

FIBER OPTIC TESTING PROCEDURE

1. Fiber Testing Equipment Required

- 1.1. Two qualified technicians using OTDR and Power Meter test sets with identical test configuration parameters will be required to provide testing of each segment within the scope of project.
- 1.2. Quantity 2 - Optical Time Domain Reflectometer (OTDR) capable of testing at 1310nm and 1550nm wavelengths for singlemode fiber, 850nm and 1300nm wavelengths for multimode fiber.
- 1.3. Optical Loss Test Set (OLTS) Consisting of a Light Source and Power Meter capable of testing at 1310nm, 1550nm wavelengths for singlemode fiber, 850nm and 1300nm wavelengths for multimode fiber.
- 1.4. Quantity 2 - Fiber Optic Launch Reels 1-km (Pulse Suppressors), one connected at each end of fiber strand / segment being tested with OTDR to allow visibility of both near and far-end loss events (i.e., reflection levels, splice loss, connector loss).
- 1.5. Fiber Optic Inspection Scopes
- 1.6. Fiber cleaning supplies (wipes, sticks, swabs, etc.)
- 1.7. Adapters/connectors for testing bare fiber strands as required

2. DOCUMENTATION REQUIRED (submitted electronically per instructions detailed below in section 2.9.)

Pre-Construction

- 2.1. Test Equipment Calibration Certifications confirming equipment calibration meets maximum 2 – year interval requirement.
- 2.2. Personnel performing fiber optic testing for NDOT are required to hold certificates of training from a nationally recognized Fiber Optic Training Organization and must have at least two years of demonstrated fiber optic testing experience. Provide Certifications and work experience documentation to NDOT per “Documentation Required” section included within these procedures.
- 2.3. Factory fiber test results reflecting the attenuation levels of each fiber in dB/km measured at 1310nm and 1550nm for singlemode fiber, 850nm and 1310nm for multimode fiber.
- 2.4. Factory test results for any other project fiber cabling such as jumpers, pigtails, CDCA cables.

2.5. Test results from pre-construction testing of fiber cable reels by NDOT contractor which demonstrate acceptable attenuation levels per the NDOT specifications contained herein.

Post-Construction

2.6. OTDR test results must be provided in PDF format, including uni-directional and bi-directional measurements indicating results meet NDOT specifications.

2.7. Power Meter test results provided in PDF format indicating results meet NDOT specifications.

2.8. Completed NDOT Loss Budget / Test Summary spreadsheet compiled based on OTDR and Power Meter test results collected during project.

2.9. Submit all documentation listed above electronically via upload to shared drive (obtain shared folder info from ITS network or fiber group....) **NOTE:** All test result submittals must be received no later than 30 days prior to scheduled start of any associated project ITS network device SALT or sub-system testing to allow adequate time for internal review.

3. EXPLANATION – STANDALONE (SALT) TESTING

Pre-Installation Testing:

- 3.1. Fiber testing is required for all new fiber facilities placed, including any existing fiber facilities modified during a project.
- 3.2. Pre-Installation Testing - Upon delivery, perform visual inspection of fiber cable(s), followed by Uni-Directional OTDR testing of every fiber on each project cable reel. Confirm consistent lengths and ensure that attenuation values do not exceed those allowed per cable attenuation specifications of .35dB per km.
- 3.3. If results are acceptable, save them in PDF format and forward them to NDOT per the instructions located in the "Documentation Required" section of these procedures. If results are unacceptable, reject and replace entire cable reel.
- 3.4. Confirm that all fiber optic cable, pigtails, jumper cables and patch panels have been tested in the factory to demonstrate compliance with the performance requirements of these procedures. Submit a copy of the results of factory tests as per instructions located in "Documentation Required" section of these specifications.
- 3.5. At job site, perform pre installation visual inspection of all cable again. Replace any material that is found to have damage.

Post-Installation Testing:

- 3.6. All fiber strands within each segment must be tested individually inclusive of cabinet to cabinet, Fiber Hut to cabinet, and Fiber Hut to Fiber Hut paths.
- 3.7. **Note:** Prior to initiating post-installation testing, obtain an electronic copy of the NDOT Loss Budget / Test Summary spreadsheet which will be utilized to log actual attenuation values recorded during OTDR and Power Meter testing for each fiber segment associated with the project. Contractor will record all required loss measurement values on the Loss Budget Test Summary Sheet while performing tests. The fields located on the form for A.) no. of connectors, B.) no. of splices, and C.) length (in kilometers), will be populated by contractor based on values obtained from OTDR traces upon execution of tests, and the spreadsheet will then calculate a budget utilizing the following formula and associated acceptable loss values. Actual recorded losses are then entered by the contractor in the relevant fields on the spreadsheet for pass/fail flags in comparison to budgeted loss allowances.
- 3.8. Loss Budget calculation for each fiber segment installed within project scope:
Cable Attenuation (length in kilometers) + Connector Attenuation (# of connectors) + Splice Attenuation (# of splices)
- 3.9. 8.2 μm (nominal) Singlemode Attenuation Coefficients:
Single-Mode Cable Attenuation = 0.35 dB/km at 1310nm and 0.25 dB/km at 1550nm
Attenuation Calculation Formula = Cable Length (km) x (0.35 dB/km at 1310nm or .25 dB/km at 1550nm)
Connector Attenuation = .25 dB per connector (.5 dB per mated pair)
Average Splice Attenuation (Bidirectional Averaged Loss) = .08 dB per splice maximum
- 3.10. Perform post - installation testing. Replace any cable in its entirety that is found not compliant to this specification. Perform the following post-installation tests using the procedures of TIA/EIA 526-7-A and all standards and procedures invoked therein, subject to the following clarification:
Contractor to create and submit a test checkoff sheet denoting each fiber path to be tested in order to ensure that all associated project fiber strand/segments/links are tested. All spare/unassigned fibers in associated project cable must be tested as well from end to end for each fiber path.
- 3.11. Deploy one technician at each end of fiber segment under test, with OTDR's and Power Meter or Light Source.
- 3.12. Scope and clean all fiber connections prior to initiating OTDR testing.
- 3.13. Connect 1 km launch reel to fiber strand under test at A side.

- 3.14. Connect 1 km launch reel to fiber strand under test at B side.
- 3.15. Uni-directional OTDR tests will be conducted on single mode fiber at 1310nm and 1550nm wavelengths, from both directions on each fiber segment (A->B, B->A).
- 3.16. Scope and clean all fiber connections prior to initiating OTDR testing. Conduct Uni-directional OTDR tests on single mode fiber at 1310nm and 1550nm wavelengths, from opposite ends of each fiber segment. Verify that OTDR **launch** port reflectance levels, indicated in OTDR traces are at a maximum level of -40.0 dB (-50.0 dB to -70.0 dB is preferred). If reflectance values outside this range are observed (e.g. -39.0, -28.3, etc.), re-clean launch reel connector and OTDR launch port, then re-establish connection and re-test until the desired reflection levels are achieved. Also verify that reflection levels at the connector on equipment side of the launch reel are at the same maximum value reflection limits as those indicated above for the OTDR launch port connection. If this is not the case, clean the equipment-side launch reel connector and mated equipment connector, then re-test until these levels have been achieved.
- 3.17. During the period that the technician is testing from the A side of the fiber segment, a 1-km launch reel must be connected at the opposite end (B side) of the segment as well, (without connectivity to the B location OTDR launch port in order to avoid damage to the far-end OTDR), in order to ensure OTDR visibility of the far-end loss/reflection values. The same procedure applies when testing in the opposite direction (from B side to A side), where the A side OTDR would then be disconnected from the launch reel, but the launch reel remains connected to the facility being tested.
- 3.18. After Uni-directional OTDR tests have been conducted from both ends of the fiber segment, utilize OTDR software to combine the Uni-directional tests for each fiber into Bi-directional files, which demonstrate averaged loss for the tested segment.
- 3.19. Provide both uni-directional and bi-directional averaged OTDR test result files for each fiber path from the Fiber Hut to all field equipment, and between field devices inclusive of all ancillary fiber cabling and patch panels. Demonstrate that the attenuation for each fiber path, termination, and splice, both individually and collectively, meet requirements per the associated segment Loss Budget and the specifications contained herein.
- 3.20. Submission of failed test results that do not meet previously identified specifications is not acceptable unless already discussed with, and approved by NDOT Fiber Management personnel. Each event must be clearly annotated on test

results (cable segment, connector, jumper cable, pigtail, splice, etc.) and identify the measured loss.

3.21. Complete the Loss Budget Summary form with relevant measurements obtained from OTDR uni-directional testing **and** bi-directional averaged measurements for each segment and submit to NDOT, along with all supporting OTDR uni-directional and bi-directional traces in PDF format for review and approval. Submit test results as per instructions included under "Documentation Requirements" contained within these procedures.

3.22. **Ensure that OTDR trace files in PDF format include the following information:**

Test Date/Time, Job ID, Contractor (Company), Customer (NDOT), A Location, B Location, Operator A name, Operator B name, Cable ID, Fiber ID (in filename and Fiber ID field), Span Loss, Span Length (km), Average Loss (dB/km), Average Splice Loss (dB), Maximum Splice Loss (dB), Span ORL (dB), trace graph with horizontal axis indicating distance and vertical axis indicating attenuation scale, summary event table displaying each event exceeding .01dB loss, event type, position / length (km), loss measurement, reflectance values, cable section attenuation value (dB/km), cumulative loss. OTDR model number, OTDR serial number, calibration date.

Test Parameters to be included on OTDR traces

Wavelength, Range, IOR, RBS, Acquisition time (duration), Pulse Width, Helix Factor, Splice Loss Detection Threshold, Reflectance Detection Threshold, End-of-Fiber Detection Threshold.

3.23. Power Meter Testing - Immediately following OTDR testing for each location / cable segment, conduct optical loss testing with a Power Meter and Light Source on the same cable segment / fiber strands as was tested with the OTDR. Use test jumpers that meet the requirements of EIA/TIA-455-171. Prior to initiating Power Meter testing, ensure nulling of power meter is performed if required by manufacturer, as well as test jumper referencing. Once test jumper reference has been taken, maintain the jumper connection to the Light Source test equipment, or re-reference the test jumper anytime connection to Light Source is broken during test session(s). Verify via cleaning and scoping that fibers to be tested are clean and that connectors have been mated properly. Test each fiber cable segment with Power Meter on one side of fiber segment, and Light Source on other side of segment. Test at 1310nm and 1550nm, ensuring that power meter and light source

are set to the same wavelengths. No launch reels should be used when conducting power meter loss testing, utilize jumpers no longer than 3 meters in length, equipped with connectors that are compatible with the test equipment and plant being tested. Provide Power Meter test results in PDF format. Also utilize the Loss Budget Summary form to log the loss measured by power meter testing for each segment in the relevant fields of the form.

- 3.24. When submitting test data, identify each fiber by cable (as it is identified in the field on plans), buffer tube (fiber number), and assignment (e.g. Spare, Data 0 4, CCTV 26, etc.). Include the Loss Budget Summary sheet with each submittal that clearly illustrates length and measured event loss for each fiber path as created during project construction. Provide calculations and notations for each fiber or fiber path and wavelength that include total loss, measured dB/km loss, the number of connectors/terminations, pigtails, and jumper cables along with any notes for splice measurement anomalies over 0.08dB (bi-directionally averaged). Following completion of all testing, compile and submit test results, which includes the NDOT Loss Budget / Test Summary Excel Spreadsheet, supporting uni-directional and bi-directional OTDR traces, and Power Meter test results in PDF format via the instructions listed in the "Documentation Required" section of these procedures.

FIBER OPTIC TESTING PROCEDURE

TEST #	FIBER TEST PROCEDURE	EXPECTED RESULT	PASS / FAIL
Project Name / Number: _____		Location: _____	
<i>Purpose and General Verification</i>			
<p>System Integrator: This SALT tests the integrity of installed fiber optic cable. The technicians conducting these tests will utilize Optical Time Domain Reflectometers and Power Meters to perform the testing. Using this test equipment, the contractor will be able to measure the amount of loss over the fiber optic cabling installed and verify that these measurements meet NDOT standards, as well as confirming continuity over the fiber between various segments or endpoints.</p> <p>General Verification: For each test below, complete the Fiber Optic Testing SALT Matrix, circling the "Pass" or "Fail" in the appropriate cell. Only indicate a "Pass" on this form if the entire matrix column related to the tested function passes for EACH Fiber Strand being tested.</p>			
<i>Test Equipment Information / Optical Time Domain Reflectometer (OTDR) and Power Meter</i>			
1.	OTDR - Verify information using the manufacturer software version and device label.	Manufacturer: _____ Model: _____ Serial Number: _____ Firmware Version: _____	Calibration Date: _____
2.	OTDR - Verify information using the manufacturer software version and device label.	Manufacturer: _____ Model: _____ Serial Number: _____ Firmware Version: _____	Calibration Date: _____
3.	Power Meter - Verify information using the manufacturer software version and device label.	Manufacturer: _____ Model: _____ Serial Number: _____ Firmware Version: _____	Calibration Date: _____
4.	Light Source - Verify information using the manufacturer software version and device label.	Manufacturer: _____ Model: _____ Serial Number: _____ Firmware Version: _____	Calibration Date: _____
<i>Fiber Testing</i>			
1.	Verify test parameters on OTDR equipment is identically configured at both ends of segment being tested.	Same configuration applied.	Pass / Fail
2.	Launch reels in place at both ends of fiber segments being tested with OTDR.	Launch reels utilized at both ends of fiber tested with OTDR's.	Pass / Fail
3.	Verify test parameters on Power Meter equipment is identically configured at both ends of segment being tested.	Same configuration applied.	Pass / Fail

4.	Loss Budget / Test Summary Sheet	Utilized to log OTDR and Power Meter test results.	Pass / Fail			
5.	Uni-directional OTDR testing conducted on all fiber strands in each project segment.	Completed.	Pass / Fail			
6.	Power Meter testing conducted on all fiber strands in each project segment.	Completed.	Pass / Fail			
7.	Bi-directional OTDR test results compiled for all fiber strands in each project segment.	Completed.	Pass / Fail			
8.	All test results reviewed and confirmed as meeting NDOT fiber acceptance standards.	Completed.	Pass / Fail			
9.	Completed Loss Budget / Test Summary Sheet, all uni-directional and associated bi-directional OTDR test results, and all Power Meter test results compiled and uploaded to NDOT as per requirements.	Completed.	Pass / Fail			
Signatures						
DATE	AGENCY/FIRM	PERFORMED BY (Print Name)	INTL	AGENCY/FIRM	WITNESSED BY (Print Name) (NDOT)	INTL
Contractor Signature						
NDOT Signature						

