VIAVI Solutions

White Paper

Four Factors in Accurate Fiber Certification

Deployment of fiber continues to grow in data centers and enterprise networks. Whether used for backbone cabling or to connect servers to switches, fiber supports higher data rates at greater distances than copper cabling. Testing and certification of installed fiber confirms the system—as installed—will support the applications that will ultimately be carried on the fiber. Certification is typically performed at initial installation by the contractor who is building the network infrastructure. The certification reports from this testing can then be used to obtain warranties from the supplier of the infrastructure. As these systems are put into service by the network owner, they are often tested again to ensure nothing has changed since installation. Finally, the fiber systems may be tested to troubleshoot network issues visible at higher layers. Regardless of when the testing is performed, the actual tests to perform are defined within various standards.

For North America and other parts of the world, the Telecommunications Industry Association (TIA) is the group that writes the standards. Specifically, TIA's TR42.11 Subcommittee on Fiber Optic Systems develops and maintains standards, specifications, and related documents for the performance, design, characterization, and description of optical fiber subsystems, systems, and networks across all applications.[1] For fiber testing, the most relevant documents are:

- TIA-568.3: Optical Fiber Cabling and Components Standard
  - Section 7: *Optical fiber transmission performance and test requirements*
  - Annex E (Informative): *Guidelines for field-testing length, loss, and polarity of optical fiber cabling*
- TIA-526–14: *Optical power loss measurements of installed multimode fiber cable plant*
- TIA-526–7: *Measurement of optical power loss of installed single-mode fiber cable plant*

Over the last number of years, these documents have been updated to better harmonize TIA standards with international (IEC) standards. For example TIA-526-14 is an adaptation of IEC 61280-4-1 and TIA-527-7 is an adoption of IEC 61280-4-2. This means that specific instructions for how to perform optical power loss measurement of installed fiber cable plant is somewhat consistent regardless of where you are in the world. As with all standards, many of the above documents call on other standards. Of importance for this article is IEC 61300-3-35, *Examinations and measurements – Fiber optic connector endface visual and automated inspection*, as this standard is called upon by all of the three TIA standards listed above.

[1] https://standards.tiaonline.org/all-standards/committees/tr-42

Standards continue to evolve to reflect current realities in terms of systems being deployed and the best-practices to ensure they perform as designed. They also evolve to define practices that, if followed, will result in more consistent test results. In other words, a close following of the standards will ensure that the measurements performed by various people (contractors, cabling vendors, end-users) are consistent.

For this reason, it is important that updates to standards and current industry best practices are reflected in specifications for installations as well as performed by those testing and certifying fiber systems at all phases of the network lifecycle.

This article is not meant to be a comprehensive listing of what is required by the standards. Rather, it is meant to highlight several key factors that will help ensure accurate and repeatable loss measurements of installed fiber systems. While the standards do describe the use of optical time domain reflectometers (OTDR), this article will focus on the use of optical loss test sets (OLTS) to perform what is often referred to as Tier 1 certification—the measurement of loss and length, checking of polarity, pass/fail analysis, and documentation of results. The four key factors to be discussed are:

1. End-Face Inspection
2. Encircled Flux for Multimode Sources
3. Use of Test Reference Cords
4. Setting and Performing Test References

1. End-Face Inspection

When two fibers are mated together, there are three key requirements to ensure light passes from fiber to fiber without excessive loss or back reflections. Today's connector design and production techniques have eliminated most of the challenges to achieving core alignment and physical contact. What remains challenging is maintaining a pristine end face. A single particle mated into the core of a fiber can cause significant insertion loss, back reflection, and even equipment damage.

As a result, the condition of fiber end faces is likely the single-most controllable factor for the consistency of loss results as well as the ability for a system to perform as designed. This impacts all industries that use fiber optics, not just enterprise and data center networks. In an effort to guarantee a common level of performance from optical connections, the IEC developed Standard 61300-3-35 that specifies pass/fail requirements for end-face quality before connection. While telecommunication service (wireline, wireless, cable), aerospace, and other industries have widely adopted this as standard practice, enterprise and data centers have yet to follow suit even though all current standards require it. The introduction and widespread rollout of higher-speed systems with tighter loss tolerances is changing this.

A simple way to ensure meeting IEC 61300-3-35 is to follow the Inspect Before You Connect™ (IBYC) process. It is important to check *both* sides of the connection—for example, check both the test reference cord and the connector in the bulkhead of the link to be tested. Inspecting both sides of the connection is the only way to ensure that it will be free of contamination and defects. With IBYC, always inspect the fiber first—there is no need to clean a fiber that is already clean. If dirty, clean and inspect again to verify the cleaning was effective. Only when both connectors are clean can you proceed with connecting them.

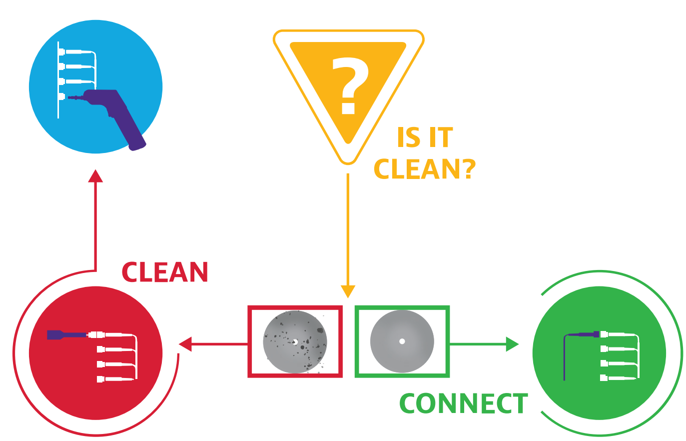

Figure 1. *Inspect Before You Connect*

A Note on Cleaning

There are many products on the market for cleaning fiber end faces. It is recommended that a product specifically designed for cleaning the fiber end face be used. There are both dry and wet cleaning methods and products. Many legacy wet-cleaning products tended to leave a film on the fiber that would then attract debris. One recommended practice to follow is to start with dry cleaning. If it is not effective, then try wet cleaning immediately followed by dry cleaning. Regardless of the cleaning method used, the only way to ensure it is effective is to inspect the fiber end face.

2. Encircled Flux for Multimode Sources

Different multimode sources have different modal power distributions, also known as launch conditions. What this means is that different sources fill the large multimode core with different amounts of light. Some sources overfill the multimode core, while others tend to underfill the core. In a very simplistic sense, overfilling the fiber results in measured losses being too high and underfilling the fiber will result in measured losses being too low. The result is a variation of measured losses from tester to tester, assuming all else is equal. IEC 61280-4-1 defines a standard method to characterize the launch conditions of multimode test sources. Known as encircled flux (EF), this is measured as a ratio between the transmitted power at a given radius of the fiber core. An important aspect of encircled flux is that it is measured at the output of the launch cord rather than at the output of the source. TIA has created a Telecommunications Systems Bulletin (TSB-4979) that describes two methods for implementing light sources to fulfill compliance requirements for the EF launch condition.

Method 1 is the use of a universal controller that can be used for legacy sources where the type of launch condition is not known. Universal controllers have been on the market for quite some time and consist of a "black box" with fixed input and output cords. The input cord connects to the legacy source directly or is mated to a launch cord. The end of the output cord provides an EF condition.

Method 2 is the use of a matched controller. A matched controller is achieved by matching specific sources with specific launch cords. The sources and launch cords are specific by their model number as opposed to their serial numbers. Test equipment vendors create matched controllers by tightly and consistently controlling the source and launch cord conditions during production. Major test equipment vendors now offer matched controller solutions to ensure EF.

A universal controller enables the use of existing sources. While form factors have gotten smaller, these can still be cumbersome to use. Once the connector at the output cord wears out, the device must be sent back to the vendor to have the connector replaced

3. Test Reference Cords

The connection between the test cords and the system under test is a leading cause of uncertainty and variability of loss measurements. Using test reference cords (TRCs) greatly reduces this variability and increases the chances of consistent and repeatable loss measurements. TRCs are not just any fiber cord—they are built to different specifications with much tighter tolerances. In particular, they use high-performance connectors that have optimal geometrical and optical characteristics. The result is that when two reference-grade connectors are mated together there should be nearly no loss. The table below shows the loss expected when mating reference grade connectors together. It also shows the expected loss when mating a reference grade connector to a standard connector.

Table 1. Allowed losses when mating test reference cords*

Termination 1	Termination 2	Attenuation Requirement
SM reference grade	SM reference grade	≤0.2 dB
SM reference grade	SM standard grade	≤0.5 dB
MM reference grade	MM reference grade	≤0.1 dB
MM reference grade	MM standard grade	≤0.5 dB

*Reference grade to standard grade losses from TIA-568.3-E

Compare the expected losses in the table above to the 0.75 dB normal maximum expected loss of two standard connectors. By reducing that maximum significantly, variability of loss measurements due to the test cord connecting to the system decreases significantly. And, since there are both transmit and receive test cords connected to the system under test, the impact is essentially doubled.

One critically-important aspect of using test reference cords is that they must be verified before testing begins as well as periodically while testing is being performed to ensure they continue to meet attenuation requirements. TRCs are consumable items that wear out over time. Fiber connectors are rated for 500 connections, and TRCs are no exception. However, with proper care and handling including inspecting the connector for debris and damage prior to every mating, they will last much longer. Verifying test reference cords is an important step in preparing to test. Fortunately, it is a very simple process. After setting a reference, simply connect the transmit and receive TRCs together with a high-quality adapter and measure loss. The result should be ≤0.2 dB for single mode and ≤0.1 dB for multimode, assuming the correct reference method is being used.

4. Setting and Performing Test References

People familiar with copper systems are used to the terms link and channel. These terms apply to fiber systems as well. A link is between two optical patch panels and may include connections and splices (such as an intermediate patch panel). Adding equipment cords at both ends creates a channel. During the construction phase of an enterprise or data center network, the link is typically what is tested. Only rarely are channels tested. This is important to understand because the test reference method specified by the various standards is different depending on if a link or a channel is being tested.

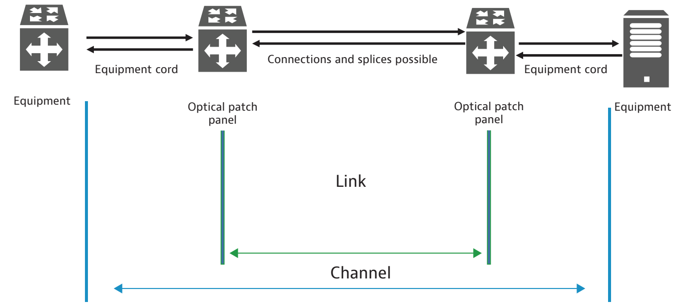

Figure 2. Links and channels

There are three test reference methods defined by the standards:

- One-cord reference method
- Two-cord reference method
- Three-cord reference method

Universally, the one-cord reference method is recommended for links, the three-cord reference method is recommended for channels, and the two-cord reference method is recommended when testing a system with an equipment cord on one end and a patch panel on the other end. The primary difference of the various reference methods is what losses associated with the connection of the test cords to the system under test are included in the loss measurement. The loss results from a one-cord reference method include both connections to the system under test. The three-cord reference method produces results that exclude the loss associated with the test cords connecting to the system under test. The two-cord reference method only excludes the loss of one connection. Of these three methods, the one-cord method is the most reliable in terms of repeatable loss measurements.

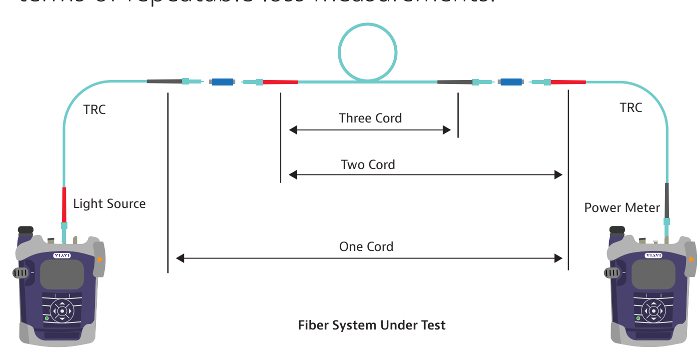

Figure 3. Losses included in measurement based on reference method

Modern OLTSs have settings for the test reference method. For accurate and repeatable results, the actual reference performed must match the setting on the test set. In other words, if the OLTS is set for a one-jumper reference method and a two jumper method is performed, the results will not be accurate or repeatable. On many OLTSs, a picture is provided as to how the reference connection should be made.

A one-cord reference method is called that because only one cord is connected between the light source and the power meter. Since an OLTS has a light source and power meter at both ends, the result is two cords are connected between devices. There is one cord without any adapters between each light source and each power meter.

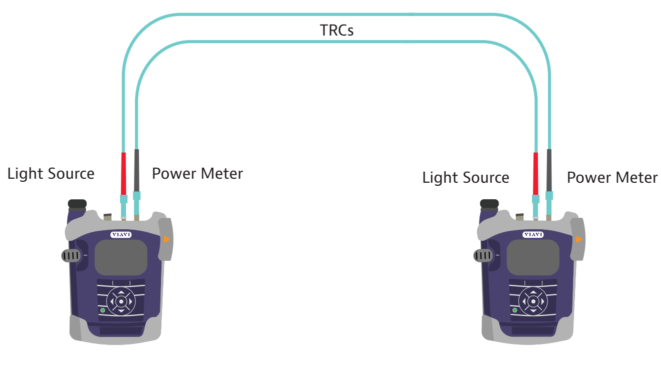

Figure 4. Connections for one-cord reference

The connector that plugs into the power meter will be connected to the link under test. For this reason, the connector that plugs into the power meter must match the connector type of the link under test (LC, for example). This means that the power meter connector itself must be the same as the connectors on the link being tested. For this reason, most OLTSs have interchangeable power meter adapters that let a user change the connector as required.

Once connected together as shown, the reference is set which sets each power meter to 0 dB. Next, the cords are disconnected from the power meter only. The TRC must not be disconnected from the light source. If disconnection occurs, the reference has to be reset. Since the connection at the power meter is a free-space connection, there is no impact from disconnecting the TRC from the power meter.

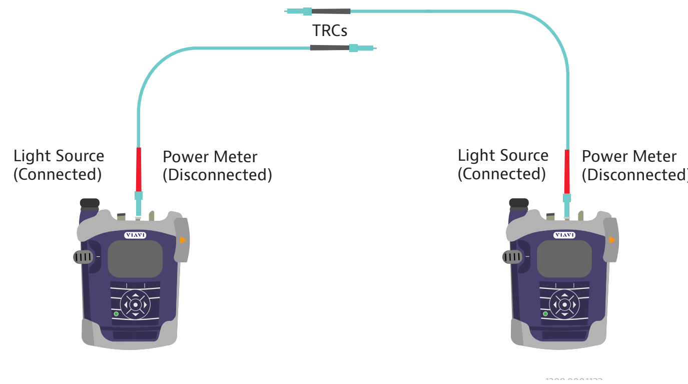

Figure 5. Cords removed from power meters

Next, the remaining two TRCs are added to the power meter resulting in four TRCs to be connected to the duplex link about to be tested. One important step remains.

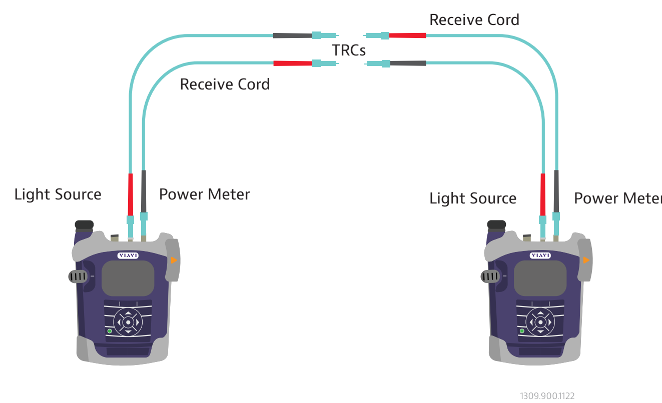

Figure 6. Receive cords added

Before testing, the TRCs must be verified by connecting the cords together with a high-quality adapter and performing a test. It is important to inspect the fiber end-faces first. The maximum loss is directly from Table 1 - ≤0.2 dB for single mode and ≤0.1 dB for multimode. It is a good idea to save this reference check as proof of a correct reference with TRCs.

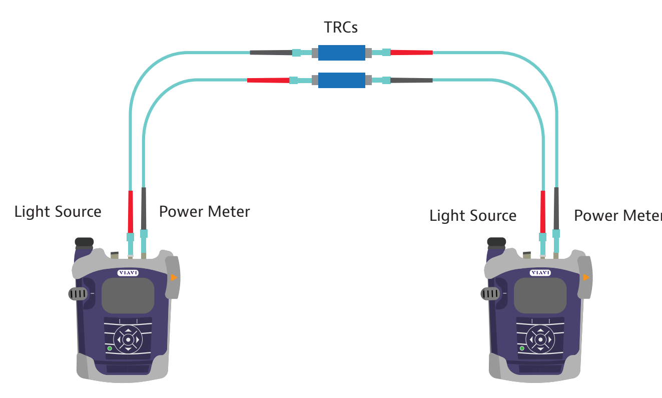

Figure 7. TRC verification

With the reference set and verified, you are almost ready to test. The remaining step is setting the pass/fail limit. Limits can be standards based, TIA and ISO/IEC for example. They can also be application based such as 10GBASE-SX. Or, they can be a simple dB limit. What limit to use depends on many factors including at what phase of the network lifecycle you are. For example, during the construction phase, it may not be known what application will be carried on the system. Therefore, generic TIA limits are often used. Using the correct limit is vital to ensuring you have a proper pass/fail analysis. Following the steps detailed in this article will help ensure the actual loss measurement is accurate and repeatable.

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