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

Splice closure for marinized terrestrial cables (MTC)

ITU-T Recommendation L.54

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Summary

This Recommendation refers to both the design and the main characteristics that an underwater splice closure for MTC should have in order to be suitable for this application, as well as to guarantee the expected lifetime of the whole transmission link.

This Recommendation provides the tests for characterization and evaluation of the underwater splice closures performance, including mechanical integrity and optical stability of the product simulating the effect of the environment (water), as well as interventions related to installation and network maintenance.

Source

ITU-T Recommendation L.54 was approved on 6 February 2004 by ITU-T Study Group 6 (2001-2004) under the ITU-T Recommendation A.8 procedure.

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 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.

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Splice closure for marinized terrestrial cables (MTC)

1 Introduction

An important part of any installed underwater optical cable system is the jointing between different cable spans.

In fact, it is very important that a splice closure utilized for an underwater (i.e., MTC) optical cable system is manufactured in order to guarantee not only a good quality of transmission during the expected lifetime, but also cost savings for maintenance purposes.

A splice closure comprises a mechanical structure (closure housing) that is attached to the ends of two or more underwater cables, and a set of boxes (organizers) for containing and protecting the fibres and passive optical devices (if any).

As a general rule, the closure housing and the armour terminations, generally designed for a whole MTC family, should be dimensioned for the strongest cable designed for that particular link (maximum tensile strength and maximum pressure resistance).

Splice closures for MTC applications may contain fibre splices, mass splices and passive devices.

Moreover, since such closures are typically mounted on the cable before it is installed, it should also be designed to withstand all handling and loads that occur during cable installation.

2 Scope

This Recommendation details:

- the mechanical and environmental characteristics of splice closures for MTC applications;
- the main optical performances that such closures have to guarantee during their lifetimes.

3 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 Recommendation G.972 (2000), *Definition of terms relevant to optical fibre submarine cable systems*.

– ITU-T Recommendation G.976 (2000), *Test methods applicable to optical fibre submarine cable systems*.

– ITU-T Recommendation L.12 (2000), *Optical fibre joints*.

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

– IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Vibration (sinusoidal)*.

– IEC 60794-1-2:2003, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures (Methods:E1, E6, E7, E18A, F1, F10)*.

– IEC 60794-3-30:2002, *Optical fibre cables – Part 3-30: Outdoor cables – Family specification for optical telecommunication cables for lake and river crossings*.

– IEC 61300-2-22:1995, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-22: Tests – Change of temperature*.

– IEC 61300-2-26:1995, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-26: Tests – Salt mist*.

– IEC 61300-3-3:2003, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-3: Examinations and measurements – Active monitoring of changes in attenuation and return loss (multiple paths)*.

4 Abbreviations and definitions

– **MTC** Marinized Terrestrial Cable (see definition in ITU-T Rec. G.972).

– **NOTS** Nominal Operating Tensile Strength (see definition in Appendix I/G.976). NOTS represents the maximum average operational tension during installation, recovery or repair.

– **NTTS** Nominal Transient Tensile Strength (see definition in Appendix I/G.976). NTTS represents the maximum transient or unexpected load that may be applied to the cable, and is normally limited to a percentage of the CBL (Cable Breaking Load) from a mechanical safety point of view.

– **NPTS** Nominal Permanent Tensile Strength (see definition in Appendix I/G.976). NPTS represents the maximum residual load, which may be permanently applied to the cable on the seabed after installation.

– **OTDR** Optical Time Domain Reflectometer.

5 Main characteristics

Hereinafter, a list of the main characteristics (optical, mechanical and environmental) for a splice closure for MTC applications is given.

Even though such a list cannot be considered exhaustive due to particular environments and applications, it is intended to give the basic and essential guidance for a suitable characterization of the splice closure.

Additional requirements can be agreed upon between Customer(s) and Manufacturer(s) to reflect local or special conditions.

Moreover, test methods already standardized are also given where applicable.

A splice closure for MTC applications is designed:

- To restore the integrity of sheath, including mechanical continuity of strength members of MTC;
- To protect the fibres, fibre splices and optical devices, from the external environment (water) and unwanted handling;
- To provide proper storage of fibre splices, passive devices (if any) and excess of fibres;
- To resist corrosion;
- To prevent hydrogen effects;
- To allow re-intervention on cables and splices;
- To provide for electrical continuity, if required.

Basic components of the splice closure are:

- Jointing box with cable core holder and optical organizer;
- Corrosion-resistant jointing box housing (e.g., stainless steel);
- Suitable jointing box covering with high grade protection and insulation;
- Appropriate bend restrictor;
- Metallic sacrificial elements (optional).

The splice closure shall be watertight in order to avoid fibres being exposed to water both during the operating lifetime, and during and after maintenance operations. Moreover, it shall be equipped to avoid the effect on fibres from hydrogen released by cable armouring.

In case metallic sacrificial elements are present, much care should be taken in order to prevent induced loss on optical fibres from hydrogen evolution.

The problem of hydrogen evolution is one that can lead to attenuation increases. It is normally solved by different engineering approaches, that shall be documented by the manufacturer.

The splice/storage trays shall meet minimum bending diameter of fibres.

NOTE – Information about the design of the closure housing and the organizer system, as well as the splicing of fibres can be found in ITU-T Recs L.13 and L.12, respectively. Splices should have an average loss less than 0.5 dB. The optical attenuation due to ageing should be less than 0.2 dB. The optical attenuation due to fibre coiling should be not more than 0.2 dB over the entire joint. Fibre bend radius should be greater than 25 mm and, where possible, greater than 30 mm.

Other information on fibre handling and fibre identification for splicing at cable joints can be found in ITU-T Manual "Construction, installation, jointing and protection of optical fibre cables".

Finally, examples of closures available on the market, patented by the most important world constructors can be found in Appendix I.

6 Qualification tests

The purpose of qualification tests is to verify the integrity of the splice closure during storage, transport, installation and service. The splice closure for MTC shall be qualified for use up to the maximum water depth of the link.

Qualification tests are carried out as part of the development program so as to choose proper design and technology, to demonstrate that they adequately satisfy the performances, reliability and lifetime expectation of the system.

Tests carried out by the manufacturer can be considered adequate and therefore taken into consideration. An evaluation test program shall be agreed between Manufacturer and Customer.

Depending on a particular application and upon agreement between Customer and Manufacturer, the test qualification program may be limited to some of the tests hereunder listed.

For each test description, where applicable, the reference to the corresponding international standard is also reported.

NOTE 1 – The tests described in this Recommendation shall assess functionalities and performances of the splice closures. Moreover, in order to guarantee the operating lifetime of splice closures, long-term ageing tests and failure effects, on materials and accessories of closures, could be necessary.

NOTE 2 – The parameters specified in this Recommendation may be affected by measurement uncertainty arising either from measurement errors, or calibration errors due to a lack of suitable standards. Acceptance criteria shall be interpreted with respect to this consideration. The total uncertainty of measurement for this Recommendation shall be less than or equal to 0.05 dB for attenuation. The expression of "no change in attenuation" means that any change in measurement value, either positive or negative, within the uncertainty of measurement shall be ignored.

7 Sample preparation

The splice closure shall be connected between two specimen cables used in the link in accordance with assembly and disassembly procedures given by the manufacturer.

Depending on specific tests, different cable lengths (specimen) may be connected to the splice closure.

Moreover, depending on the topology and criticality of the link, a different number of samples can be accordingly defined between the Customer(s) and the Manufacturer(s).

8 Reference measurements

Prior to the tests, optical attenuation, electrical continuity of the metallic sheath and the insulation resistance between metallic tube and steel armour wires shall be measured for reference.

The optical fibres may be spliced in loop(s) in order to achieve the desired accuracy in attenuation measurement.

Optical attenuation measurements shall be performed at the wavelength of 1550 nm. Evaluation at 1625 nm is under consideration.

The evaluation of optical attenuation of fibres and splices shall be performed either with the transmitter power technique or with the backscattering technique as described in IEC 61300-3-3, Part 3-3.

The electrical insulation resistance shall be performed at 500 V DC. The detected value should be approximately equal to the insulation resistance of the cable as stated in its type-approval certificate.

Moreover, the electrical continuity measurement of the metallic sheath should give a resistance value across the closure of around 0.2 Ohm.

9 Tests

The tests should be done in the following sequences, unless otherwise agreed between the Customer and the Manufacturer.

The expression of "no significant change in attenuation" means that any change in measurement value, either positive or negative, within the uncertainty of measurement shall be ignored.

Sample 1, 2, 3 and 4

Sample	First test	Second test	Third test	Fourth test
Sample 1	Temperature cycling	Tensile with twist restrained	none	none
Sample 2	Temperature cycling	Tensile with torque minimized	Repeated bending NOTE – For practical reasons shorter pieces of cables can be used.	Bumps
Sample 3	Temperature cycling	Bending under tension NOTE – Shorter (about 50 m) pieces of cables can be jointed to the closure.	Hydraulic pressure resistance	Vibration
Sample 4	Corrosion resistance	none	none	none

9.1 Temperature cycling

Objectives

- To prove that the optical characteristics of the closure are not modified by storage, transportation and service temperature ranges;
- To determine any specific storage or transportation requirements to ensure the above.

International standard	7.2.1.3/G.976; IEC 60794-1-2, Method F1; IEC 61300-2-22.
Sample preparation	The splice closure shall be connected between two samples of cable used in the link of approximately 100 m long, in accordance with assembly and disassembly procedures given by the manufacturer. The fibres of the two cable-free ends shall be spliced in loop(s) for connection to measurement apparatus.
Test conditions	*Temperature cycle*: 1 cycle of 24 hours (6 hours at each temperature step) at +20° C, –20° C, +50° C, +20° C.
Test description	The samples shall be placed in a climatic chamber as a loose coil and cycled as reported in test conditions. The free cable ends shall be placed out of the climatic chamber and the fibres connected to the measurement apparatus. NOTE – Test monitoring at the end of each temperature step should be performed when the sample has reached a stable temperature.
Test monitoring	OTDR measurements shall be carried out before and after the test and at the end of each temperature step.
Requirements	– At the end of each temperature step, the change in attenuation shall be less than 0.1 dB/splice; – After the tests, there is no significant change in attenuation of splices.

9.2 Tensile with twist restrained

Objectives

- To prove that the closure can withstand the maximum expected tensile load that can be applied on a cable during the laying, service and recovery, with a known degree of safety;
- To prove that the closure can withstand mechanical twisting applied either during load or after unload;
- To determine whether the performance of the closure under load would permit its reuse after intervention and/or recovery operation.

International standard	7.2.2.1/G.976; IEC 60794-1-2 Method E1.
Sample preparation	As described in 9.1. Moreover, each end of the sample is terminated with an anchoring device. The anchoring devices shall be such as to permit access to both ends of the cable specimens for optical testing.
Test conditions	– Temperature: ambient; – Load: = NTTS. NOTE – For closure connected to armoured cables, the load shall be = 80% of the strength of the outer armour layer of cable; – Time: 1 cycle of 1 hour at NTTS plus 1 of short time.

Test description	One anchoring device of the sample is fixed to a rotating cable clamp, the other anchoring device is fixed to a fixed cable clamp. The rotating cable clamp is connected to a suitable turning equipment (e.g., a torquing lever, for detecting the applied torques). Both ends of the sample are not twisted during the tensile test. The sample is pulled, increasing the load up to NTTS and maintained for 1 hour; then the load is decreased to a minimum value and again is pulled up to NTTS, maintained for short time and then completely released.
Test monitoring	The optical attenuation of fibres and splices shall be continuously monitored throughout the test. Cable elongation, tensile load and torque of the cable ends are continuously measured during the test.
Requirements	– During the test: the change in attenuation shall be less than 0.1 dB/splice. – After the test, there should be no significant change in attenuation; nor closure break.

9.3 Tensile with torque minimized

Objectives

- To prove that the closure (and cable terminations) can withstand the maximum expected tensile load that can be applied on a cable during laying, service and recovery, with a known degree of safety;
- To prove that the optical fibres inside the cable specimens and inside the closure, are not subjected to excessive strain either during loading or after unloading.

International standard	7.2.2.2/G.976; IEC 60794-1-2 Method E7.
Sample preparation	As described in 9.2.
Test conditions	– Temperature: ambient; – Load: = NOTS; – Time: 1 cycle of 1 hour plus 1 short.
Test description	The testing method of sample n.1 is repeated but the torque is minimized. The sample is pulled twice increasing the load up to NOTS, maintained for 1 hour and then completely released. For the short cycle test, see the previous test description.
Test monitoring	The optical attenuation of fibres and splices shall be continuously monitored throughout the test. The elongation of the cable shall be continuously measured during the test.
Requirements	– During the test: the change in attenuation shall be less than 0.1 dB/splice; – After the test, there should be no significant change in attenuation; nor closure break.

9.4 Bending under tension (sheave passage)

Objective

To prove that the closure can withstand the bending forces applied during its installation or recovery without degradation.

International standard	7.2.2.5/G.976; IEC 60794-1-2, Method E18.
Test conditions	– Temperature: ambient; – Load: = NOTS and NTTS; – Time: 10 cycles at NOTS plus 3 at NTTS;
Test description	One end of the sample is fixed to a hydraulic cylinder, the other end is fixed to a clamp. Then, under a constant load equal to NOTS, the sample is passed around a 3 m diameter sheave, with a speed of about 0.3 knots (approximately 9.24 m/minute), in a clockwise and anti-clockwise direction 10 times and again three times with a load equal to NTTS. The terminations are not allowed to rotate. If different cable types are used at each end of the closure, the lower NOTS value shall be selected.
Test monitoring	– Continuously monitoring the attenuation of the optical link; – Splice attenuation measurements shall be carried out before the test (as reference) and about 20 minutes after the test.
Requirements	– During the test: the change in attenuation shall be less than 0.1 dB/splice. – After the test, there should be no significant change in attenuation; nor closure break.

9.5 Repeated bending (optional)

Objective

To prove that the closure can withstand repeated bending (bend fatigue) that can be applied near the cable terminations during the handling (from factory-to-ship, tank-to-tank, etc.), without degradation.

International standard	7.2.3.3/G.976; IEC 60794-1-2 (E6).
Test conditions	– Temperature: ambient; – Duration: 100 cycles of approximately 5 seconds duration.
Test description	The upper cable shall be fastened to a pivot arm; the lower cable is loaded with a weight sufficient to keep the cable straight. With the pivot arm vertical, the cable termination to the closure shall be at the centre height of the sheave of typically 1 m diameter. The sample is alternately bent, for example by means of an airdriven pendulum, between two test fixtures representing at least a quadrant of such a sheave.
Test monitoring	OTDR measurements shall be carried out before (reference measurements), during and after the test.

Requirements
- During the test: the change in attenuation shall be less than 0.1 dB/splice.
- After the test, there should be no significant change in attenuation; nor closure break.

9.6 Hydraulic pressure resistance

Objectives

- To prove that the closure is waterproof and can withstand the maximum water pressure;
- To prove that the electrical insulation resistance is maintained.

International standard: 7.2.1.4/G.976; IEC 60794-1-2 Method F10 (under consideration).

Sample preparation: All ports of splice closure shall be terminated with cable samples; the other ends of such cables shall appropriately be sealed. For practical reasons, the cable armour wires are removed from the sample.

Test conditions
- Time: more than 24 h;
- Pressure: The pressure on the sample (pressure inside the chamber containing water) is increased to a level simulating the maximum water depth for the installation.

Test description: The sample shall be externally pressurized with water. The pressure shall be gradually raised to the maximum foreseen value and kept stable before the pressure is relieved. The rate of pressure builds up and relief should be approximately 15 bar/minute typically (simulating the normal laying speed).

Test monitoring: Splice attenuation and insulation resistance (optional) should be monitored during the test period;

Requirements
- During the test: the change in attenuation shall be less than 0.1 dB/splice; the electrical insulation resistance shall be more than 20 MΩ (optional).
- After the test, there should be no change in attenuation; nor evidence of creep or deformation of closure; nor water ingress in the sample; nor closure collapse.

9.7 Bumps

Objective

To prove that the joint closure can withstand mechanical shocks (bumps or impacts) that may occur during laying and/or recovery operations, without sustaining either physical damage or residual attenuation increases.

International standard: Not Available

Sample preparation: See 9.6.

Test conditions
- Temperature: ambient;
- Acceleration of 20 g;

  NOTE 1 – A lower value can be chosen among agreement between the Customer and Manufacturer.
- Number of Bumps: 100 along each principal axis.

Test description	The sample is inserted in a machine bumping the closure at the required acceleration. The closure is stressed 100 times along each of the principal axes with an acceleration of 20 g (see Note 1) and for a time of 6 ms (each bump).
Test monitoring	Optical attenuation of fibre splices is continuously monitored during the test. NOTE 2 – Due to possible oscillations transferred from the sample to the patch cords linking the test apparatus, it is possible that high optical attenuation can be detected during the test.
Requirement	After the test: no significant change in attenuation shall be detected; no physical damage (cracks or fissures) should be observed on the closure.

9.8 Vibration

Objective

To demonstrate that the closure is able to withstand vibrations caused during loading, transport and laying (recovery) operations.

International standard	IEC 61300-2-1; IEC 60068-2-6
Sample preparation	See 9.6. Both the free ends of cables shall be sealed.
Test conditions	– Sweep range: from 10 to 100 Hz; sweep rate 0.5 octave/min; – Acceleration: 5 g; – Number of cycles: 5 sweeps per each axis; – Direction: 3 mutually perpendicular axes.
Test description	The sample for each one of its axes is vibrated for 8 hours at frequencies varying between 10 and 100 Hz, with an acceleration of 5 g. NOTE – A lower value of test duration can be agreed between the Customer and Manufacturer.
Test monitoring	Optical attenuation of fibre splices are continuously monitored.
Requirements	– During the test: the change in attenuation shall be less than 0.1 dB/splice. – After the test, no significant change in attenuation nor any physical degradation should be observed.

9.9 Corrosion resistance (optional)

Objectives

- To prove that the closure can withstand long-term exposure to sea water;
- To prove that any corrosion present will not impair the mechanical, optical and electrical function of the closure.

International standard	7.2.4.2/G.976; IEC 61300-2-26.
Sample preparation	The closure is terminated to both ends with about 10 m of underwater cables having the other ends sealed.

Test conditions	– Sea water or artificial sea water (i.e., salt content of 5% NaCl in water); – Pressure: 0 kPa; – Temperature: 50° C (typically); – Time: 5 days.
Test description	The submersible plant (closure and cable) is immersed in water having characteristics similar to those that the closure will be operating under (as reported in test conditions). The plant is then inspected to determine the degree of corrosion and, if applicable, the build-up of hydrogen gas. A provision must be made for suitably sealing the cable ends prior to the test. If artificial sea water is used, its specification is to be stated.
Requirement	After the test: no evidence of variation in mechanical, optical and electrical function should be observed.

Appendix I

Examples of different closure designs available on the market

This appendix can be filled and updated in the future by adding information coming from closure designs available on the market.

SERIES OF ITU-T RECOMMENDATIONS

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