SECTION 27 08 10

OPTICAL FIBER TESTING AND MEASUREMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings, Contract Forms, Conditions of the Contract, including Construction Manager/General Contractor (CM/GC) Agreement, Exhibits and other Specification Sections that apply to this section.

1.2 SCOPE OF WORK

A. Provide all labor, materials, tools, field-test instruments and equipment required for the complete and proper test measurements of the installed optical fiber cabling.

B. In order to conform to the overall project event schedule, the contractor shall survey and coordinate the optical fiber testing with other applicable trades.

C. In addition to the test regiment detailed in this document, the contractor shall notify the Owner or the Owner's representative of any additional tests that are deemed necessary to guarantee a fully functional system. The contractor shall carry out and record any additional measurement results at no additional charge.

D. The contractor shall provide all test measurement results two (2) weeks prior to substantial completion in manifest spreadsheet format and native file format from the test instrument. Software shall also be provided to view the native results.

1.3 SCOPE

A. Test measurements shall be carried out in accordance with the Tier 2 specification of ANSI/TIA-568-C.0, Annex E, plus an image capture of connector end-faces. Tier 2 testing is a higher level of testing that provides qualitative measures of the installed condition and performance of the cabling system and its components. Tier 2 testing includes length measurement, attenuation measurement, verifying polarity (using an optical loss test set (OLTS) and obtaining a trace and event table of the fiber with an optical time domain reflectometer (OTDR). OTDR traces are used to evaluate the installed cabling for anomalies and assuring uniformity of cable attenuation and connector insertion loss.

B. Testing shall be performed on each optical fiber cabling link (adapter to adapter).

C. All tests shall be documented including OLTS dual wavelength attenuation measurements for multimode (850nm and 1300nm) and singlemode links (1310nm and 1550nm), OLTS length measurements for multimode and singlemode links, OTDR traces and event tables for multimode and singlemode links, and image captures of connector end-faces.

1.4 DEFINITIONS

A. Optical fiber cabling link: A fiber with an adapter on each end.

1.5 QUALITY ASSURANCE

A. All testing procedures and field-test instruments shall comply with applicable requirements of:

1. ANSI Z136.2, ANS For Safe Use Of Optical Fiber Communication Systems Utilizing Laser Diode And LED Sources

2. ANSI/EIA/TIA-455-50B, Light Launch Conditions For Long-Length Graded-Index Optical Fiber Spectral Attenuation Measurements
3. ANSI/TIA/EIA-455-59A, Measurement of Fiber Point Discontinuities Using an OTDR.
4. ANSI/TIA/EIA-455-60A, Measurement of Fiber or Cable Length Using an OTDR.
5. ANSI/TIA/EIA-455-61A, Measurement of Fiber or Cable Attenuation Using an OTDR.
6. ANSI/TIA/EIA-526-7, Optical Power Loss Measurements of Installed Singlemode Fiber Cable Plant.
7. ANSI/TIA/EIA-526-14-A, Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant.
8. ANSI/TIA -568-C.0, Generic Telecommunications Cabling for Customer Premises.
9. ANSI/TIA -568-C.3, Optical Fiber Cabling Components Standard.

B. Trained technicians who have successfully attended an optical fiber testing training program, which includes testing with an OLTS and an OTDR and have obtained a certificate as proof thereof shall execute the tests. These certificates may have been issued by any of the following organizations or an equivalent organization:

1. Manufacturer of the fiber optic cable and/or the fiber optic connectors.
2. Manufacturer of the test equipment used for the field certification.
3. Training organizations (e.g., BICSI, A Telecommunications Association).

C. The Owner or the Owner's representative shall be invited to witness, review or both witness and review field-testing.

1. The Owner or the Owner's representative shall be notified of the testing start date, five (5) business days before testing commences.
2. The Owner or the Owner's representative will select a random sample of 5% of the installed links and test that sample. The measured results obtained from the random sample shall be compared to the data provided by the contractor. If more than 2% of the sample results differ in terms of the pass/fail determination, the contractor under supervision of the Owner or Owner's representative shall repeat 100% of the testing at no cost to the Owner.

1.6 SUBMITTALS

A. Manufacturers catalog sheets and specifications for the fiber optic field-test instruments including optical loss test sets (OLTS), optical time domain reflectometer (OTDR) and endface inspection capture device.

B. A schedule (list) of all optical fibers to be tested identified per UT Administration Office specifications.

C. Sample test reports.

1.7 ACCEPTANCE OF TEST RESULTS

A. Link attenuation measurement and allowance calculation

1. The measured link attenuation shall be less than the link attenuation allowance. The link attenuation allowance is calculated as:

   Link Attenuation Allowance (dB) = Cable Attenuation Allowance (dB) + Connector Insertion Loss Allowance (dB) + Splice Insertion Loss Allowance (dB)

   where:

Connector Insertion Loss Allowance (dB) = Number of Connector Pairs × 0.4dB

Splice Insertion Loss Allowance (dB) = Number of Splices × 0.15dB

Cable Attenuation Allowance (dB) = Maximum Cable Attenuation Coefficient (dB/km) × Length (km)

Optical fiber cable attenuation performance

Optical fiber and cable type [2]	Wavelength (nm)	Maximum attenuation (dB/km)
62.5/125 µm Multimode (OM1)	850 1300	3.5 1.5
50/125 µm Multimode (OM2)	850 1300	3.5 1.5
850 nm Laser-Optimized 50/125 µm Multimode (OM3)	850 1300	3.5 1.5
Single-Mode Indoor-Outdoor (OS1) (OS2)[3]	1310 1550	0.5 0.5
Single-ModeInside Plant (OS1) (OS2)[3]	1310 1550	1.0 1.0
Single-ModeOutside Plant (OS1) (OS2)[3]	1310 1550	0.5 0.5

B. All installed cabling links shall be field-tested and pass the link attenuation measurement and allowance calculation and OTDR analysis. Any optical fiber link that fails these requirements shall be diagnosed and corrected. Any corrective action that must take place shall be documented and followed with a new test to prove that the corrected link meets performance requirements. The final and passing result of the tests for all links and channels shall be provided in the test results documentation in accordance with Part 3.

C. Individual connector, splice and fiber insertion loss shall be evaluated using the OTDR trace. These components shall meet or exceed the values in 1.7, A.

PART 2 - PRODUCTS

2.1 OPTICAL FIBER CABLE TESTERS

A. The field-test instrument shall be within the calibration period recommended by the manufacturer.

B. The field-test instrument shall contain the most recent software and firmware provided by the manufacturer prior to testing.

C. Optical loss test set (OLTS)

1. The OLTS shall be capable of providing length measurement of the fiber under test.

2. Multimode optical fiber light source

a) Provide dual LED light sources with central wavelengths of 850 nm (±30 nm) and 1300 nm (±20 nm)

b) Output power of -20 dBm minimum.

c) The light source shall meet the launch requirements of ANSI/EIA/TIA-455-50B, Method A. This launch condition can be achieved either within the field test equipment or by use of an external mandrel wrap (see Part 3, 3.2, C, 1, c) with a Category 1 light source.

3. Singlemode optical fiber light source

a) Provide dual laser light sources with central wavelengths of 1310 nm (±20 nm) and 1500 nm (±20 nm).

b) Output power of –10 dB minimum.

4. Power Meter

a) Provide 850nm, 1300nm and 1500nm wavelength test capability.

b) Power measurement uncertainty of ± 0.25 dB.

c) Store reference power measurement.

d) Save at least 100 results in internal memory.

e) PC interface (serial or USB).

5. Acceptable manufacturers, models:

a) Fluke Networks, OptiFiber (OLTS and OTDR combined)

b) Fluke Networks, DTX (OLTS; MFM2, SFM2)

c) Corning Cabling Systems OTS-613QD (OLTS)

d) Exfo, FOT-600 OLTS (OLTS)

e) Approved equivalent

D. Optical Time Domain Reflectometer (OTDR)

1. Shall have a bright, color transmissive LCD display with backlight.

2. Shall have rechargeable Li-Ion battery for 8 hours of normal operation.

3. Internal non-volatile memory and removable memory device with at least 16 MB capacity for results storage.

4. Serial and USB ports to transfer data to a PC.

5. Multimode OTDR

a) Wavelengths of 850 nm (± 20 nm) and 1300 nm (± 20 nm).

b) Event deadzones typically of 0.5 m at 850 nm and 1.3 m at 1300 nm.

c) Attenuation deadzones 4.5 m at 850 nm and 10.5 m at 1300 nm.

d) Distance range 3 km at 850 nm and 7 km at 1300 nm.

e) Dynamic range 15 dB at 850 nm and 14 dB at 1300 nm.

6. Single-mode OTDR

a) Wavelengths of 1310 nm (± 25 nm) and 1550 nm (± 30 nm).

b) Event deadzones typically of 1 m at 1310 nm and 1 m at 1550 nm.

c) Attenuation deadzones typically of 8 m at 1310 nm and 8 m at 1550 nm.

d) Distance range at least 60 km.

e) Dynamic range 26 dB at 1310 nm and 24 dB at 1550 nm.

7. Acceptable manufacturers, models:

a) Fluke Networks, OptiFiber (OLTS and OTDR combined with end face image capture)

b) Fluke Networks, DTX (QUAD-OTDR)

c) Corning Cabling Systems, OV-1000 OTDR

d) Exfo, FTB-150 OTDR

e) Approved equivalent

E. Fiber Microscope

1. Magnification of 250X or 400X for end-face inspection

2. Video camera and display showing magnified end-face image.

3. Camera probe tips permitting inspection through adapters.

4. Capable of saving end-face image.

5. Acceptable manufacturers, models:

a) Corning Cabling Systems, VIP-CCO-K17

b) Fluke Networks, OptiFiber (OLTS and OTDR combined with end face image capture)

c) Approved equivalent

F. Administration

1. The test result information for each link shall be recorded in the memory of the field-test instrument upon completion of the test.

2. The test result records saved within the field-test instrument shall be transferred into a Windows™-based database utility that allows for the maintenance, inspection and archiving of these test records.

PART 3 - EXECUTION

3.1 GENERAL

A. All tests performed on optical fiber cabling that use a laser or LED in a test set shall be carried out with safety precautions in accordance with ANSI Z136.2.

NOTE – A visible fault locator (VFL) normally uses a Class 2 or 3 light source and should not be directly viewed. Safe usage of the tool requires indirect viewing of the light source by pointing the end of the fiber at an adjacent surface (or introducing another surface in front of a fixed mounted connector) until the presence of light is determined.

B. All outlets, cables, patch panels and associated components shall be fully assembled and labeled prior to field-testing. Any testing performed on incomplete systems shall be redone on completion of the work.

C. Dust caps shall be placed on fiber endfaces or adapters for each optical fiber link after all testing is complete on the fiber link.

D. Testing shall be performed in accordance with ANSI/TIA-568-C.0 Annex E, Tier 2 testing on each cabling segment (i.e., verify polarity, measuring length, OLTS attenuation measurement, and OTDR trace).

E. In addition to Tier 2 testing of ANSI/TIA-568-C.0 Annex E, an image of each fiber optic connector endface shall be taken, recorded and provided as part of the records.

F. Optical fiber link test results from the OLTS, OTDR and endface image shall be recorded in the memory of the field-test instrument.

G. Each optical fiber test shall be uploaded to a PC in which the administrative documentation (reports) shall be generated.

H. The records for each test shall be provided to the owner a minimum of two weeks prior to substantial completion in Excel format and the native format to the test instrument. The Owner can supply an Excel spreadsheet template upon request for the contractor's use.

3.2 OPTICAL FIBER TESTING

A. Polarity

1. For duplex connector systems, polarity shall be verified. The polarity shall be verified with an OLTS while performing attenuation tests.

B. Length measurement

1. Each optical fiber link shall be measured for its length. The fiber length may be obtained by a capable OLTS or by an OTDR.

C. Attenuation measurement (OLTS)

1. General

a) Optical sources shall be turned on for a minimum of 5 minutes prior to referencing.

b) Test jumpers shall be reference quality and between 1m and 5m in length.

c) Mandrels shall be used when testing attenuation of multimode optical fiber cabling with an OLTS. The mandrel sizes are shown in the following table

Fiber core/cladding size (μm)	**900 μm buffered fiber (mm)**	**2.0 mm jacketed cable (mm)**	**2.4 mm jacketed cable (mm)**	**3.0 mm jacketed cable (mm)**
50/125	25	23	23	22
62.5/125	20	18	18	17

d) Where mandrels are used, secure the mandrel to the light source by some means such as a cable tie or tape. Care should be taken to ensure that the fiber jacket is not deformed or damaged when using a cable tie or tape.

e) The light source shall be referenced to the meter a minimum of twice daily (i.e., in the morning and noon).

f) Fiber test jumpers shall be of the same core size as the cabling under test (e.g., singlemode to singlemode, 62.5µm multimode to 62.5µm multimode, 50µm multimode to 50µm multimode). Additionally the test jumpers shall meet the performance specifications of the fiber under test and that of the test instrument manufacturer.

g) Fiber test jumpers shall be cleaned prior to connection to the test instrument. After cleaning, cleaning solutions shall be given sufficient time to evaporate (approximately 30 seconds) prior to the mating of fiber test jumper to the test instrument.

h) The end of the fiber test jumper that will connect to the fiber link to be tested, the adapters and fiber under test shall be cleaned immediately prior to each fiber being tested. After cleaning, cleaning solutions shall be given sufficient time to evaporate (approximately 30 seconds) prior to the mating of fiber test jumper to the fiber under test.

i) The test jumper connected to the source shall not be removed after referencing so as not to adversely influence the attenuation measurement. Removal and reattachment of the test jumper connection from the source may affect the referenced power level. Re-referencing is to be performed if the test jumper is disconnected from the light source.

j) Singlemode optical fiber links shall be tested at 1310 nm and 1550 nm in accordance with ANSI/TIA/EIA-526-7, Method A.1, One Reference Jumper.

k) Multimode optical fiber links shall be tested at 850 nm and 1300 nm in accordance with ANSI/TIA/EIA-526-14-A, Method B, One Reference Jumper.

l) Multimode and singlemode optical fiber links shall be measured and reported for attenuation in each direction and attenuation bi-directionally (averaged in both directions). The measurements shall be less than or equal to the link attenuation allowance calculation (see Part 1, 1.7, A.).

2. Steps to measure and calculate optical fiber link attenuation include a) verifying test jumper quality; b) setting the reference; c) measuring link attenuation; and d) calculating link attenuation.

This example below describes the process when testing multimode fiber with the test jumper connected to the source having five non-overlapping wraps of multimode fiber on a mandrel. The procedure is also applicable to single-mode cabling, however, the five non-overlapping wraps of multimode fiber would be replaced with a single 30 mm (1.2 in) diameter loop of single-mode fiber.

a) Verifying test jumper quality

1) Test jumpers shall be tested for quality prior to use as a test jumper. See example below.

To verify that the test jumpers are in acceptable condition, first reference the light source to the optical power meter (see figure 1). Disconnect test jumper (J1) from the power meter (only) and

insert a second test jumper (J2) by connecting it to the power meter and to (J1) with a mating adapter (see figure 2) and record the measurement. Disconnect both ends of J2, interchange the ends, and reconnect it and record the measurement. The resulting measurements, P_{verify}, should be within the appropriate connector loss specification. For example, if the connector used is specified at 0.32 dB, the reading on the power meter should be within 0.32 dB of P_1.

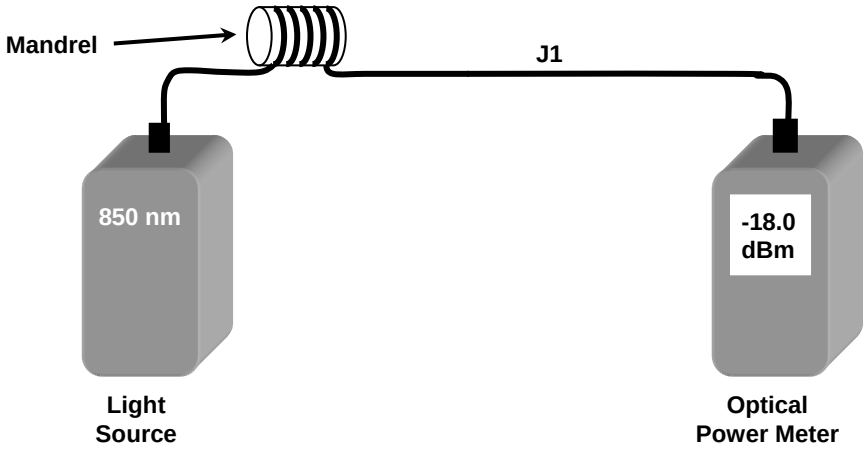

Figure 1 – Example of OLTS reference measurement (P_1) with one test jumper (multimode)

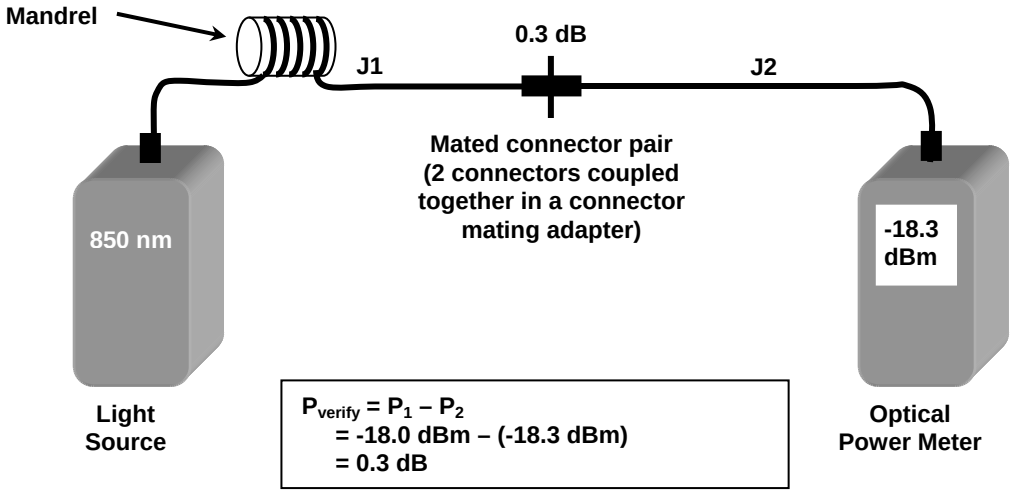

Figure 2 – Example of a measurement (P_2) when verifying OLTS test jumpers (multimode)

b) Setting the reference

1) One test jumper (J1) is to be connected between the light source and the power meter and a reference measurement taken (P_1[dBm]). When testing a multimode optical fiber link, a mandrel wrap shall be applied to the test jumper (J1) prior to setting the reference and for all subsequent measurements.

When testing a singlemode optical fiber link, a single 30 mm (1.2 in) diameter loop shall be applied to the test jumper (J1) prior to setting the reference and for all subsequent measurements.

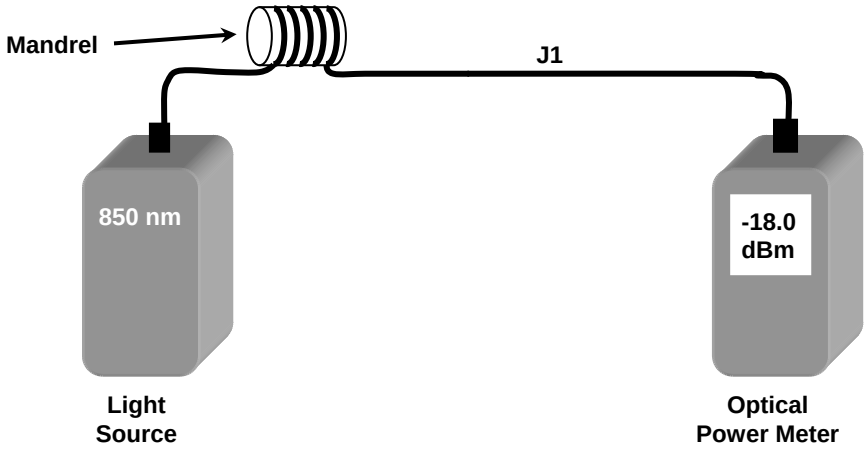

Figure 3 – Example of OLTS reference measurement (P_1) with one test jumper (multimode)

c) Measuring link attenuation

1) Connect the end of test jumper (J1) (source end) to one end of the link, and connect an verified test jumper (J2) between the other end of the link and the meter (see figure 4). The optical power reading is P_2 (dBm).

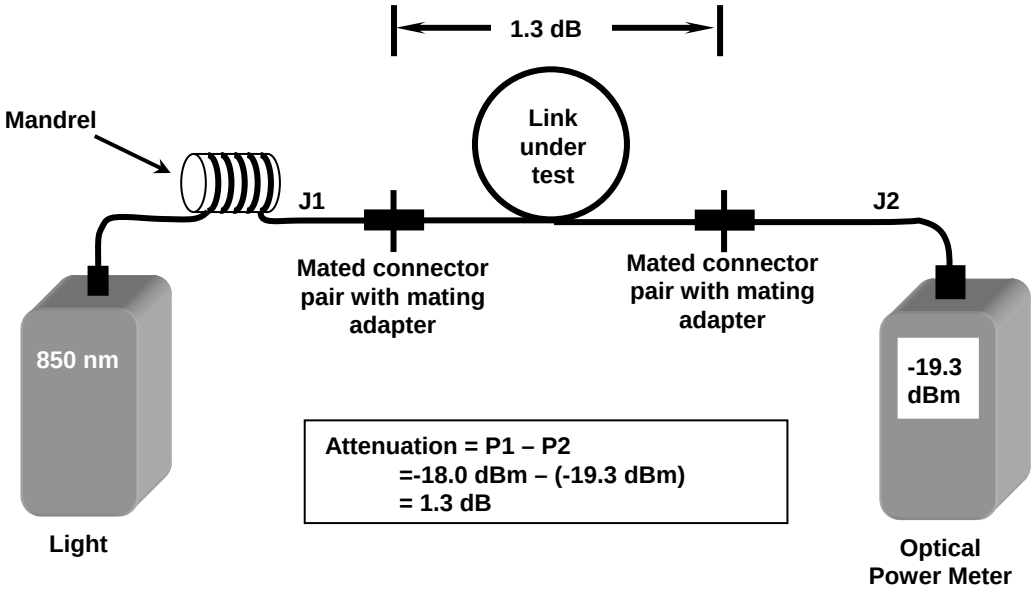

Figure 4 – Example of a multimode link attenuation measurement (P_2)

d) Calculating link attenuation
Link attenuation shall be calculated by the OLTS. Calculated optical fiber link attenuation is applied by using the following equation.

$$Attenuation(dB) = P_1(dBm) - P_2(dBm)$$

where:
P_1 = Reference power measurement
P_2 = Cabling test power measurement

3. Link attenuation measurement and allowance calculation

a) The measured link attenuation shall be less than the link attenuation allowance (see Part 1, 1.7, A.).

D. Optical fiber endface image

1. An image of each optical fiber endface shall be taken and recorded after Tier 2 testing of the optical fiber link is completed. The endface image shall be captured at either 250X or 400X.

E. OTDR trace

1. An OTDR trace shall be taken of each optical fiber link in one direction to ensure uniformity of cable attenuation and connector insertion loss. Multimode fiber traces shall be taken at 850nm and 1300nm. Singlemode fiber traces shall be taken at 1310nm and 1550nm.

2. A launch cable to the length specified by the manufacturer of the OTDR shall be installed between the OTDR and the first link connection. The launch cable shall be of the same fiber type as the link under test.

3. A receive cable shall be installed after the last link connection to be part of the OTDR trace. The receive cable shall be at least 100m (328ft) in length and of the same fiber type as the link under test.

4. Selectable parameters affecting the OTDR measurement may include the test source wavelength, pulse duration or signal strength, length range, backscatter coefficient, signal averaging (time or count) and the group index of the fiber (also known as the index of refraction or the refractive index). The display shall be adjusted to view the region of interest on the trace on both the horizontal and vertical axes.

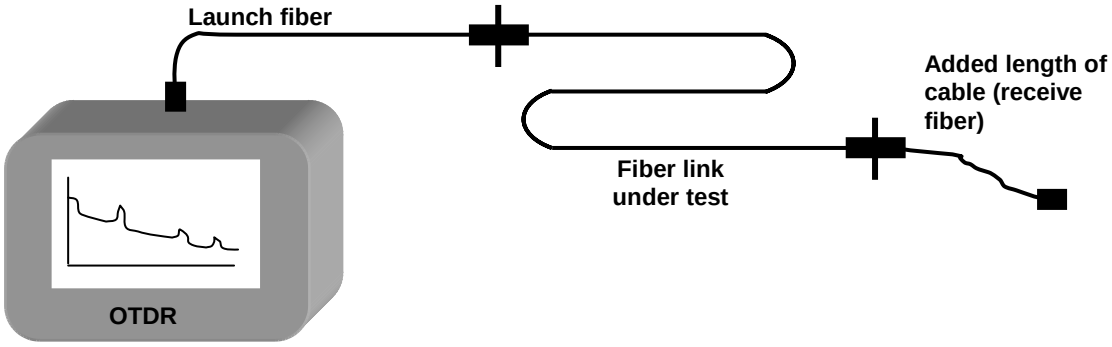

Figure 5 – OTDR setup illustration of fiber link testing

3.3 ADMINISTRATION

A. Test results documentation

1. Test results saved within the field-test instrument shall be transferred into a Windows™-based database utility that allows for the maintenance, inspection and archiving of the test records. These test records shall be uploaded to the PC unaltered, i.e., “as saved in the field-test instrument”.
2. The test results documentation shall be available for inspection by the Owner or the Owner’s representative during the installation period. The contractor shall retain a copy to aid preparation of as-built information.
3. The records for each test shall be provided to the owner a minimum of two weeks prior to substantial completion in Excel format and the native format to the test instrument. The Owner can supply an Excel spreadsheet template upon request for the contractors use.
4. Circuit IDs reported by the field-test instrument shall match the label ID specified by the Owner.
5. The detailed test results documentation data is to be provided in an electronic database for each tested optical fiber and shall contain the following information
    a) The identification of the customer site as specified by the end-user
    b) The name of the standard selected to execute the stored test results
    c) The name of the test personnel
    d) The date and time the test results were saved in the memory of the tester
    e) The manufacturer, model and serial number of the field-test instrument
    f) The version of the test software and the version of the test standards database held within the test instrument
    g) The value of the ‘index of refraction’ used for length calculations
    h) The fiber identification number
    i) The length for each optical fiber calculated by the OLTS.
    j) Test results to include OLTS attenuation link and channel measurements at 850 nm and 1300 nm for multimode cabling, and at 1310 nm and 1550 nm for singlemode cabling and the margin (difference between the measured attenuation and the test limit value).
    k) Test results shall be submitted to include OTDR link and channel traces and event tables at 850 nm and 1300 nm for multimode cabling, and at 1310 nm and 1550 nm for singlemode cabling and the margin (difference between the measured attenuation and the test limit value).
    l) The length for each optical fiber calculated by the OTDR.
    m) The overall Pass/Fail evaluation of the link-under-test for OLTS and OTDR measurements
    n) A picture or image of each fiber end-face

END OF SECTION