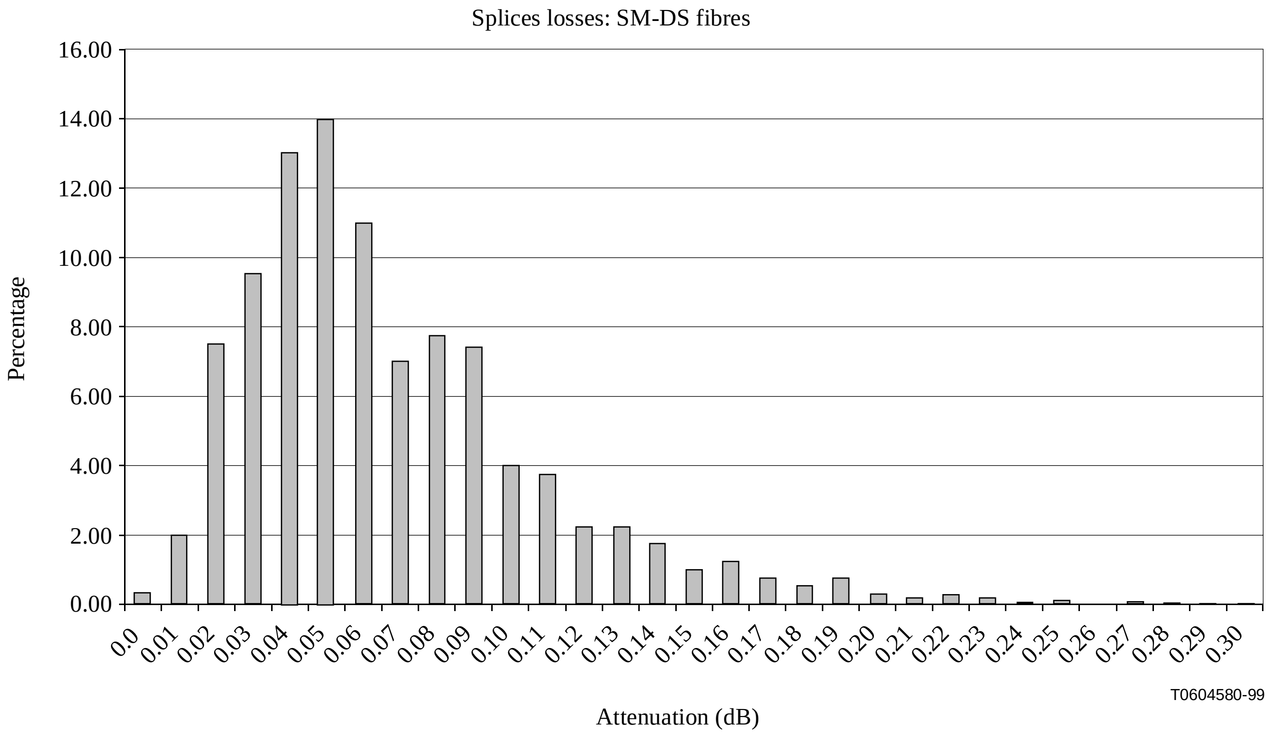

Figure II.3/L.12 – Bar graph of SM-DS single splices attenuation distribution

Kind of test suitable to check splice reliability

The aim of the following tests is to allow the functional properties of the complete splice to be verified. The optical fibres shall be in compliance with the International Standards, as well as all the instrumentation used and the splices shall be made following the previous procedure at standard conditions to IEC 61300-1 [6]. Some of those tests have been already reported in the main body of the Recommendation: here a description of the test and other possible tests that can be performed on both mechanical and fusion splices have been reported, according to the Italian experience.

Optical performances

Splice loss

The measurement of the splice loss shall be performed according to IEC 61073-1 [7], clause 4.4.4, method 1 or 2.2 (depending on the tested lengths), independently of the estimated splice loss provided by the splicing equipment, at least on 30 samples.

The splice loss requirement will depend on the application. The contribution of splices to the overall link loss shall be considered with the overall loss budgets and cable plant, which vary from, for example, trunking routes to access networks.

Individual operators may specify splice loss according to their specific needs, but the following values are recommended for single-mode fibres (see Table II.2).

Table II.2/L.12 – Recommended average splice losses for different applications

<table>
<tr><th></th><th>Average loss</th><th>Maximum value for 95%</th><th>Typical application</th></tr>
<tr><td rowspan="2">Single fusion
Splices</td><td>≤0.1 dB</td><td rowspan="2">≤0.5 dB</td><td>Trunking route</td></tr>
<tr><td>≤0.2 dB</td><td>Access network</td></tr>
</table>

Table II.2/L.12 – Recommended average splice losses for different applications (end)

	Average loss	Maximum value for 95%	Typical application
Multiple fusion splices	≤0.2 dB	≤0.8 dB	–
Single mechanical splices	≤0.2 dB	≤0.5 dB	Access network
Multiple mechanical splices	≤0.2 dB	≤0.8 dB	Access network

Return loss

This measurement shall be performed on mechanical splices only, in accordance with IEC 61073-1, clause 4.5.5, method 1 (launch fibre length between 2 and 3 m) or alternatively by using an OTDR in accordance with IEC 61300-3-6, method 2, at least on 30 samples.

The allowable return loss shall be ≥55 dB (grade V) and ≥35 dB (grade T).

Mechanical performances

In order to assess the mechanical performances of the splices, the following set of tests is recommended: visual inspection, tensile, bending, torsion and vibration test.

Visual inspection

Visual inspection shall be carried out in accordance with IEC 61073-1, clause 4.4.1, for fusion splices only and before the application of the protection device, at least on 10 samples.

The splices shall be examined for defects using magnifying glass giving a magnification of between 3 and 8 times. The fused region and the stripped fibre on each side of the fused region shall be fully enclosed within the splice protector. It shall grip the fibre coating at each end of the splice. The fibre shall emerge from the protector without any visible sign of bending or kinking.

The completed protector shall be free of debris and air voids.

The mechanical splices shall be properly packed: the package shall be marked with the name of manufacturer and the production date.

Tensile tests

The samples, e.g. the splice with fibre tails, will be gripped on 6 cm diameter steel capstans and then secured with a small clamp. The gauge length between capstans shall be 60 cm as shown in Figure II.4 (typically, from each side of the splice the available fibre length is 1 m).

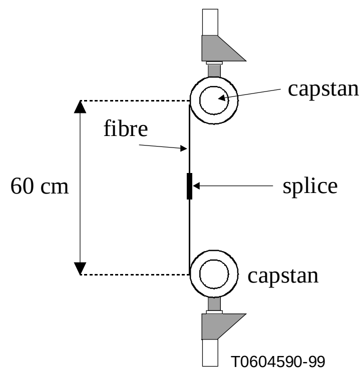

Figure II.4/L.12 – Schematic test set-up for tensile tests

Breaking load

At least 30 samples shall withstand a tensile test up to fracture. The tensile load shall be applied with a screw-driven universal tensile testing machine at a rate of 0.5 N/s in a test environment of 23° ± 2 °C, 50 ± 5% Relative Humidity (R.H.).

The average breaking load shall be ≥10 N and the minimum ≥5 N for protected fusion splices (single or multiple). It will be ≥6 N (average) and ≥3 N (minimum) for mechanical splices (single or multiple).

Fibre retention

Another set of at least 30 samples shall be loaded up to 5.0 ± 0.5 N at a rate of 0.5 N/s and the load maintained for 60 seconds, in accordance with IEC 61073-1, clause 4.5.2.

During the test (at least once while the load is at the maximum level) the samples shall be actively monitored at 1550 ± 30 nm (by using an optical source and a power meter connected at ends). The measured attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences (a difference is intended to be a change in the attenuation ≥0.05 dB) between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous paragraph ("Return loss").

Bending test

This test shall be performed on fusion splices only (multiple or single).

A two-point bending test shall be performed on 10 samples, with a load of at least 5 N at 5% of deformation rate, as shown in Figure II.5: the splices shall not break or permanently deform.

During the test the samples shall be actively monitored at 1550 ± 30 nm (by using an optical source and a power meter connected at ends) and the attenuation shall be within ±0.10 dB of the initial value. At the end of the test there shall be no differences between the initial and final attenuation.

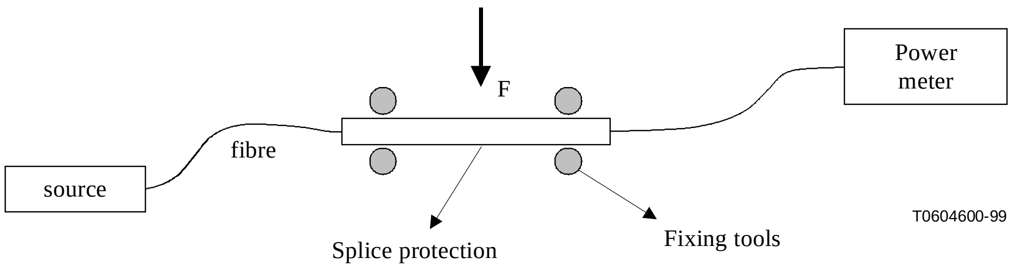

Figure II.5/L.12 – Schematic set-up for the bending test

Torsion test

This test shall be performed on fusion and mechanical single splices only.

At least 10 samples will be subjected to a torsion stress, according to IEC 61073-1, clause 4.5.31, applied at a distance of 30 cm from the splice. In the meantime, a tensile load of 2 N will be applied.

The number of complete (±180°) cycles shall be 50, with 5 seconds interval between each cycle.

During the test (at least once every time when the torsion angle is at the maximum value) the samples shall be actively monitored at 1550 ± 30 nm (by using an optical source and a power meter connected at ends). The measured attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Vibrations

At least 5 complete splices shall be placed in an organizer and shall be subjected to vibrations, according to IEC 61073-1, clause 4.5.1.

After an initial loss measurement, the samples will be subjected to sinusoidal vibration having amplitude of 0.75 mm. The frequency shall be varied uniformly in the range 10-55-10 Hz. The samples shall be tested in each of the three perpendicular planes for 15 cycles with endurance duration per axis of 0.5 hour.

During the test (the maximum sampling interval shall be 2 s) the samples shall be actively monitored at 1550 ± 30 nm (by using an optical source and a power meter connected at ends). The measured attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Environmental performances

In order to assess the environmental performances of the protectors of the fusion and mechanical splices, the following set of tests is recommended.

Installation conditions

The protectors shall be capable of being applied at the various temperature and humidity levels specified below. The tests shall be performed on at least 5 samples.

Five protectors shall be applied on the splices at the specified temperature/humidity levels. Prior to the application of the protectors, these have been conditioned for two hours at the same temperature and humidity levels. The protected splices shall meet the requirements of attenuation and mechanical strength reported in the previous paragraphs.

Low temperature

Conditioning at 0° ± 2 °C, uncontrolled humidity.

High temperature, low humidity

Conditioning at 45° ± 2 °C, 15 ± 5% relative humidity.

High temperature, high humidity

Conditioning at 45° ± 2 °C, 90 ± 5% relative humidity.

Life test criteria at different environmental conditions

The protected splices shall be subjected to the following ageing tests, to check their reliability, and they shall meet the requirements of attenuation and mechanical strength reported in the previous clauses.

The tests, described in the paragraphs below and according to the relevant IEC test methods, shall be performed on at least 5 samples.

Three categories of operational temperature range (see Table II.3) have been identified by IEC, among which each country can choose the severity of the tests to be performed on splice samples:

Table II.3/L.12 – IEC operating categories

Category	Operational temperature range (°C)	Humidity	Environment
E	–40/+85	Water immersion optional	Extreme
U	–25/+70	No limitations	Uncontrolled
C	–10/+60	RH <85%	Controlled

Change of temperature

The samples shall be exposed to 12 temperature cycles at the relevant humidity and temperature for the chosen category.

The temperature rate of change shall be 1 °C/min and 2 hours of stabilization time at each temperature.

During the test (at least once every time when the temperature reaches the extreme values) the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method, according to IEC 61300-3-4.

The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Water immersion

The samples shall be immersed in de-ionized water (pH = 5.5 ± 5), with head of water of 1.5 metres, for 30 days at a temperature of 43 °C ± 2 °C.

During the test the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method (IEC 61300-3-4).

The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Damp heat

The samples shall be exposed for 96 hours at 40 ± 2 °C, 93 ± 2% R.H. (IEC 61300-2-19).

During the test the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method (IEC 61300-3-4). The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Cold

The samples shall be exposed for 96 hours at the relevant temperature for the chosen category.

During the test the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method (IEC 61300-3-4). The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Cyclic damp heat

The samples shall be exposed to 10 temperature cycles in the temperature range of the chosen category at the relative humidity of 93 ± 3%. This test is not applicable to category C environment.

During the test the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method (IEC 61300-3-4). The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

Corrosive atmosphere

This test refers to category U only.

The samples shall be exposed to corrosive atmosphere in accordance with IEC 61300-2-26 (prEN 61300-2-26). During the test the attenuation shall be monitored at 1550 nm with an optical source and a power meter connected at the ends. Before the test and 2 hours after the end of the test, the attenuation shall be measured at 1550 nm with the "cut-back" method (IEC 61300-3-4). The attenuation shall be within ±0.10 dB of the initial value for fusion splices and ±0.20 dB for mechanical splices. At the end of the test there shall be no differences between the initial and final attenuation.

For mechanical splices, an additional measurement of the return loss shall be performed, during and on completion of the test at 1550 ± 30 nm, and the measured value shall be above the value requested in the previous clause ("Return loss").

APPENDIX III

Japanese experience on optical fibres splicing

See Tables III.1 to III.3.

Table III.1/L.12 – 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; IEC 61073-1 Clause 4.4.4 Method 1 or 2.2		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
Insertion loss	Single fibre mechanical splice (access)	IEC 61300-3-4; IEC 61073-1 Clause 4.4.4 Method 1 or 2.2 (IEC 874-1 Clause 4.4.7)		Attenuation: Mechanical splice SM: 90% = 0.4 dB 100% = 0.5 dB MT connector SM: 100% = 0.6 dB
Insertion loss	Multiple fibre mechanical splice (access)	IEC 61300-3-4; IEC 61073-1 Clause 4.4.4 Method 1 or 2.2 (IEC 874-1 Clause 4.4.7)		Attenuation: Mechanical splice SM: 90% = 0.4 dB 100% = 0.5 dB MT connector SM: 100% = 0.7 dB
Return loss	Single or multiple fibre mechanical splices	IEC 61300-3-6; IEC 61073-1 Clause 4.4.5 Method 1, 2		Return loss: Mechanical splice SM: > 40 dB MT connector SM: > 40 dB
NOTE 1 – In Japan, fusion splice covers ITU-T G.651, ITU-T G.652 and ITU-T G.653 and mechanical splice covers only ITU-T G.652. NOTE 2 – The former IEC numbers are given in parenthesis.				

Table III.2/L.12 – 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; IEC 61073-1 Clause 4.5.2	Load: Single: <8.9 N Multiple: <21.6 N	Not break
Fibre retention	Single or multiple fibre mechanical splices	IEC 61300-2-4; IEC 61073-1 Clause 4.5.2 (IEC 874-1 Clause 4.5.2)	Load: Mechanical splice Single: 3 N Multiple: 8.5 N MT connector 5.9 N	Attenuation change: Mechanical splice Single: <0.2 dB Multiple: <0.2 dB MT connector <0.2 dB

Table III.2/L.12 – Mechanical performance of fibre splice (end)

Test	Type of splice	Test method	Condition	Performance
Vibration (sinusoidal)	Single or multiple fibre mechanical splices	IEC 61300-2-1 IEC 61073-1 Clause 4.5.1 (IEC 874-1 Clause 4.5.1)	Amplitude: 0.75 mm Frequency: 10-55 Hz Duration: 24 cycles (2 hr.) Direction: 3	Attenuation change: Mechanical splice <0.2 dB MT connector <0.2 dB
NOTE 1 – In Japan, fusion splice covers ITU-T G.651, ITU-T G.652 and ITU-T G.653 and mechanical splice covers only ITU-T G.652. NOTE 2 – The former IEC numbers are given in parenthesis.				

Table III.3/L.12 – Environmental performance of fibre fusion or mechanical splice

Test	Test method	Condition	Performance
Change of temperature	IEC 61300-2-22 (IEC 874-1 Clause 4.5.22)	Temperature range: –40 ~ +70 °C Duration: 10 cycles (60 hr.)	Attenuation change: Mechanical splice <0.3 dB Fusion splice <0.2 dB MT connector <0.3 dB
Dry heat	IEC 61300-2-18 (IEC 874-1 Clause 4.5.18)	Temperature: +70 °C Duration: 240 hr.	Attenuation change: Mechanical splice <0.2 dB Fusion splice <0.2 dB MT connector <0.2 dB
Cold	IEC 61300-2-17 (IEC 874-1 Clause 4.5.17)	Temperature: –40 °C Duration: 240 hr.	Attenuation change: Mechanical splice <0.3 dB Fusion splice <0.2 dB MT connector <0.3 dB
Cyclic damp heat (condensation)	IEC 61300-2-21 (IEC 874-1 Clause 4.5.21)	Temperature range: –10 ~ +25 ~ +65 °C Humidity: 93% at 60 °C Duration: 10 cycles (240 hr.)	Attenuation change: Mechanical splice <0.3 dB Fusion splice <0.2 dB MT connector <0.3 dB
Corrosive atmosphere	IEC 61300-2-26 (IEC 874-1 Clause 4.5.26)	Temperature: +35 °C Salt content: 5% Duration: 24 hr.	Attenuation change: Mechanical splice <0.2 dB MT connector <0.2 dB
NOTE 1 – In Japan, fusion splice covers ITU-T G.651, ITU-T G.652 and ITU-T G.653 and mechanical splice covers only ITU-T G.652. NOTE 2 – The former IEC numbers are given in parenthesis.			

APPENDIX IV

Bibliography

[B1] ASTM D1218-99, *Standard Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids.*

[B2] ASTM D972-97, *Standard Test Method for Evaporation Loss of Lubricating Greases and Oils.*

[B3] *Measurement of industrial fugitive emissions by the FTIR Tracer Method (FTM)* – FTM 791, Method 321.2.

[B4] *Measurement of industrial fugitive emissions by the FTIR Tracer Method (FTM)* – FTM 791B, Method 3005.

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