Superseded by a more recent version

INTERNATIONAL TELECOMMUNICATION UNION

CCITT

L.12

(07/92)

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLE AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE JOINTS

Recommendation L.12

Superseded by a more recent version

Geneva, 1992

Superseded by a more recent version

FOREWORD

The CCITT (the International Telegraph and Telephone Consultative Committee) is a permanent organ of the International Telecommunication Union (ITU). CCITT 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 Plenary Assembly of CCITT which meets every four years, establishes the topics for study and approves Recommendations prepared by its Study Groups. The approval of Recommendations by the members of CCITT between Plenary Assemblies is covered by the procedure laid down in CCITT Resolution No. 2 (Melbourne, 1988).

Recommendation L.12 was prepared by Study Group VI and was approved under the Resolution No. 2 procedure on the 31st of July 1992.

____

CCITT NOTE

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

Recommendation L.12

OPTICAL FIBRE JOINTS[1), 2)]

Introduction

Optical fibre cables have become common in telecommunications for trunk, undersea and feeder routes and are now expanding into the subscriber and indoor sections of the network. They are installed in all environments: aerial, duct, cable tunnels, direct buried and on-premises. Thus, optical fibre cables are exposed to all of the hazards that copper cables are. An important part of any installed optical fibre cable system is the fibre joint, which can have a great influence on the transmission quality and maintenance costs. The loss of a joint can equal the insertion loss of as much as one half to one kilometre of fibre.

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

1 Scope

This Recommendation:

- refers to the jointing of optical fibre cables that are used for telecommunications networks, in duct, tunnel, buried, aerial, and underwater[1)] installations;
- deals with loss factors of optical fibre joints in multimode graded index and single-mode fibres;
- deals with optical and physical characteristics of optical fibre joints concerned;
- acknowledges there are two basic types of optical fibre joints (fusion and mechanical) with numerous design variations;
- advises on appropriate test methods for optical fibre joints.

2 Characteristics of optical fibre joints

2.1 *Optical loss characteristics*

2.1.1 *General*

Joint losses can be divided into two basic categories: extrinsic and intrinsic to the fibres for both multimode graded-index and single-mode fibres. Extrinsic losses are related to the techniques used to joint fibres and are caused by parameters such as transverse offset between the fibre cores, and separation, axial tilt and fibre end quality. Intrinsic losses are related to the properties of fibres and caused by mismatches in fibre core and cladding diameters, circularity and concentricity of fibre mode field diameters, differences in the cutoff-wavelengths of single-mode fibres, and differences in the numerical aperture of multimode fibres.

---

1) This Recommendation does not cover joints in undersea cables.

2) This Recommendation uses the term "fibre joint" which is the same as the term "fibre splice" used in IEC documentation.

2.1.2 *Multimode fibres*

Extrinsic loss factors: multimode fibre joints are more sensitive to small transverse offsets and angular tilt than to end separation. For example, an offset of 0.14 core radius or a 1° tilt will cause ≈0.25 dB loss, while a one core radius end separation only causes ≈0.14 dB loss.

Intrinsic loss factors: multimode graded-index fibre joints are most sensitive to mismatches in core radius and NA and less sensitive to mismatches in profile parameters, and core circularity and concentricity.

2.1.3 *Single-mode fibres*

In single-mode fibres the mode-field diameter is the diameter of the radiated light and equates to the core diameter of graded-index fibres (for an exact definition, see Recommendation G.652). Single-mode fibre joints are even more sensitive on an absolute scale than multimode fibre joints to mode-field diameter. This is due to the much smaller dimensions of the mode field diameter. For example, a transverse offset of 1.2 μm will produce a joint loss of ≈0.3 dB for fibres conforming to Recommendation G.652 with a mode field diameter of 8 to 10 μm. Sources of transverse offset in single-mode fibres are differences in fibre diameters and core eccentricities. The angular sensitivity of single-mode fibres is about the same as that of multimode fibres for small angles. Single-mode joint loss is less sensitive to small (≤ 10%) mismatches in mode-field diameter.

2.2 *Physical characteristics of optical-fibre joints*

2.2.1 *Methods*

Two basic methods for making an optical-fibre joint are:

1) *fusion welding* – jointing of pre-aligned fibres by a melting process. The welding apparatus may control the core alignment or the cladding alignment. The best joint loss of single-mode fibres is achieved with core alignment. Mechanical splinting is used to strengthen the fused joint and provide environmental protection to the uncoated glass;

2) *mechanical* – the jointing of fibres in which the fibre alignment is determined by the jointing components and the alignment is maintained mechanically or by adhesives. Light injection (local or far end) and detection may be used to position the jointing components to achieve lowest joint loss.

Within the two basic methods are numerous design variations, features and properties. The choice of method and design features depends on the balance of properties and features desired in the final installation. Three groupings of properties and features for consideration are shown below:

1) design features which include:
   a) individual or multiple joint;
   b) integrity of the joint;
   c) joint loss and return loss values;
   d) packing density;
   e) complexity of the methods;
   f) universality of installation;
   g) installation tooling;
2) installed properties which include:
   a) stability of the joint loss and return loss;
   b) mechanical ruggedness;
   c) environmental stability;

3) economic factors which include:

   a) tooling and cost of tooling;

   b) installation labour costs;

   c) cost of materials for the joint;

   d) initial and refresher training required.

3 Fusion joints

3.1 *Process*

Electric arc fusion welders are used to make reliable multimode and single-mode fibre joints in the field. This method is used to make both single and multiple fibre joints.

During the fusion cycle the fibre ends shall be fire-cleaned (prefused) by the arc, then brought together and fused. It is necessary to continue feeding the fibres together during the fusion to prevent a reduced section at the weld point. These two operations shall be controlled by the welding apparatus. Finally, the joint can be proof tested to assure longevity in the field. The proof test may be built into the fusion apparatus and be part of the normal jointing process.

The melting point of the glass is an important characteristic when jointing fibres by fusion welding. It may be necessary to tailor the fusion cycle (time and current level for both prefusion and fusion) to the type of fibres which are being joined. Further, fibres with greatly differing melting points may be difficult to fusion weld.

3.2 *Single fibre joints*

3.2.1 *Fibre preparation*

It is necessary to remove all coatings in the region of the fibre ends. The length of the uncoated fibre varies with the jointing apparatus. The coatings may be removed using chemicals or preferably a mechanical stripping tool for operator safety. The stripping tools and procedures shall not scratch the fibre. Scratches can severely reduce fibre strength.

The bare ends of the fibre shall be cleaved cleanly and perpendicularly to the fibre axis; the end surfaces shall be mirror-like without chips or hackle. Typically, end angles shall be less than 1° from perpendicular to achieve a satisfactory joint. There are a number of commercial cleaving (scoring and breaking) tools that consistently produce an end angle of less than 1°. A fibre cleaving tool shall have the following characteristics:

1) good control of the blade pressure on the fibre surface to make a consistent-sized flaw;

2) assurance that the blade makes contact with the fibre;

3) a controlled length of the bared part of the cut fibre; and

4) controlled axial tension on the fibre.

It is preferable that the tool be simple to use and be of one continuous action.

3.2.2 *Fibre alignment*

The fibres are secured in v-grooves of x-y-z axis positioners. In a very basic apparatus the outer diameters of the bare fibre ends are aligned in v-grooves with the aid of a mirror system, which allows viewing in two perpendicular directions. This simple alignment is satisfactory for low loss multimode joints, but a more sophisticated apparatus may be required for low loss single-mode joints to compensate for concentricity errors between the core and cladding of the fibre.

Due to intrinsic fibre properties the cores or mode-field diameters may not be very well aligned when the outer diameters are aligned which results in larger than minimum joint loss. Joint loss can be minimized by using active fibre core alignment. The jointing apparatus can automatically optimize the light transmitted through the joint, and consequently minimize the joint loss. The optimization may be controlled by a micro-processor. It is desirable that the apparatus gives an estimate of the joint loss.

During the fusion process surface tension and intrinsic fibre properties can cause misalignment of the fibre cores, which will increase the joint loss. Minimizing the amount of free fibre in the melt zone can minimize the fibre core misalignment in the fused joint. Alternatively, compensation programmes can control the fusion parameters and fibre positioners to minimize the shift in core alignment.

3.2.3 *Joint protection*

The fusion joint requires recoating of the fibre to protect it from the environment, to provide mechanical protection, and to increase the tensile strength of the bare fibre. By splinting the splice with a rod and covering the rod and joint with an adhesive lined thermoshrinkable tube the joint can be strengthened and protected against moisture damage. Another alternative is to imbed the joint in an adhesive between two rigid parallel plates or in a small housing (case).

3.3 *Multiple fibre joints*

Multiple fibres (including fibre ribbons) can be jointed with mass fusion apparatus which uses the same concepts as those used to joint single fibres above. The following two key parameters shall be controlled:

1) variance suppression of the fibre end face positions by suitable clamps;

2) the same fusion temperature for all fibres.

The fusion apparatus shall control the fusion temperature for each fibre, this can be done by offsetting the fibres a prescribed distance from the axis of the electrodes.

Using suitable adapter clamps, single fibres can be mass fused in the same apparatus used to fuse fibre ribbons.

3.3.1 *Fibre preparation*

To control variance of fibre end face positions, all fibres shall be stripped and cleaved simultaneously. Chemical solvents or a heated mechanical stripping tool can be used for stripping depending on the characteristics of the coating.

3.3.2 Fibre alignment

Multiple fibres are aligned in v-grooves. Optical systems can be used to check the variance of the fibre ends and quality of the fibre cleaves. The fusion apparatus may automatically measure these parameters and compare them to prescribed limits. If an out-of-limit condition occurs, fusion shall not proceed until corrections are made.

3.3.3 *Joint protection*

Mass fusion joints can be protected using the same methods as used with single fused joints as specified in § 3.2.3.

4 Mechanical joints

A mechanical fibre joint has many physical embodiments but usually all include the following basic components:

1) surface for aligning mating fibre ends;

2) a retainer to keep the fibres in alignment; and

3) an index matching material (gel, grease, adhesive, etc.) placed between the fibre ends.

Some mechanical joints are re-enterable and provide flexibility to rearrange the cable plant.

There are single fibre and multifibre mechanical joints. Some designs can be installed on the ends of the fibres of a cable in the factory for faster jointing in the field.

To reduce Fresnel reflections it is necessary to use an optical matching material between the ends of mating fibres. These materials shall be chosen to match the optical properties of the glass. Common materials are silicon gels, UV-curable adhesive, epoxy resins, and optical greases.

4.1 *Adhesive bonded joints*

Adhesive bonded joints are a sub-class of mechanical joints. The fibres are aligned using the same methods as other mechanical joints. The ends of the fibres are butted in an adhesive. The bonded joint adhesive:

1) closely matches the index of refraction of the fibres;
2) permanently secures the fibres in the aligned position;
3) provides strain relief and supports the joint;
4) protects the joint from the environment;
5) provides axial tensile strength; and
6) requires fully cured resins.

4.2 *Fibre preparation*

It is necessary to remove the coating from a portion of the region near the fibre ends as indicated in § 3.2.1.

Depending on the mechanical jointing method it may be necessary to cleave the ends of the fibres as indicated in § 3.2.1.

When a fibre end is bonded in a ferrule it is necessary to polish the end of the fibre and ferrule to produce a common surface. The Fresnel reflection from the polished ends is dependent on the quality of the end polish and the matching material used between the fibre ends. To get the lowest possible reflection, it may be necessary to polish the end of the ferrule and fibre at an angle to the axis of the fibre. For example an angle of 5° to 10° has been used by Administrations.

In a mechanical splice, which joints bare cleaved fibres, it is possible to cleave the fibre ends with an angle of 5° to 10° to also significantly reduce reflections.

The ends of the fibres of a ribbon or a multifibre joint may be polished. The ends may also be angled to reduce reflections.

4.3 *Fibre alignment*

V-grooves, v-grooves in combination with an inflexible plane surface, and compliant triangular v-grooves are used to align mechanical joints. The v-grooves may be straight, curved, or result from the forming of the joint material (metal, etc.) as the joint is made.

Multigroove substrates, are used for multiple fibre joints. A joint may be constructed of a sandwich of several substrates. The number of fibres in a single joint matches the number of fibres in a sub-unit of the cable. The substrates shall have excellent geometric characteristics, shall be environmentally stable, and stable over time.

The fibres may be bonded into a secondary component, such as a glass ferrule, for alignment and retention. The ferrules may be inserted into an alignment sleeve which permits active alignment of the fibres. Local injection and detection (LID) of light through the splice may be used to minimize the splice loss.

Prealigned components may be used to reduce joint loss without using active alignment techniques.

4.4 *Joint protection*

Generally, the integral housing of the joint provides mechanical protection. The index matching materials used in the joint may also provide protection against moisture damage.

5 Test methods

5.1 *Test methods for mechanical characteristics*

This section advises appropriate tests and test methods for verifying the mechanical characteristics of optical fibre joints.

Note – The first edition (1990) of IEC Publication 1073-1, "Generic specification for splices for optical fibres and cables" is referred to throughout this section.

5.1.1 *Tensile strength*

This test applies to a completed fibre joint, and is a measure of the joint integrity under normal use conditions.

The test shall be carried out in accordance with IEC 1073-1. A typical performance value is ≥ 5 N.

5.1.2 *Static load*

This test applies to a completed fibre joint; it is a measure of the joint integrity that is left under a small tensile strain.

The test method is under consideration.

5.2 *Test methods for environmental characteristics*

5.2.1 *Change of temperature*

This test applies to a completed fibre joint; it is a measure of material compatibility and temperature stability of the joint.

The test shall be carried out in accordance with IEC 1073-1. Typically, the increase in insertion loss during temperature cycling, shall be ≤ 0.1 dB and a permanent insertion loss increase ≤ 0.05 dB.

5.2.2 *Damp heat (steady state)*

This test applies to a completed fibre joint; it is considered an accelerated test to give a measure of the joint stability in the presence of moisture.

The test shall be carried out in accordance with IEC 1073-1. Typically, the permanent insertion loss increase shall be ≤ 0.05 dB.

5.2.3 *Storage temperature*

This test applies to components of mechanical splices; it is a measure of the thermal stability and shelf life of the components.

This subject requires more study.

5.2.4 *Vibration*

This test applies to a completed fibre joint, and is a measure of the joint integrity and signal quality.

The test shall be carried out in accordance with IEC 1073-1. Typically, the loss increase during vibration shall be ≤ 0.1 dB and a permanent loss increase ≤ 0.05 dB.

5.3 *Test methods for optical characteristics*

5.3.1 *Insertion loss*

This test applies to a completed fibre joint; it is a measure of the joint quality.

The test shall be carried out in accordance with IEC 1073-1. Measurements can be made in the laboratory or the field. The cut-back method is preferred for the laboratory, and two way optical time domain reflectometry (OTDR) methods can be used in the field. Typical values may vary according to the application and/or method used. Lowest joint losses are typically ≤ 0.1 dB. In some applications typical insertion losses of ≤ 0.5 dB may be acceptable.

Further, a number of fusion jointing machines and mechanical jointing apparatus make estimates of the joint loss as the joint is made. Some Administrations and private operating companies use these estimates during construction of field joints and may review the entire route with an OTDR at the completion of route construction. Other methods can also be used to estimate joint loss in the field, such as clip-on power meters and local-injection-detection.

5.3.2 *Return loss*

This test applies to a completed fibre joint; it is a measure of the quality of the joint. Several types of transmission systems can be sensitive to reflections from joints.

The test shall be carried out in accordance with IEC 1073-1, a value of 30 dB or more below the incident signal, is used depending on the system.

5.3.3 *Cross talk*

This test applies to a completed fibre joint; it is a measure of the signal integrity.

The test shall be carried out in accordance with IEC 1073-1. Typical cross-talk values are 60 dB or more.

5.3.4 *Spectral loss*

This test applies to completed fibre joint; it may affect the ability to upgrade the fibre route.

The test shall be carried out in accordance with IEC 1073-1. For example, loss variations ≤ 0.1 dB over a range of wavelengths from 1200 to 1600 nm may be considered.