Guidelines

LANscape® Solutions Recommended Fibre Optic Test Guidelines

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1. Introduction

This paper explains the recommended guidelines for testing an installed fibre optic system. Fibre optic testing of a newly installed system not only verifies that the system meets its design requirements, but also creates a performance baseline for all future testing and troubleshooting of that system. Corning recommends that all fibre optic systems be tested to a minimum set of standards. This testing will ensure that the data necessary to properly evaluate any future system malfunctions will be available.

2. Why Test?

Imagine your end user calls to report his recently installed cabling system is not functioning. So, you drop everything and investigate. He's right – it is not working. However, because you followed proper testing procedures, troubleshooting is easy. You can quickly compare current test readings to original records and identify the problem.

Because you created the proper as-built documentation in the beginning, you can better service your customer's needs. You have the information available to quickly evaluate his system, identify the problem and fix it. Furthermore, your customer is going to feel good about relying on you when he needs you most.

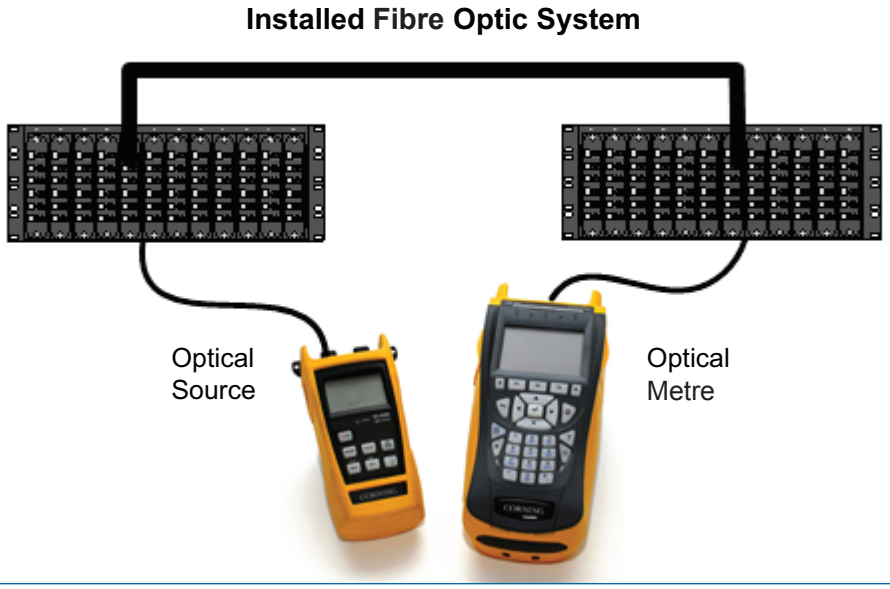
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3. Tier 1 and Tier 2 Testing

Corning strongly supports the two tiering level of testing as recommended by TIA/EIA 568 C.0.

Tier 1 testing is the minimum level of testing that is required. This level of testing consists of link attenuation testing, link length, and a polarity check. The fibre optic link attenuation is tested using an optical loss test set (OLTS) or a light source and power meter (LSPM) (Figure 1). This type of testing is the most accurate testing available and is the most accurate characterisation of the fibre optic system's capability. Testing with an OLTS/LSPM can be conducted at one or more wavelengths, but at a minimum, it is recommended that testing be performed at the wavelength that the network will operate (for example 850 nm for a laser-optimised fibre network where a VCSEL will be used for data transmission). Unidirectional testing is the minimum level, but the system owner may require that a bidirectional test be performed (testing performed from both directions). The link length can be obtained by recording the sheath distance found on the cable jacket or with the OLTS if it has this capability. Polarity verification is performed by either using a visual fault locator (VFL) or while performing the attenuation testing with the OLTS/LSPM.

Figure 1. Tier 1 Testing



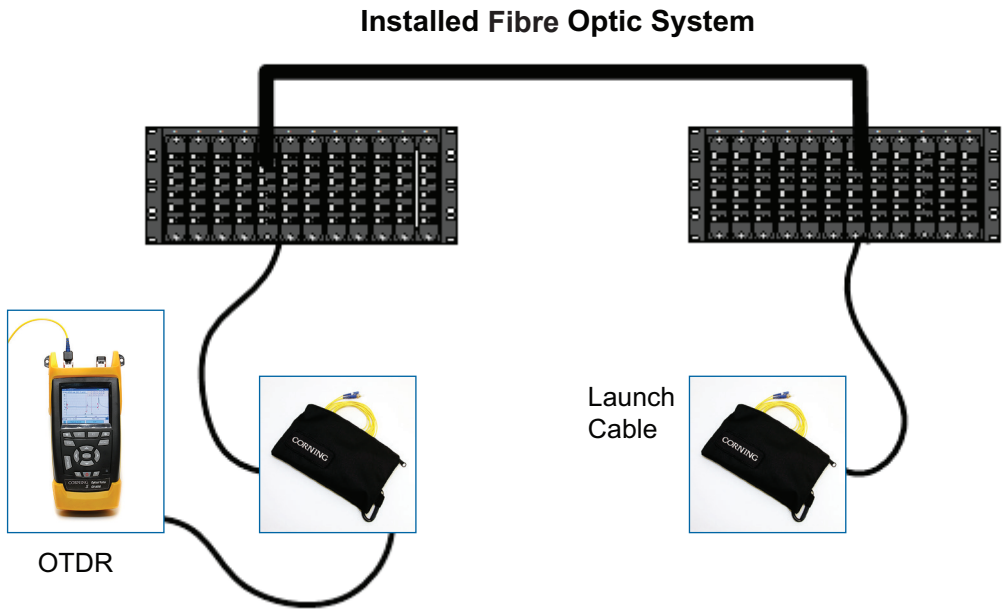
Tier 2 testing involves the use of an optical time domain reflectometer (OTDR) to provide a trace (visual picture) of the installed fibre optic network (Figure 2). The wavelength(s) used for acquiring the OTDR traces should be the same as the wavelengths used for the Tier 1 testing. Tier 2 testing is listed as optional in TIA-568-C.0, but this does not mean it is not important. The OTDR trace can be used for cable acceptance, splice and connector loss, documentation, troubleshooting, fault location, optical return loss, and to measure the length of the system. The OTDR

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trace can provide a visual picture of the fibre link that the OLTS/LSPM cannot. Even though the OTDR is a powerful tool, it does not replace the need for Tier 1 testing, because OTDR testing results can vary as a result of user setup. To get a true measurement of an event with an OTDR, a trace needs to be shot from both directions, and the average of the losses needs to be calculated.

Certain precautions should always be taken when performing any type of fibre optic testing. The use of appropriate mating adapters for launch cords is necessary to ensure reliable test results. All launch cords and adapters need to be clean and free of defects prior to and during testing. It is highly recommended that reference-grade launch cords be used for end-to-end attenuation testing. Launch cables should be used for OTDR testing to enable a stable launch and to ensure that the first event in the fibre link is visible in the trace. It should be a given that the fibre type of the launch cables/reference jumpers match the fibre link.

Figure 2. Tier 2 Testing



4. Encircled Flux

As data rate transmissions increase (1 Gb/s and higher), more consistent and reproducible test results are required. Consistency across a variety of field instruments is currently impossible due to different launch conditions from source to source. This is also the case because of different procedures used for mandrel wrapping and referencing for each unit. As a result, the telecommunications industry implemented (starting January 2013) a new testing standard involving the use of encircled flux (EF). Using EF-conditioned launches will allow test sets to be within +/- 10 percent variability. The use of an EF-compliant launch will replace the use of mandrels for testing multimode fibre.

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The EF definition is determined from the near field measurement of the light coming from the end of the launching cord. This means that even with an EF-compliant source, you will still need an EF condition launch cord. (Ref. Annex E of IEC 61280-4-1)

Corning believes that EF is the most accurate method to test multimode fibre. An EF-conditioned launch will reduce the variability among sources today (+20/-40 percent) to the respectable +/- 10 percent variability, and it will provide the best system characterisation for 1 Gb/s and beyond.

Corning recommends that fibre optic system installers take measures to become EF-compliant by upgrading their test equipment when feasible. Corning offers an EF-compliant solution that provides an out-of-port light source. Installers should be aware that fibre optic system owners may require that multimode fibre be tested using an EF-conditioned launch which will require upgraded testing components.

As installers move toward EF compliance, the Corning stance on mandrel wrapping remains the same. All testing of multimode fibre it requires at least the use of mandrels (mandrel wrapping of launch cords) if an EF-conditioned launch is not used or if an EF-conditioned launch is not required by the fibre owner.

NOTE: If additional information is desired concerning encircled flux, please refer to Applications Engineering Note (AEN) 129: "What is Encircled Flux and other related questions."

5. Link-loss Budgets

Before any fibre optic link-loss testing begins, a link-loss budget needs to be calculated. A loss budget will aid in determining whether the system was installed correctly, and the combined loss of all installed components is within allowable limits. Using a budget will also ensure that the active components will work with the installed passive fibre optic system. The components that are entered into the link-loss budget are the fibre optic connectors, fibre splices and the fibre. The link-loss budget should be agreed upon by the installer and fibre link owner.

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A minimum budget can be calculated, but the fibre link owner may require a more stringent budget depending on the active component requirements and intended use of the system.

The first step is to calculate the allowable loss of the installed fibre. You need to acquire four items to calculate the fibre loss.

1. The fibre type needs to be known which would be either single-mode or multimode.
2. You need to note the wavelength at which the measurements will be taken. The wavelengths should be the same for the OLTS/LSPM and the OTDR, with 850/1300 nm used for multimode and 1310/1550 nm used for single-mode.
3. The installed cable length can be recorded from the sheath markings on the cable or from an OTDR after installation of the fibre optic system.
4. The fibre loss (attenuation) in dB/km is required. This information can be found on the cable specification sheets provided by the cable manufacturer. If this information is not available, the maximum allowable fibre loss per ISO/IEC 11801 Ed 2.2 2011 may be used. Table 1 below provides these values.

Table 1. Maximum Fibre Loss per ISO/IEC 11801 Ed 2.2 2011

Optical Fibre Type	Wavelength (nm)	Maximum Attenuation (dB/km)
62.5/125 µm (OM1)	850	3.5
62.5/125 µm (OM1)	1300	1.5
50/125 µm (OM2)	850	3.5
50/125 µm (OM2)	1300	1.5
50/125 µm (OM3)	850	3.5
50/125 µm (OM3)	1300	1.5
50/125 µm (OM4)	850	3.5
50/125 µm (OM4)	1300	1.5
Single-mode Indoor/Outdoor Cable	1310	0.5
Single-mode Indoor/Outdoor Cable	1550	0.5
Single-mode Inside Plant Cable	1310	1.0
Single-mode Inside Plant Cable	1550	1.0
Single-mode Outside Plant Cable	1310	0.5
Single-mode Outside Plant Cable	1550	0.5

The second step is to count the number of connector pairs and the allowable loss for these connector pairs. The connector pair count includes the connectors (patch panels) at the end of the system that you plug into for testing. The maximum loss value according to TIA standards is 0.75 dB per connector pair.

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The last step is to count how many splices (mechanical and/or fusion) are in the installed system. Be sure to include the splices that are used to connect pigtailed connectors to the system. These splices are a separate component and need to be accounted for accordingly. Do not count the mechanical splice inside a UniCam® or OptiSnap® connector; this termination should just be included as a single connector. The maximum splice loss according to ISO/IEC 11801 Ed 2.2 2010 standards is 0.3 dB.

You could also use the following work sheet to manually calculate the link-loss budget.

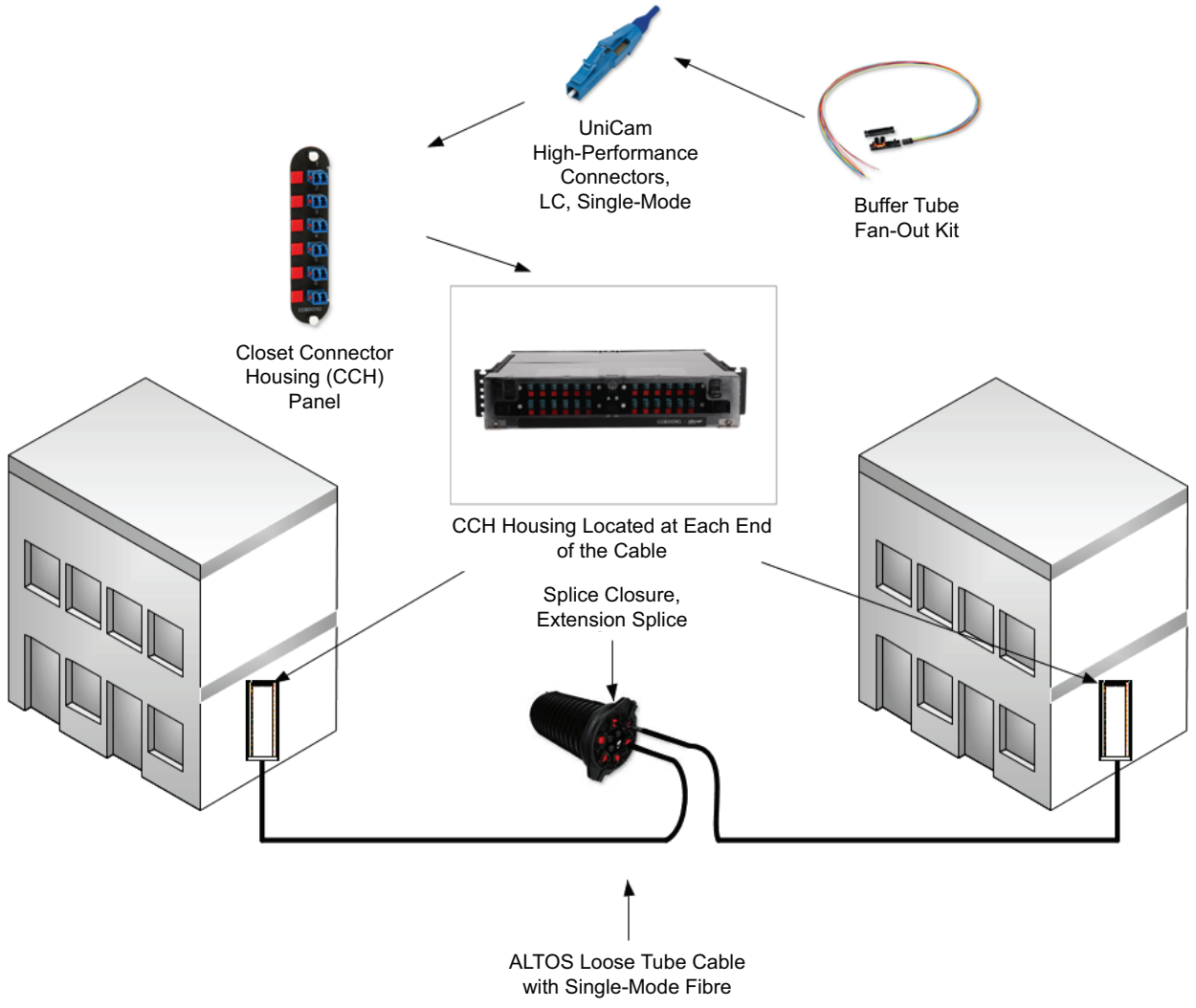
Link-loss Budget		
Step 1: Determine fibre loss at operating wavelength.		(nm)
Cable length *(1000 m = 1 km = 3281 ft)*		(km)
Fibre attenuation	x	(dB/km)
Total Fibre Loss	=	(dB)
Step 2: Determine connector loss.		
Individual connector loss (*ISO/IEC 11801 Ed 2.2 2012: 0.75 dB/connector pair)*		(dB)
Number of connector pairs	x	
Total Connector Loss	=	(dB)
Step 3: Determine splice loss.		
Individual splice loss (*ISO/IEC 11801 Ed 2.2 2012: 0.3 dB/splice)*		(dB)
Number of splices	x	
Total Splice Loss	=	(dB)
Step 4: Determine total system budget loss.		
Total Fibre Loss		(dB)
Total Connector Loss	+	(dB)
Total Splice Loss	+	(dB)
Total Link-loss Budget	=	(dB)

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The following is an example of a fibre optic system (Figure 4), and following that will be the link-loss budget for that system using the ISO/IEC 11801 Ed 2.2 2011 maximum allowable losses for installed components. This will require that the fibre loss value be pulled from Table 1 of this document.

The fibre optic system consists of two closet connector housings (CCH) at each end of the system with CCH patch panels. All fibres will be terminated with single-mode UniCam® connectors. There will be an extension splice located in a splice closure located at the midpoint of the system. The installed cable will be an ALTOS® loose tube cable with single-mode fibre. There will be 1 km of the ALTOS cable installed. The operating wavelength will be 1550 nm.

Figure 4. Fibre Optic System Example



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EXAMPLE: Link-loss Budget for Figure 4.		
Step 1: Determine fibre loss at operating wavelength.		1550 (nm)
Cable length *(1000 m = 1 km = 3281 ft)*		1 (km)
Fibre attenuation *(Note: From Table 1.)*	x	0.5 (dB/km)
Total Fibre Loss	=	**0.5 (dB)**
Step 2: Determine connector loss.		
Individual connector loss *(ISO/IEC 11801 Ed 2.2 2012: 0.75 dB/connector pair)*		0.75 (dB)
Number of connector pairs	x	2
Total Connector Loss	=	**1.5 (dB)**
Step 3: Determine splice loss.		
Individual splice loss *(ISO/IEC 11801 Ed 2.2 2012: 0.3 dB/splice)*		0.3 (dB)
Number of splices	x	1
Total Splice Loss	=	**0.3 (dB)**
Step 4: Determine total system budget loss.		
Total Fibre Loss		**0.5 (dB)**
Total Connector Loss	+	**1.5 (dB)**
Total Splice Loss	+	**0.3 (dB)**
Total Link-loss Budget	=	**2.3 (dB)**

The allowable loss when performing Tier 1 testing for the fibre installation in Figure 4 would be 2.3 dB. This loss is calculated using the ISO/IEC 11801 Ed 2.2 2011 maximum allowable losses. The cable loss would be less using the maximum loss from the cable specification sheet. It is also good to keep in mind that the end user may require a tighter budget than the ISO/IEC maximum. This tighter budget can be obtained by having better connector and splice losses. The end user and installer should agree what the budget should be before testing begins.

NOTE: If calculating the link-loss budget for pre-terminated modular, factory-built systems such as Corning's Plug & Play™ products, please refer to AEN 115: "Plug & Play Link-loss Budget Determination."

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6. Proper Reference Procedures

To perform Tier 1 testing, an important step needs to be completed which is the referencing of the launch cables (test jumpers). This step needs to be completed before any testing can occur.

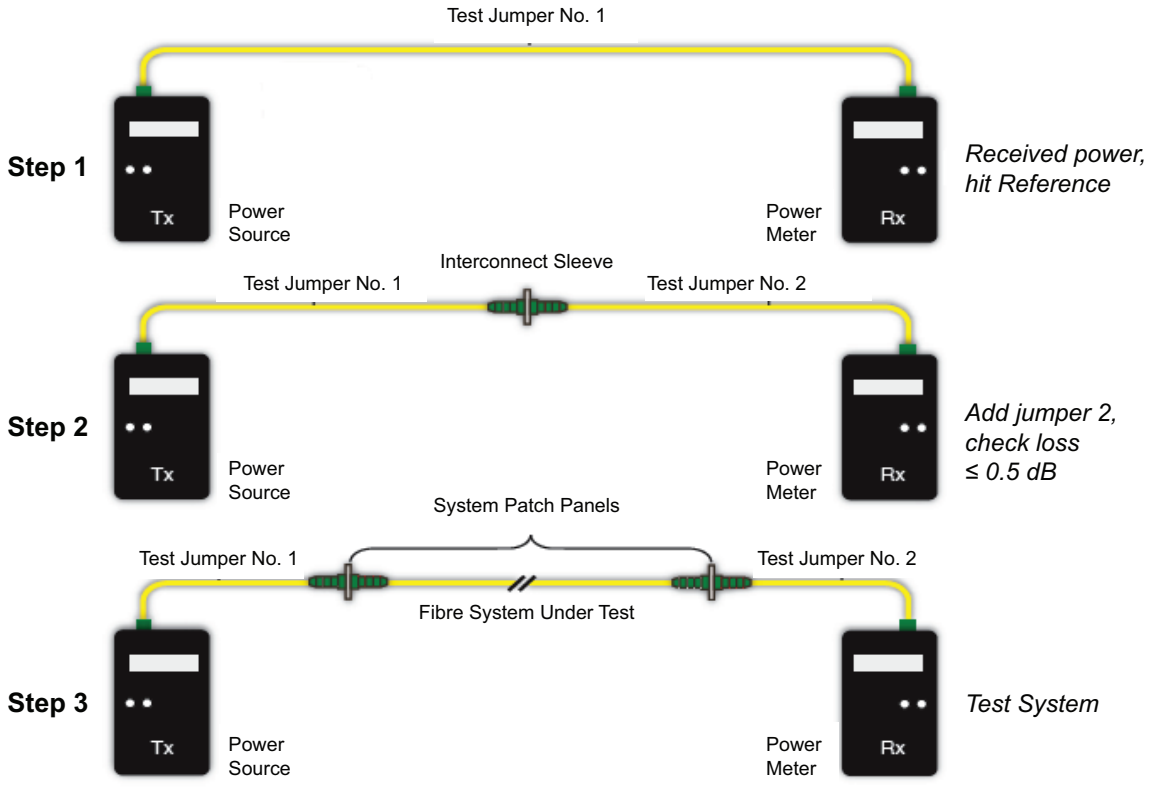
NOTE: Corning recommends that reference-grade jumpers be used for testing the installed fibre optic system. Also, all jumper end faces should be visually inspected prior to mating to test equipment and before the reference process begins.

There are three methods of referencing test jumpers.

- One-jumper reference
- Two-jumper reference
- Three-jumper reference

The recommended reference method for the vast majority of end-to-end link testing is the one-jumper reference method (Figure 5). Your test procedure should emulate your system as it will operate.

Figure 5. One-Jumper Reference Steps

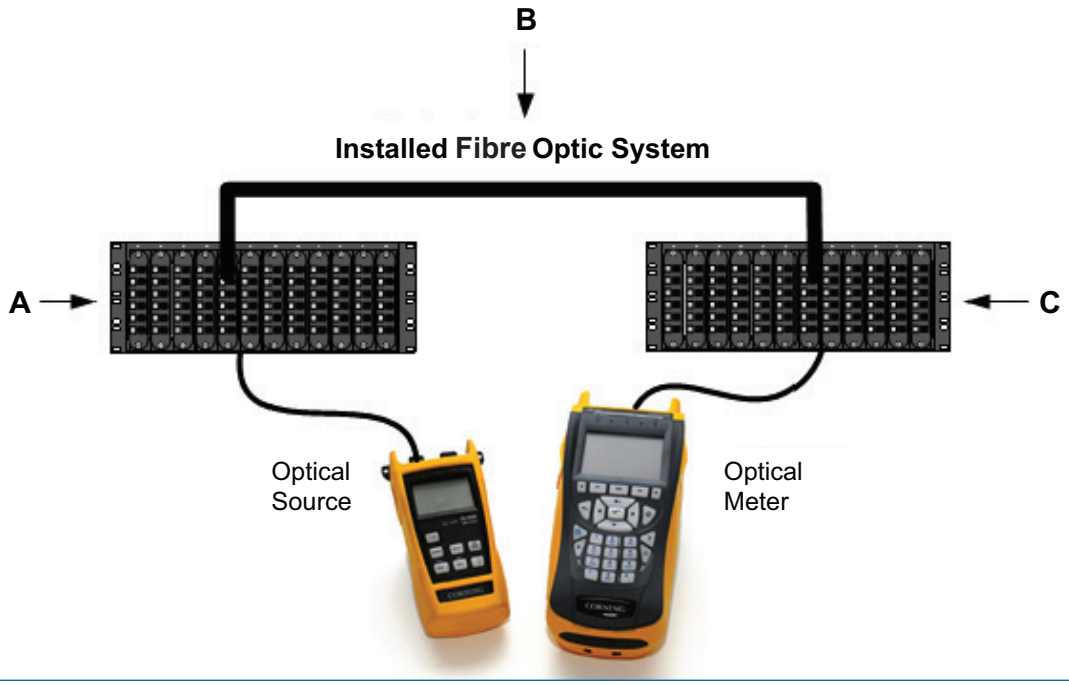


NOTE: Use EF-compliant source and launch cord or a mode conditioning jumper (mandrel wrap).

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If the fibre optic system to be tested includes a patch panel (connector pair) on each end of the system, then the one-jumper reference method should be used. One-jumper reference measurement results include the loss within the installed system plus the loss of two connector pairs (patch panel A, cable B, and patch panel C in Figure 6). If the fibre optic system to be tested includes one patch panel (connector pair) in the system, then the two-jumper reference method should be used. Two-jumper reference measurement results include the loss of the installed system with the loss of one connector pair (patch panel A and cable B in Figure 6). And if the fibre optic system to be tested has no patch panels (the connectors on the end of the system are plugged directly into the active equipment), the three-jumper reference method should be used. The three-reference jumper measurement results include only the loss of the cable (cable B in Figure 6).

Figure 6. Patch Panel A, Fibre Optic System B and Patch Panel C



NOTE: The procedure to reference an OLTS/LSPM can be different from one test equipment manufacturer to another. Please refer to the specific manufacturer's test equipment reference methods to ensure the test equipment is referenced correctly.

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7. Documentation

Documentation is an important part of the service package provided to the fibre optic system owner. Documentation allows for easier planning when performing upgrades. It also allows for seamless moves, adds, and changes (MACs). Proper documentation allows for easier troubleshooting and faster repairs. These benefits not only save time but also save money. Ultimately the fibre optic installer and system owner need to agree on what documentation will be provided before the job is started. It is good to remember that a good documentation package says a lot about the fibre optic installer. Besides the quality of the completed work, the documentation is the last piece that the system owner will see and keep for the life of the system.

Documentation can be broken down into two categories: optical and non-optical. Optical documentation includes link attenuation, component loss and distance readings (from an OTDR). Non-optical documentation includes cable route diagrams, splice plans, connector labelling schemes, cable sheath markings, cable datasheets/reel numbers, cable/fibre specifications, and a bill of materials used in the installation.

Corning recommends the following be included in the optical documentation.

For OLTS test results:

- Date of the test
- Test personnel
- Description of the field instrument used (manufacturer model number and serial number)
- Test equipment calibration date
- Type and length of the reference jumpers
- Fibre ID
- Test procedure and reference method used
- Link-loss results

For OTDR test results:

- Date of the test
- Test personnel
- Description of the field instrument used (manufacturer model number and serial number)
- Test equipment calibration date
- Type and length of the launch cables
- Fibre ID
- Trace file
- Tested wavelengths

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8. Conclusion

This paper was written to help installers understand the recommended guidelines for testing installed fibre optic systems. It was not meant to replace the standards, but to clarify them and provide guidance to ensure the proper steps are taken before, during, and after testing. These guidelines include building the proper loss budget based on installed components, determining the necessary tests to be performed, using the correct test equipment referencing method and delivering a complete and informative documentation package. Following all the outlined steps in this document will ensure all testing was performed properly, and the fibre optic system is accurately characterised to include the system's capabilities and limitations.

9. References

1. ANSI/TIA/EIA-568-C.0-2 Generic Telecommunications Cabling For Customer Premises – Addendum 2, General Updates
2. AEN 068: Improving Multimode Fibre Testing Accuracy with Mandrel Wrapping
3. AEN 104: Standards-Compliant Optical Test Equipment and Test Procedures (Testing with mandrel wrap)
4. MEA AEN004 Testing Method for Pretium EDGE® and Low-loss Multimode Plug & Play™ Solutions
5. AEN 129: What is Encircled Flux? and Other Related Questions
6. AEN 134: OTDR Testing Basics
7. AEN 135: Fibre Optic System Testing Tutorial (Testing with mandrel wrap)
8. ISO/IEC 11801 Ed 2.2 2011 Information Technology - Generic cabling for Customer Premises
9. IEC 61280-4-1 2009 Fibre Optic Communication Subsystem Test Procedures – Part 4-1: Installed Cable Plant – Multimode Attenuation Measurement

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