DEPARTMENT OF THE NAVY
NAVAL SURFACE WARFARE CENTER
CARDEROCK DIVISION

NAVAL SHIP SYSTEMS
ENGINEERING STATION
5001 S. BROAD STREET
PHILADELPHIA, PA 19112-1403

IN REPLY REFER TO
9504
Ser 963210/06-005

OCT 3 1 2005

From: Commanding Officer, Naval Surface Warfare Center,
Carderock Division, Naval Ship Systems Engineering Station
To: Defense Logistics Agency,
Defense Supply Center Columbus (Code VQP)

Subj: OPTICAL TEST MEASUREMENT GUIDE, QUALIFIED PRODUCTS LIST, TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Encl: (1) Optical Test Measurement Guide, Revision B, dated 31 October 2005

1. Purpose.

This letter addresses the requirements for performing optical test measurements on Fiber Optic Cable Topology (FOCT) components. Proper optical test measurement documentation and performance are required for test laboratory suitability status audits from the Defense Supply Center Columbus (DSCC), proper test performance to FOCT military specifications (such as Qualified Products List or QPL inspections), and a complete review of test procedures and test reports. The applicable FOCT military specifications, that are under DSCC cognizance and require QPL testing, are as follows: MIL-PRF-24623, MIL-I-24728, MIL-C-28876, MIL-PRF-29504, MIL-PRF-49291, MIL-C-83522, MIL-PRF-85045. An optical test measurement guide has been prepared to address military requirements and methods of performance. Enclosure (1) of this letter is an updated version of this guide in which comments under revision B have been incorporated.

2. Background.

Naval Surface Warfare Center, Carderock Division, Ship Systems Engineering Station (NSWCCD-SSES) is tasked by the Naval Sea Systems Command (NAVSEA) to provide technical support for qualification and test efforts regarding FOCT components. One subtask is to provide technical support/consultation to DSCC. As part of the subtask, NSWCCD-SSES has supported DSCC in the past efforts to qualify component vendors. These efforts include auditing of their in-house test facilities or an independent, commercial test laboratory, clarifications of requirements in military specifications, review of documentation (such as test procedures and reports) and other miscellaneous technical support. Development of this optical test measurement guide is another type of support being provided.

3. Distribution statement

Distribution Statement A: Approved For Public Release, Distribution Is Unlimited.

4. Addressees.

This letter is intended for DSCC and other Government agencies/activities, parties in direct support of the Government agencies/activities, vendors, and out-of-house (outside the component's vendor facilities or independent) test laboratories.

Subj: OPTICAL TEST MEASUREMENT GUIDE, QUALIFIED PRODUCTS LIST, TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

5. Point of contact.

DSCC-VQP is to be the initial point of contact for the qualification issues/inquiries that pertain to this matter. Principle point of contact is J. Casto. He can be contacted by telephone: (614) 692-7076 or E-mail: john.casto@dla.mil. Alternative point of contact is Richard Marbais. He can be contacted by telephone: (614) 692-0620 or E-mail: richard.marbais@dla.mil. NSWCCD-SSES point of contact for technical support to DSCC on this matter is E. Bluebond.

K. COLVILLE
By direction

Copy to:
NAVSEA 05Z5 (M. McLean)
NAVSEA PEO IWS (J. Moschopoulos)
NAVSEA PEO IWS (H. Lewis)
NSWC DD B35 (G. Brown)
NSWC DD B35 (R. Throm)
NAVAIR 3.2 (M. Breckon)
NAVAIR 4.1D/6.7.1.6 (H. Proffitt)
NAVAIR 4.4.4.3 (J. Collins)
NAVAIR 4.4.4.3 (D. Harrell)
NAVAIR 4.5.1.1 (G. Walles)
NAVAIR 4.5.6 (T. Curran)
NAVAIR 4.5.7 (B. McDermott)
NAVAIR 4.5 7 (M. Beranek)
NAVAIR 4.5.7 (J. Namkung)
NAVAIR 4.5.7 (M. Hackert)
NAVAIR 4.8.1.3 (A. Michon)
SPAWAR PMW-160 (N. Freije)
SPAWAR PMW-160 (R. Orchard)
SPAWAR. PMW-164 (R. Evans)
SPAWAR 04N-43A (D. Zsutty)
SPAWAR 051 (C. Suggs)
SPAWAR 053 (D. Kinsey)
DSCC-VQP (J. Casto)
DSCC-VAT (D. Leight)
DSCC-VCB (J. Hemmila)

OPTICAL TEST MEASUREMENT GUIDE, TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Revision: Original
29 February 2004
Revision: A
28 February 2005
Revision B
31 October 2005

Enclosure (1)

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Table of Contents

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section I

Introduction

1. Intended use.
   a. This Optical Test Measurement Guide is intended for Government Personnel (including Government contractors acting on behalf of the Government) performing audits of test laboratories doing testing for fiber optic cable topology (FOCT) components
   b. This Optical Test Measurement Guide is intended for Government Personnel reviewing optical test procedures for a FOCT component.
   c. This Optical Test Measurement Guide is intended for Government Personnel reviewing optical tests as part of a test report for a FOCT component.

2. Supplemental use.
   a. This Optical Test Measurement Guide is intended to identify to vendors and test laboratories the areas of emphasis for Government review for optical test measurements performed as part of a FOCT component qualification process.

3. Format.
   a. Descriptive format. Sections II through XII contain test methodology and performance requirements in a narrative format.
   b. Tabular format. Section XIII contains checklists for the various optical tests in table format. Further clarification of the items in the table can be found in Sections II through XII.

4. Constraints.
   a. This Optical Test Measurement Guide is not intended as a tutorial. There are significant differences in Government mandated optical tests versus performance in some parts of the commercial sector. Commercial entities are expected to be familiar with the test standards cited by the Government for use. This Optical Test Measurement Guide does provide some guidance and clarifications for successful implementation within the test standards cited.
   b. This Optical Test Measurement Guide is not intended to be used in lieu of a test laboratory developing optical test procedures specific to their test instrumentation.

5. Dedication. This Optical Test Measurement Guide is dedicated to Jim Day and the other DSCC auditors who succeeded him. During the first audit of NSWCCD-SSES Fiber Optic Component Test Laboratory on 11 February 1992, Jim asked how are we were in compliance with launch conditions. Since that time, other auditors have inquired about other aspects of optical test performance including a repeated request for a checklist. This document has been prepared in response to these requests.

6. Acknowledgements. Michael Hackert, NAVAIR 4.5.7 and Gair Brown, NSWC DD B35 for efforts, with a strained work schedule, that were made to review the draft of this document. Joel Hemmila, DSCC VCB for his document review and preparation of figures from very crude sketches.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section II

General Requirements

1. Terminology.

   a. Use of term "insertion loss" versus the term "change in optical transmittance". The correct terminology must be used and the proper measurement must be performed.

      (1) Insertion loss. This test is performed when there is the requirement to take a measurement relative to that of the uncut cable. The uncut cable measurement acts as the baseline measurement. The test method to be used may be one of the following variations:

         (a) Original insertion method. Cut the cable, insert the component/device under test (DUT) and take the measurements relative to a baseline measurement of the uncut cable.

         (b) Cut-back method. Take the DUT measurement then perform a cut-back of the cable between the source and the DUT. Place the cut-back pigtail into a bare fiber adapter and obtain the baseline measurement. A wide area detector must be used for power meter measurements when using this variation.

         (c) Simulated cut-back method. Take the DUT measurement then perform a simulated cut-back of the cable between the source and the DUT. The simulated cut-back is performed by disconnecting the DUT and placing the source end of the DUT directly into the power meter to obtain the baseline measurement. A wide area detector must be used for power meter measurements when using this variation.

      No other methods, such as cable assembly loss methods A, B or C per TIA/EIA-526-14, are acceptable for performing this test. No fusion splicing of already constructed cable assemblies is permitted. No disconnection of the source end of the test sample from the source is permitted during this test.

      (2) Change in optical transmittance. This test is performed when there is the requirement to take the measurements during and/or after the test relative to a pre-test measurement. The pre-test measurement act as the baseline measurement.

   b. Use of term "monitor fiber" versus the term "reference fiber". The correct terminology must be used and the proper fiber, if required, employed in the measurement.

      (1) Monitor fiber.

         (a) Background. Per 4.3 of TIA/EIA-455-20, a monitor fiber is used to compensate for instability in the optical source.

         (b) Compliance. A monitor fiber is required unless it can be verified that the stability of the optical source is sufficient to obtain the specified measurement accuracy over the duration of the test. The stability of most optical sources are specified in dB/hr or dB/8 hr, whereas, some tests, especially the environmental ones, are weeks in duration.

      (2) Reference fiber.

         (a) Background. Per 4.2 of TIA/EIA-455-20, the distinction of the reference fiber is that no DUT has been inserted into the middle of the fiber length. The reference fiber is the same fiber type and cable construction as the other channels which a DUT was inserted. The reference fiber is to be placed in close proximity to the cable with the DUT inserted. The reference fiber does go through environmental/mechanical testing. EIA-455-20 referred to this reference lead of optical fiber or fiber optic cable as the "reference fiber". The revision to TIA/EIA-455-20 now refers to it as the "reference specimen". The guide uses the term reference fiber.

         (b) Compliance. Unless required for a particular test, the use of a reference fiber is optional.

2. Test sample configurations.

   a. Connectors and splices. Cable assembly configuration normally consists of 10 meters of cable with the DUT in the middle (at 5 meters) and single ferrule connectors on the ends to mate with the optical instrumentation. For insertion loss tests on multiple termini connectors where a cut-back must be done, a 13 meter length of cable is used with the DUT placed 8 meters from the launch end of the cable. This allows 3 cut-backs to be performed, each cut-back being one meter long.

   b. Optical fiber and cable. DUT lengths are generally over 1000 meters for optical fiber and 500 meters for fiber optic cable. These lengths are required to permit sufficient optical measurement resolution for deviations in optical performance during testing. Some mechanical and environmental tests permit cutting the DUT into multiple sections for testing. Mechanical tests are mostly performed on short lengths (usually less than 10 meters) and environmental tests on longer lengths (150 to 500 meters for fiber optic cable, over 1000 meters for optical fiber). Due to these different lengths, the optical transmittance measurements (for change in optical transmittance) are done in dB for mechanical tests and in dB/km for environmental tests.

3. Environmental Conditions. Test equipment to perform the optical test measurements must be placed in an area in which specified ambient temperature and humidity conditions are maintained. “Standard Ambient” conditions (23 $\pm$ 5°C/73 $\pm$ 9°F & 20 to 70% RH), per TIA/EIA-455-B, is acceptable if the test equipment is built to operate throughout that ambient temperature and humidity range. If not, then the “Controlled Ambient” conditions (23 $\pm$ 2°C/73 $\pm$ 4°F & 45 to 55% RH) are to be followed. For uncontrolled spaces where local weather is normally within the “Standard Ambient” range (or the specified test equipment operating ambient conditions, whichever is more conservative), testing can be performed only when the acceptable conditions exist.

4. Vendor minimum inspection responsibilities. When the vendor has in house capabilities to perform Group A inspections, the vendor is encouraged to do the initial qualification inspections that are also listed under Group A inspections. When the initial qualification is done outside the vendor’s facility, the vendor should submit the results of the Group A inspections to the outside test laboratory for inclusion as part of the initial qualification report.

5. Test conditions.

   a. Connection type at instrument optical port.
      (1) Optical interface connections. Different types of connections may be used to join the optical path and mechanically affix the connection for the cable assembly under test to the instrument optical ports. Instruments include optical sources, detectors and switches.
      (2) Preferred type. It is recommended that there be a direct connection at the instrument optical port. Bare fiber adapters, fusion splices and mechanical splices may cause a noticeable change in optical loss. Also, connectors terminated with a two-part epoxy process are found to give the most stable results at the instrument optical port.

   b. Test setup cable routing to minimize macrobending and microbending.
      (1) Occurrence. Macrobend losses may be caused when the bend in the cable becomes less then a critical bend diameter. Microbend losses may be caused when external forces are applied over a very small area. This applied force is sufficient to place a small bend in the fiber. This bend may change light paths resulting in the coupling of lower and higher order modes. With both macrobend and microbend losses, the higher order modes may be radiated out of the fiber causing a higher optical loss.

(2) Preventative measures. To minimize macrobending, the cable routing shall be done so that any bend is not less than the minimum, long term, bend diameter of the cable. Sharp twists and bends are to be avoided. Cable routing is to avoid protrusions on shelving, runs perpendicular over other cable and other obstacles that may cause microbending. Long term, bend diameter values should be stated in the applicable test procedures.

c. Test interruption.

(1) Occurrence. Test interruption is considered to occur any time the test parameters fall outside of the ones specified. An example would be a temperature deviation exceeding $\pm$ 2 ^{o}C.

(2) Corrective action. Once a test interruption occurs, the test sample shall be brought back to the unstressed condition at a controlled rate. The test shall then be continued from the point of repeating the last cycle prior to the interruption.

d. Environmental chamber test charts.

(1) Requirement. Defense Supply Center Columbus (DSCC) specifies specific data requirements for some test methods. Test charts are required for tests performed in environmental chambers and contain recordings of the environmental conditions (such as temperature and humidity) inside the chamber. The test chart is to include the environmental chamber manufacturer, model and serial number with the date of the recording.

(2) Implementation. Objective evidence that test requirements were achieved whether it be circular chart, stored data on disk or by other means approved by the Qualification Activity. Any stored data must be retained and made available at Government request.

e. Multiple channel optical monitoring.

(1) Number of channels to monitor. Unless otherwise specified, test samples with eight or less fibers/channels require that all channels be monitored. For test samples, excluding fiber optic cable, with higher fiber counts/number of channels, at least eight channels are to be monitored at difference channels on each test sample. A minimum of 12 fibers are to be monitored in fiber optic cable with higher fiber counts (cables having greater than 8 fibers) unless otherwise specified. For optical signal discontinuity, only four channels per test sample must be monitored.

(2) Compliance. Each fiber/channel must be monitored individually with no fiber concatenation allowed. Exceptions will be considered on a per case bases only for test samples with no optical interfaces (such as fiber optic cable) and only for the optical signal discontinuity measurement during mechanical shock and vibration.

f. Recording & verifying pass/fail criteria.

(1) Proper test criteria must be specified. Pass/fail criteria must be stated in the test procedure and available to the operating personnel performing the test.

(2) Proper test fail criteria must be implemented. Operating personnel performing the test are to be knowledgeable in what constitutes a failure. The test laboratory is to determine if each performance requirement for a test is a "pass" or "fail" and record that determination on the data sheet. A description of any failure is to be noted on the data sheet or supplemental documentation. Corrective measures, within the scope of the test setup (such as cleaning and reseating), are to be taken to resolve a failure. If the measurements obtained are outside of the performance requirements, it is designated a failure. Alternative terminology (such as discrepancy or deviation) is not to be used.

(3) Government determination of marginal performance. Government personnel, upon review of test documentation and instrumentation specifications, may determine that data just outside of the performance requirement is marginal. Allowance for this

determination is made when using specialized test equipment for a more unique measurement. This allowance is not applicable for test equipment used in most of the optical tests conducted.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section III

Insertion Loss

Applicable military specifications: MIL-PRF-24623, MIL-PRF-29504, MIL-C-28876, MIL-C-83522

Requirements (pass/fail criteria).

1. Optical performance: The initial insertion loss shall not exceed the value (initial loss) specified (see table III-1). Any subsequent insertion loss shall not exceed the value (maximum loss) specified at any time during testing of the device under test

Table III-1. Insertion loss.

Fiber Type (MIL-PRF-49291)	DUT (Termini/ Splice/Connector)	Fiber style	Initial loss (dB)	Maximum loss (dB)
/3	M29504/1 or /12	50/125	N/A	2.00
/3	M29504/2 or /13	50/125	N/A	2.00
/4	M29504/1 or /12	100/140	N/A	1.50
/4	M29504/2 or /13	100/140	N/A	1.50
/6	M29504/14	62.5/125	0.75	1.25
/6	M29504/15	62.5/125	0.75	1.25
/7	M29504/14	SM	0.75	1.25
/7	M29504/15	SM	0.75	1.25
Aerospace 2/	M29504/4	SM	0.75	1.25
Aerospace 2/	M29504/5	SM	0.75	1.25
Aerospace 2/	M29504/4	50/125,100/140	1.00 1/	1.50 1/
Aerospace 2/	M29504/5	50/125,100/140	1.00 1/	1.50 1/
/6 & /7	M83522/16	SM, 62.5/125	1.00 1/	1.50 1/
/6 & /7	M24623/4	SM & 62.5/125	0.2 tuned	0.90
/6 & /7	M24623/4	SM & 62.5/125	0.6 un-tuned	0.90
/6 & /7	M24623/4	SM & 62.5/125	0.6 fixed splice	0.90

1/ Long-term objective: Initial insertion loss shall not exceed 0.75 dB, Maximum loss for subsequent insertion loss tests shall not exceed 1.25 dB.
2/ Aerospace fiber/cables used are to be specified by the Qualifying Activity.

Conductance of test.

1. General.
   a. Test methods. The test method may be performed using one of three variations. These variations (original insertion, cut-back, simulated cut-back) are described in Section II.
      (1) Multimode. Perform in accordance with method A of TIA/EIA-455-34, using both 70/70 and overfill launch conditions. See launch conditions under "Setup" below for specific requirements for initial and subsequent insertion loss testing.
      (2) Single mode. Perform measured in accordance with method B of TIA/EIA-455-34.
2. Test sample configuration. See Section II, General Requirements.
3. Setup.
   a. Generic representation. Three variations on the method to perform the insertion loss measurement is defined under terminology in Section II.
      (1) Insertion loss: Original insertion method. See figure III-1.
      (2) Insertion loss: Cut-back method. See figure III-2.
      (3) Insertion loss: Simulated cut-back. See figure III-3.

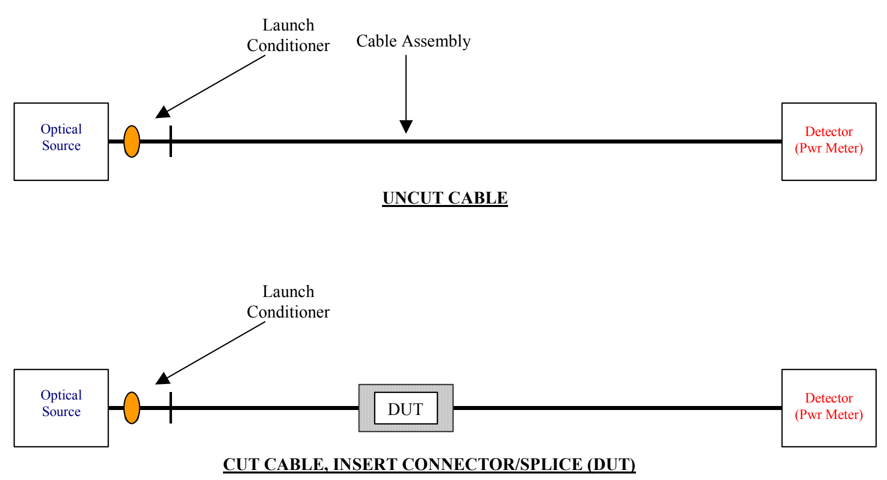


Figure III-1. Insertion Loss: Original Insertion Method

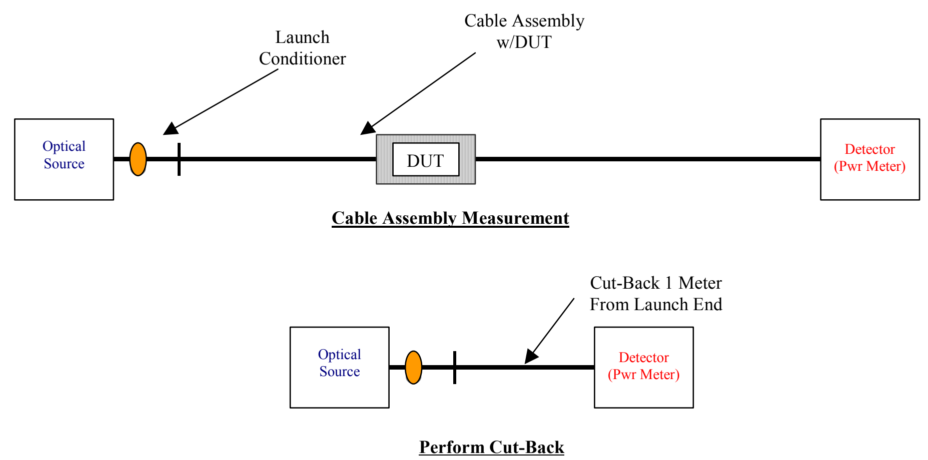


Figure III-2. Insertion Loss: Cut-Back Method

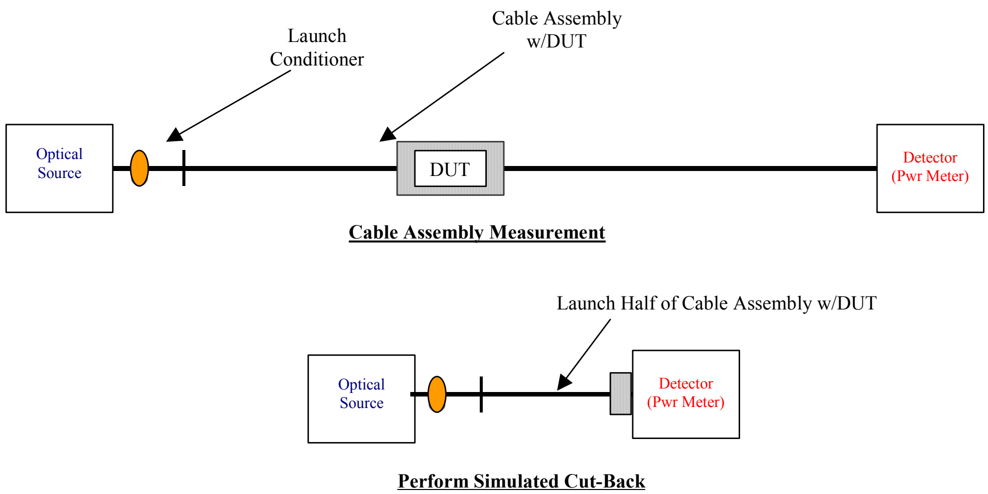


Figure III-3. Insertion Loss: Simulated Cut-Back Method

b. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test.

c. Test equipment. Requirements for test equipment compliance are listed in Section X.
   (1) No switches. Test sample/DUT is connected directly from source to power meter. No intermediary devices, such as switches, that contribute additional sources of error are used.
   (2) Not a cable assembly loss test. No splicing is permitted. The intent is to measure only the insertion loss, not the insertion loss plus end connection losses.
   (3) Use of wide area detector for cut-backs. To ensure all light emitted for the fiber is captured, a power meter with a wide area detector must be used.
   (4) Launch conditions. Requirements for launch conditions are listed in Section XI.
      (a) Insertion loss, multimode.
         1 Initial insertion loss, multimode. Initial insertion loss for components with multimode fiber must be done first using an overfilled launch condition, then repeated with the specified restricted launch condition. For a restricted launch condition, a 70/70 launch conditions or equivalent shall be used as defined in Section XI.
         2 Subsequent insertion loss, multimode. Subsequent insertion loss for components with multimode fiber must be performed with the specified restricted launch condition (see above).
      (b) Insertion loss, single mode. For components with single mode fiber, light launch conditions (mode conditioning for filtering out higher order modes), as listed in Section XI, shall be used.
   (5) Light source(s).
      (a) Optical source wavelength. Measurements are to be taken at 1310 nm for single mode fiber and at 1300 nm for multimode fiber unless otherwise specified.
      Note: For aircraft designated components, the following optical source wavelength constraints shall be used. Single mode fiber optic components shall be tested using optical sources at both the 1310 nm and the 1550 nm wavelengths. Multimode fiber optic components can be tested using an

optical source at either the 850 nm or the 1300 nm wavelength. Current preference is to use the 850 nm wavelength.

Note: For single mode, a different loss mechanism dominates each window. Connection losses are greater at the 1310 nm wavelength. Microbend sensitivity losses dominate the l550 nm wavelength. For multimode, difference in loss at the 850 nm and 1300 nm wavelength are cable length dependent. This loss is greater at the 850 nm wavelength.

(b) Optical source type. The insertion loss test for components with multimode fiber is to be done using an optical source with non-coherent light. Coherent light source (LD) is preferred for components with single mode fiber.

Note: The military specifications state the optical source wavelength (1300 nm window) to use, but not the source type (LED, LD, VCSEL, etc.). Some TIA standards specify the use of a non-coherent or non-monochromatic source. In general, an LED source should be used for components tested with multimode fiber. A laser diode (LD, Fabry Perot type) source is to be used for components with single mode fiber. An LED source used for testing a component with single mode fiber would provide a more conservative result and is not indicative of the way the component would be used in service. If the component passes using this latter configuration, then the test is valid. If the component fails, then the test would need to be repeated using a LD to determine if it is indeed a failure. Also, a LD source provides too optimistic of a result for components tested with multimode fiber and may lead to unacceptable noise in measurements. For consistency in a multiple component test procedure, it is preferable to state the use of an LED source for components tested with multimode fiber and a laser diode (LD) source for components with single mode fiber.

(6) Power meter. See Section X.

d. Verifications.

(1) Verify conformance to requirements for optical light sources and detection system parameters listed above and in Section X.

(2) Verify conformance to requirement for a wide area detector when the cut-back or the simulated cut-back method is used. Unless otherwise specified, a wide area detector for use in the cut-back method with a bare fiber adapter is one with a minimum active surface of 5 mm in diameter (2 mm diameter if verification technique can confirm complete light impingement on active area). The same condition holds for a connector inserted into a different configuration connector port when performing a simulated cut-back. For performing the original insertion loss method, verification of sufficient detector surface area as stated in Section X is acceptable.

4. Test procedure.

a. Test performance, eliminate/reduce other sources of error. The intent is to measure insertion loss and eliminate or minimize potential sources of error.

(1) Connector mates. Variation in mating the connector is minimized by performing the mating ten times. Mates should be done in a manner to that minimizes variation. Techniques such as tying down cabling except close to the connectors, use of substantial receptacle/adapter fixtures and in-line approach to mating/demating connectors should be practiced. Each mating, and not the average of the ten mates, is used in the evaluation of the pass/fail criteria.

(2) Connector mating for cut-backs. For received cable assemblies, ten mates and de-mates are performed. Next the cable is cut back close to the source and a bare fiber adapter is placed on the fiber end. The bare fiber adapter is inserted into the power meter.

(3) No switches. Test sample/DUT is connected directly from source to power meter. No intermediary devices, such as switches, that contribute additional sources of error are used.

c. Test synopsis.

Note: It is assumed that the vendor has prepared the cable assemblies (containing the DUT) and sent to the test laboratory (either in-house or outside) for testing. Test synopsis addresses performance of the cut-back method. This method is used after the DUT has been inserted into the cable assembly.

(1) Perform ten mates and de-mates of the DUT for each measurement channel.

Note: Ten mates and de-mates are to be performed for insertion measurements, but none of the ten measurements can exceed the maximum acceptable value to meet the pass/fail criteria.
Note: For a multiple channel connector, all channels in the connector may not be monitored at once if sufficient number of optical sources and power meters are not available. If this is the case, continue the test with the channels connected before going back and repeating this step for other channels. Once the DUT/channel is connected to the optical source, this connection must be maintained until after the insertion loss measurement is completed for the DUT/channel.

(2) Perform cut-back test measurement.
Note: Depending upon the connection configuration being tested, this may be either a cut-back or a simulated cut-back.
(3) Calculate the insertion loss.
(4) Repeat steps (1) to (3) for other DUT's/channels.

5. Insertion loss calculation (with no monitor fiber used).

$$\text{Insertion loss (OIL)} = -10 \log_{10} (P_1/P_0)$$

Where P_0 = optical power measurement for the uncut cable.
P_1 = optical power measurement with the DUT inserted.
Note: Insertion loss is defined (per the equation above) as a positive value.

6. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list which launch condition was used for samples with multimode fiber (overfilled or restricted) and how the launch condition was achieved.

Insertion Loss Measurements for Multiple Termini Connectors.

1. Methods used. The insertion loss measurement is usually performed twice on the test sample during a test sequence. An insertion loss test is performed prior to the start of a mechanical or environmental test sequence (initial insertion loss test). Once this sequence is concluded, a second insertion loss measurement (insertion loss verification test) is performed. The insertion loss test for multiple termini connectors is performed using the cut back method. Two alternative methods have been done to perform this measurement in the past. One method involved simulating the cut back by removing the terminus in the connector half on the launch end of the cable. The other method involved not disturbing any connections on the measurement system until the insertion loss verification measurement was performed.
2. Implementation.
   a. Simulated cut back. Studies performed to assess optical performance have shown that termini removal and re-insertion into the cavities may impact the optical performance. This process has been shown to be a possible source of error in assessing insertion loss performance.
   b. Not disturbing connections. Each insertion loss test requires a baseline measurement to determine the optical loss prior to inserting the test sample into the cable assembly. A "true" initial insertion loss test is performed by
      (1) Taking the baseline measurement of the uncut cable.
      (2) Cutting the cable in half and inserting the test sample.
      (3) Obtaining the measurement with the test sample inserted.
      (4) Calculating the optical loss (insertion loss).
      If the optical instrumentation is connected at the time prior to taking the baseline measurement and remains connected throughout the test sequence, then the baseline measurement can be used to determine insertion loss for both the initial and verification measurements.
   c. Sending pre-assembled test samples to test laboratory. With a multiple termini connector, the test sample is received as an already terminated cable assembly. No baseline measurement can be obtained unless a cut back or simulated cut back is performed.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section IV

Change in Optical Transmittance Test

Applicable military specifications: MIL-PRF-24623, MIL-PRF-29504, MIL-C-28876, MIL-PRF-49291, MIL-C-83522, MIL-PRF-85045

Requirements (pass/fail criteria).

1. Optical performance: The change in optical transmittance during or after any specified environmental or mechanical requirement shall not exceed the value listed in table I.

Table I. Change in Optical Transmittance.

Device Under Test (DUT) (Termini, Connector, Splice, Fiber, Cable)		Maximum Allowable Change in Optical Transmittance (dB unless noted)	
Specification	Component Description	Mechanical tests	Environmental tests
MIL-PRF-29504	Termini	0.5	0.5
MIL-C-28876	Connector, multiple termini	0.5	0.5
MIL-C-83522	Connector, single ferrule	0.5	0.5
MIL-PRF-24623	Splice	0.3	0.3
MIL-PRF-49291, multimode, graded index & step index	Optical fiber	0.5	0.5
MIL-PRF-49291, single mode, dispersion shifted & dispersion unshifted	Optical fiber	0.3	0.3
MIL-PRF-85045, multimode	Fiber optic cable	0.5	0.5 dB/km 1/
MIL-PRF-85045, single mode	Fiber optic cable	0.2	0.3 dB/km 1/

1/ The change in optical transmittance requirement for freezing water immersion, gas flame, and shock are for the specified test length and shall not be normalized for one kilometer.

Conductance of test.

1. General.
   a. Test methods. The change in optical transmittance shall be measured in accordance with EIA-455-20. The periodicity of the measurements shall be sufficient for the environmental test performed as approved by the qualifying activity.
      (1) Not a stand-alone optical test. This test is not a "stand-alone" test, but performed during various specified mechanical and environmental tests.
      (2) Use of a monitor fiber. Perform utilizing a monitor fiber to compensate for optical source drift during exposure of the DUT to environment/mechanical and other tests of sufficiently long duration (see Section X for requirements/discussion).
      (3) Measurements during test, when specified. The periodicity of the measurements shall be sufficient for the mechanical/environmental test performed as approved by the qualifying activity when the periodicity is not specified.
2. Test sample configuration. See Section II, General Requirements.
3. Setup.
   a. Generic representation.
      (1) Measurement using optical switching system. See Figure IV-1.

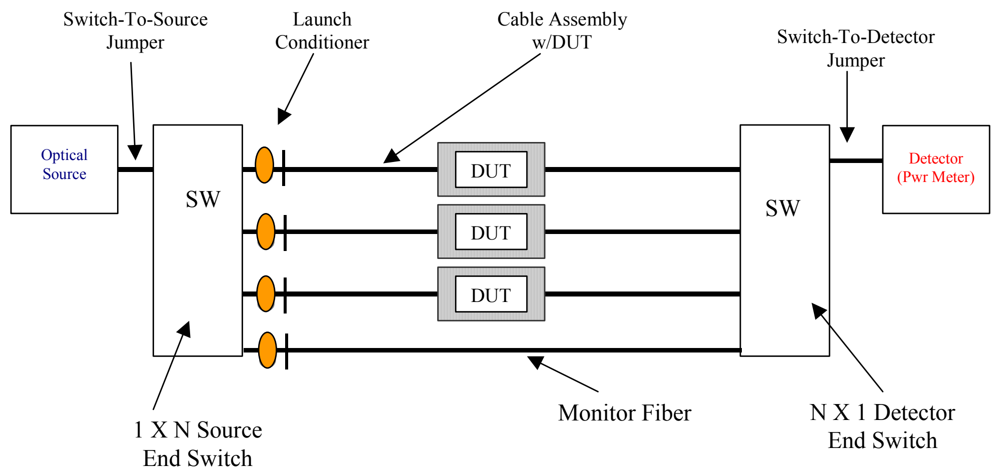


Figure IV-1. Change in Optical Transmittance

b. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test.
c. Test equipment. Requirements for test equipment compliance are listed in Section X.
   (1) Use of multiple channel, optical switches. A measurement system that includes optical switches is acceptable for use with this measurement. Optical switches are permitted with the following constraints:
      (a) Verification for repeatability and stability. Switch repeatability is to be 0.03 dB or better for either random or sequential switching. Drift in any switch channel, relative to a designated monitor/reference channel, is to be 0.06 dB or better within the ambient environmental conditions (see Section II, General Requirements) for a duration of ten days.
      (b) Fiber size. Switches with the same fiber size as the DUT are to be used at the launch end switch. Switches of the same fiber size or larger than the DUT may be used at the detector (receive) end switch. Switches with a smaller fiber size cannot be used. Fiber size includes fiber type.
         1 Launch end switch (1xN). Specified launch condition must be obtained at the output port of each channel using one of the methods in Section XI, Launch Conditions. The test jumper, connecting the optical source to the input port of the switch, is to have the same fiber size as the launch end switch.
         Note: Theoretically, a larger core fiber may be used at the launch end switch; however, difficultly in demonstrating adequate stability precludes its allowance.
         2 Detector (receive) end switch (Nx1). The test jumper, connecting the output port of the switch to the power meter/test set, is to have the same fiber size as the detector end switch.
         Note: Test jumper with a larger fiber size than the detector end switch may be used if it can be demonstrated that all light emitted from the fiber will be captured on the detector.
      (c) Launch condition. Switches must not reduce the launch condition to be more restrictive than the launch condition specified for the test.
      (d) Switching speed. Switching speed must be set so that switch bounce has stabilized and optical power measurements are obtained at a steady state condition.
      (e) Crosstalk effects. Since only one channel is being measured at a time in an automated, multiplexed switching system, taking each measurement after transitory effects have obtained

steady state conditions and not the light transmission path during the transitory timeframe is the issue to address. Crosstalk, from optical power in adjacent channels, should only occur if measurements are obtained before the switch has settled/stabilized.

(2) Splicing.
   (a) Allowance. Splicing is permitted to affix the cable assembly, containing or being the DUT, to the test instrumentation. No splice is to be disturbed from the pre-test optical transmittance measurement to the post test optical transmittance measurement.
   (b) Verification. Test procedure shall be in place and verification shown to demonstrate each splice is low loss and presents a stable connection.

(3) Launch conditions. Requirements for launch conditions are listed in Section XI.
   (a) Multimode. The change in optical transmittance is to be performed using the specified restricted launch condition. For a restricted launch condition, a 70/70 launch condition or equivalent shall be used as defined in Section XI. Note that an exception for the 100/140 micron fiber size is listed in Section XI. The optical source used must provide an overfilled launch condition into the device used to restrict the launch condition. One exception is an optical source built to provide a particular restrictive launch.
   Note: EIA-455-50, replaced by TIA-455-78, stated two methods to achieve restrictive launch. Method A specified 5 turns around a smooth mandrel of different diameter for each core size (same as specified in TIA/EIA-455-34). Method B specified producing a 70/70 launch condition by the use of beam optics. See Section XI to implement compliance for this launch condition.
   (b) Single mode. For components with single mode fiber, light launch conditions (mode conditioning for filtering out higher order modes), as listed in Section XI shall be used.
   Note: EIA/TIA-455-78, replaced by TIA-455-78, references EIA/TIA-455-77 (withdrawn 1/2003) for the higher order mode filter. Mandrel wrap mode filters include those that have a sufficient insertion loss (about 4 dB) or a determined cutoff wavelength. TIA-455-78 (IEC 60793-1-40) states the same two methods as EIA-455-50 for multimode, but is more vague for single mode. An example of a higher order mode filter is given as a single loop of radius sufficiently small to shift cut-off wavelength below the minimum wavelength of interest. See Section XI to implement compliance for the single mode launch condition.

(4) Light source(s).
   (a) Optical source wavelength. Measurements are to be taken at 1310 nm for single mode fiber and at 1300 nm for multimode fiber unless otherwise specified.
   Note: For aircraft designated components, the following optical source wavelength constraints shall be used. Single mode fiber optic components shall be tested using optical sources at both the 1310 nm and the 1550 nm wavelengths. Multimode fiber optic components can be tested using an optical source at either the 850 nm or the 1300 nm wavelength. Current preference is to use the 850 nm wavelength.
   Note: For single mode, a different loss mechanism dominates each window. Connection losses are greater at the 1310 nm wavelength. Microbend sensitivity losses dominate the l550 nm wavelength. For multimode, difference in loss at the 850 nm and 1300 nm wavelength are cable length dependent. This loss is greater at the 850 nm wavelength.
   (b) Optical source type. The change in optical transmittance test for components with multimode fiber is to be done using an optical source with non-coherent light. Coherent light source (LD) is preferred for components with single mode fiber.
   Note: The military specifications state the optical source wavelength (1300 nm window) to use, but not the source type (LED, LD, VCSEL, etc.). Some TIA standards specify the use of a non-coherent or non-monochromatic source. In general, an LED source should be used for components tested with multimode fiber. A laser diode (LD, Fabry Perot type) source is to be used for components with single mode fiber. An LED source used for testing a component with single mode fiber would provide a more conservative result and is not indicative of the way the component would be used in service. If the component passes using this latter configuration, then the test is valid. If the component fails, then the test would need to be repeated using a LD to

determine if it is indeed a failure. Also, a LD source provides too optimistic of a result for components tested with multimode fiber and may lead to unacceptable noise in measurements. For consistency in a multiple component test procedure, it is preferable to state the use of an LED source for components tested with multimode fiber and a laser diode (LD) source for components with single mode fiber.

(5) Power meter. See Section X.

(6) Monitor fiber.

(a) A monitor fiber shall be used unless an allowance is made (see Section II). In this latter case, a monitor fiber is still preferred.

(b) Determination based on source stability. For tests of a short duration (less than 1 hour), a monitor fiber to compensate for optical source stability is not required (based on detector stability requirement of the power meter listed in Section X). For tests of longer duration, a monitor fiber is required unless otherwise specified by the Qualifying Activity after review of data from optical transmittance instrumentation (see Section X).

(7) Coupler (splitter).

(a) Mode filtering. A coupler cannot be used as a mode filter. Specifically, a coupler must have the same core size as the fiber with the component being tested. For example to provide a restricted launch condition, a coupler with 50/125 micron fiber is not to be used when the fiber size for the component being tested (DUT) is 62.5/125.

(b) Modal dependence. A fused biconnic coupler is typically more mode sensitive, a substrate filter coupler less sensitive.

(c) Splitting or branching effect on launch condition. Couplers do not necessarily pass the launch condition through unchanged. Some legs may be more restrictive, one or more legs may be more fully filled (lower order modes may split down one or more legs whereas higher order modes down other legs).

(d) Fiber size for acceptable usage. Use of a coupler with the same fiber size as the fiber for the component being tested is acceptable. This acceptance is contingent upon verification of acceptable launch conditions at the output legs of the coupler/acceptable launch conditioning after the coupler.

d. Verifications.

(1) Verify conformance to requirements for optical light sources and detection system parameters listed above and in Section X.

(2) Verify instrumentation used in the performance of the change in optical transmittance test meets the optical stability requirements (see verification requirements in Section X). This verification is to be done and submitted for approval prior to start of testing. The test procedure must list the test equipment to be used. Verification must be submitted for optical stability of the test instrumentation.

(3) Verify switch repeatability and stability. Switch repeatability is to be 0.03 dB or better for either random or sequential switching. Drift in any switch channel, relative to a designated monitor/reference channel, is to be 0.06 dB or better within the ambient environmental conditions (see Section II, General Requirements) for the duration of ten days.

4. Test procedure.

a. Method.

(1) Baseline. A pre-test, optical power (transmittance) measurement is made. This is considered as the baseline measurement. Subsequent optical power (transmittance) measurements are obtained at specified times during and after the test or only after the test.

(2) Subsequent measurements. All optical power measurements, subsequent to the pretest measurement, shall be referenced to the pretest measurement. The change in the optical transmittance, calculated in dB, shall be included as part of the data for the mechanical/environmental test to determine compliance to this optical requirement.

b. Test performance, sources of error. The intent is to measure change in optical transmittance and eliminate or minimize potential sources of error.

(1) Mating and un-mating during the test. Connections are to be left mated during the test. It is recognized that some specifications state to test "mated and un-mated connections". Connector performance during the test is to be evaluated under the mechanical/environmental condition imposed; therefore, each DUT must remain mated. Connections are to remain mated from pre-test measurement until after post test measurement.

(2) Environmental Test Conditions. The specific ambient conditions of temperature and humidity under which the test is to be performed. For change in optical transmittance measurements, the ambient test condition in which the optical test instrumentation is placed, outside of any test apparatus, is relevant and must be specified to verify compliance. Also, DSCC requires that the ambient temperature and humidity during the test be listed on the data sheet. This information is in addition to those required when a test/environmental chamber is used.

c. Test synopsis.

(1) Perform the baseline or pre-test, optical transmittance measurement prior to initiating the mechanical/environmental test condition.

(2) Perform optical transmittance measurements during the test at the specified test intervals.
Note: Some tests require only the change in optical transmittance after the test. In this case, only the baseline and post test measurements are required. Optical transmittance measurements may be obtained during the test for engineering informational purposes, but are not to be considered in evaluating the pass/fail criteria.
Note: When no measurement intervals are specified for an environmental test, at a minimum optical transmittance measurements are to be obtained during each high and low temperature plateaus for each cycle.

(3) Perform post test measurement.
Note: It is acceptable to wait 24 hours for the cable assembly to return to stable/ambient conditions after the conclusion of the test prior to obtaining the post test measurement. The DUT is not to be disturbed until the post test measurement is obtained.

5. Calculation, change in optical transmittance (with a monitor fiber being used).

a. Change in optical transmittance (OOT) = $\Delta D_i = -10 \log_{10} (P_{ti}/P_{Mi}) - 10 \log_{10} (P_{to}/P_{M0})$

Where:

P_{t0} = optical power measurement of the DUT/DUT channel before the start of the test.
P_{M0} = optical power measurement of the monitor fiber before the start of the test.
P_{ti} = optical power measurement of the DUT/DUT channel at a specified point during or after the conclusion of a mechanical or environmental test.
P_{Mi} = optical power measurement of the monitor fiber at a specified point during or after the conclusion of a mechanical or environmental test.
ΔD_I = Change in optical transmittance at a specified point during or after the conclusion of a mechanical or environmental test.

Notes:

The change in optical transmittance is defined (per the equation above) as a negative value for a decrease in the transmitted power. A decrease in optical power, from a baseline measurement, is an increase in the optical loss or attenuation.
The subscript "$_o$" = the baseline or pre-test measurement.
The subscript "$_i$" = a specific test measurement in the sequence of the test where "i = 1, 2, 3 …n" and n = the post test measurement.

b. Length normalization measurement. Unless otherwise specified, the change in optical transmittance shall be normalized for optical fiber and for fiber optic cable that are (1) undergoing environmental testing and (2) where the length of the sample exceeds 15 meters or the requirement for optical performance is specified in dB/km. Normalization shall be done for one kilometer.

c. Reference fiber measurements. Optional reference fiber measurements may be obtained, but may not be used in the denominator or the change in optical transmittance calculation in lieu of the monitor fiber. The cable assembly is supposed to be constructed with already tested components (as was not always the case early in the Military fiber optic QPL program). Any effect seen by a reference fiber should also be referenced to the monitor fiber.

6. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list:
   a. Which launch condition was used for samples with multimode fiber (overfilled or restricted) and how the launch condition was achieved.
   b. Each channel (identifying each DUT, position, monitor or reference fiber).
   c. The calculated value for the change in optical transmittance for each during or post test measurement required to be provided for the test.

Details on various methods to observe for performing this test are as follows:

1. Test sample position during mechanical testing with multiple cycles.
   a. Occurrence. Applicable for mechanical tests in which the position of the test sample is re-positioned or re-oriented during each cycle.
   b. Implementation. Optical measurements are to be obtained at the same position or orientation of the cycle during mechanical testing. If necessary, the cycling may be halted only for the duration required to perform each measurement. The test sample is not to be relaxed while the measurement is performed.

2. Maintain integrity of launch conditions during change in optical transmittance measurements.
   a. Occurrence. Applicable for mechanical tests and environmental tests in which the change in optical transmittance is measured either both during and after the test or only after the test.
   b. Implementation. The instrumentation attached to the test sample must remain affixed to the test sample to maintain the integrity of the launch conditions. This instrumentation is used to measure the change in optical transmittance. As an example, the test sample may be moved from one chamber to another for the thermal shock test. The instrumentation must not be disconnected from the cable launch end during this move.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section V

Optical Crosstalk

Applicable military specifications: MIL-C-28876, MIL-PRF-85045

Requirements (pass/fail criteria).

1. Optical performance:

    a. MIL-PRF-28876: When connectors with 3 or more channels are tested, the signal power levels, or sum of levels of the passive channel or channels, shall be below the signal level of the active channel by at least 60 dB.
    b. MIL-PRF-85045: The far end crosstalk between any two fibers shall be not greater than minus 60 dB below the active fiber optical output level.

Conductance of test.

1. General.
    a. Test methods. The crosstalk measurement shall be measured in accordance with EIA/TIA-455-42.
        (1) Multiple fiber cable. The crosstalk shall be determined between a minimum of three randomly selected fibers in a multiple fiber cable, using each selected fiber sequentially as the actively transmitting element, and measuring the far-end power output of all other fibers in the cable specimen.
2. Test sample configuration. See Section II, General Requirements.
    a. Multiple termini connector. The cable assembly length may be a minimum of 10 meters versus the 20 meter length stated in EIA/TIA-455-42.
    b. Fiber optic cable. The test sample length of 0.5 km for cable supercedes the 20 meter length specified in EIA/TIA-455-42.
3. Setup.
    a. No switches. . For crosstalk, optical source and detector are to be connected directly to the DUT (cable for a cable DUT or cable assembly for connector/splice DUT). See figures 1 and 2 in EIA/TIA-455-42. Test sample/DUT is connected directly from source to power meter. No intermediary devices, such as switches, that contribute additional sources of error are used.
    b. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test until that fiber/channel is no longer the one connected to the optical source (active channel).
    c. Test equipment. Requirements for test equipment compliance are listed in Section X.
        (1) Generic representation.
            (a) Crosstalk: Measurement for cable. See figure V-1.
            (b) Crosstalk: Measurement for connectors. See figure V-2.

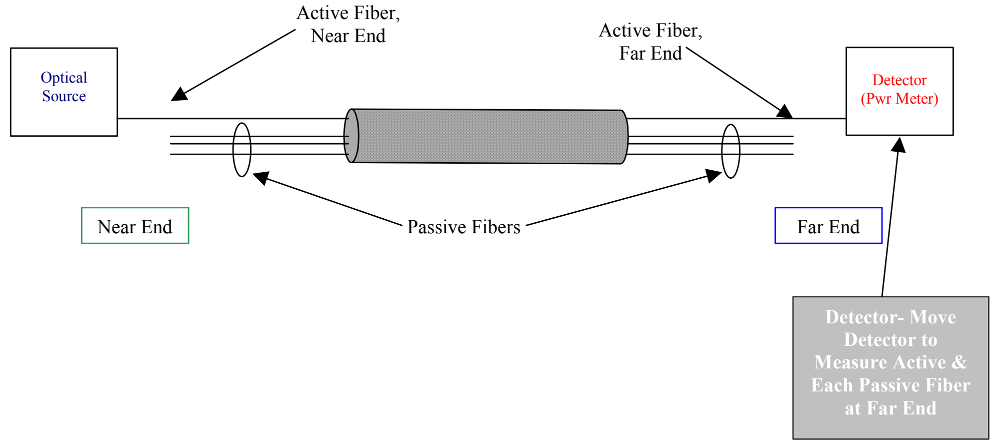


Figure V-1. Crosstalk: Measurement for Cable

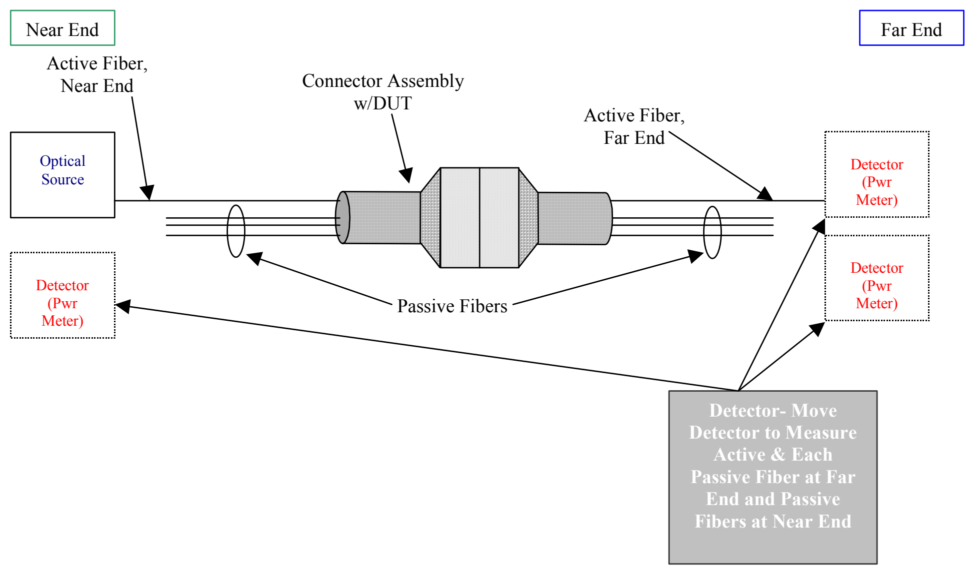


Figure V-2. Crosstalk: Measurement for Connectors

(2) Launch conditions. Requirements for launch conditions are listed in Section XI.
   (a) Multimode configuration. The overfilled launch condition is to be used.
   Note: For the multiple termini connector test sequence, crosstalk may be performed after the initial insertion loss using an overfilled launch condition, but prior to the initial insertion loss using a restricted launch condition.
   (b) Single mode configuration. The 30 mm mandrel specified is applicable for this application
(3) Light source(s). Requirements for parameters specified for the change in optical transmittance and insertion loss tests shall apply.
   (a) Optical source wavelength. Cross talk measurements are to be taken at 1310 nm for single mode fiber and at 1300 nm for multimode fiber unless otherwise specified.
   Note: For aircraft designated components, the following optical source wavelength constraints shall be used. Single mode fiber optic components shall be tested using optical sources at both the 1310 nm and the 1550 nm wavelengths. Multimode fiber optic components can be tested using an optical source at either the 850 nm or the 1300 nm wavelength. Current preference is to use the 850 nm wavelength.
   Note: For single mode, a different loss mechanism dominates each window. Connection losses are greater at the 1310 nm wavelength. Microbend sensitivity losses dominate the l550 nm wavelength. For multimode, difference in loss at the 850 nm and 1300 nm wavelength are cable length dependent. This loss is greater at the 850 nm wavelength.
   (b) Optical source type. The insertion loss test for components with multimode fiber is to be done using an optical source with non-coherent light. Coherent light source (LD) is preferred for components with single mode fiber.
   Note: The military specifications state the optical source wavelength (1300 nm window) to use, but not the source type (LED, LD, VCSEL, etc.). Some TIA standards specify the use of a non-coherent or non-monochromatic source. In general, an LED source should be used for components tested with multimode fiber. A laser diode (LD, Fabry Perot type) source is to be used for components with single mode fiber. An LED source used for testing a component with single mode fiber would provide a more conservative result and is not indicative of the way the component would be used in service. If the component passes using this latter configuration, then the test is valid. If the component fails, then the test would need to be repeated using a LD to determine if it is indeed a failure. Also, a LD source provides too optimistic of a result for components tested with multimode fiber and may lead to unacceptable noise in measurements. For consistency in a multiple component test procedure, it is preferable to state the use of an LED source for components tested with multimode fiber and a laser diode (LD) source for components with single mode fiber.
(4) Power meter. Requirements for parameters specified for the change in optical transmittance and insertion loss tests shall apply (see Section X) except for a more restrictive requirement for the optical noise floor (see below).
   (a) Power level of noise floor. The power level obtained on the active channel must be at least 60 dB above the noise floor to do the measurement. On power meters with simple circuitry, the display will follow the noise power level at the noise floor and not remain constant or hold a value. On power meters with more complex circuitry, the electronics integrates over a sufficiently long time constant to stabilize the displayed value. Measurements can be taken close to the power level at the noise floor.
   (b) Verification. Verification is required to show test equipment is sensitive enough to detect the optical signal. Note that the power in the active channel must be 60 dB above the noise floor of the detector versus 40 dB requirement that is specified in EIA/TIA-455-42.
   (c) Verification calculations.
   The following method may be used to determine if sufficient power to do crosstalk measurement. Numbers provided for the following example using an available test set.
   1 Passive channel. Power level recorded = 0.09 x E –9 W.

10 log ([0.09 x E –9]/E-3) = -70.5 dBm

2 Active channel. Power level recorded = 22.14 x E –6 W.
10 log 0.02214 = -16.5 dBm

3 Subtract active power level from passive power level.

-70.5 dBm
-(-16.5) dBm
54 dBm

Since 54 dBm < 60 dBm, the power meter does not have a sufficient range to do crosstalk measurements.

Note: Reiteration of test equipment verifications required.

1 Verify conformance to requirements for optical light source and power meter parameters.
2 Verify sufficiently low noise floor to adequately measure for crosstalk.

d. Verifications.
   (1) Verify conformance to requirements for optical light sources and detection system parameters listed above and in Section X.
   (2) Verify conformance of optical power meter to requirements at the noise floor (as listed above).

4. Test procedure.
   a. Number of passive channels to test. At a minimum, two adjacent channels/fibers to the active channel/fiber are to be measured.
   b. Test synopsis. Obtain the measurement for the parameters specified for the multiple termini connector or fiber optic cable, as applicable (see Crosstalk calculations below).
      (1) Cable.
         (a) Select, at random, one fiber in the cable and connect an optical source to one end (designated the near end).
         (b) Measure the optical power of this "active fiber" at the other end (designated the far end) of the cable using an approved power meter (see above).
         (c) Measure the far end optical power at the far end for all the other fibers in the cable. These other fibers (channels) are to be passive (i.e., not have an activated optical source at the near end).
         (d) Separately determine the far end crosstalk of each passive channel relative to the designated active channel.
         (e) Calculate the crosstalk.
         (f) Repeat this process for a minimum of three, randomly selected, active fibers.
      (2) Multiple termini connector.
         (a) Select, at random, one fiber in the connector assembly (DUT) and connect an optical source to one end (designated the near end).
         (b) Measure the optical power of this "active fiber" at the other end (designated the far end) of the DUT using an approved power meter (see above).
         (c) Measure both the near end and the far end optical power for all the other fibers in the DUT. These other fibers (channels) are to be passive (i.e., not to have an activiated optical source at the near end).
         (d) Calculate the crosstalk. Determine both the far end and the near end crosstalk of two passive channels, per crosstalk calculation, relative to the designated active channel and to the test fiber.
         (e) Repeat this process for a minimum of three, randomly selected, active fibers.
      (3) Test fiber. To account for the inherent crosstalk in the cable, a measurement may be taken from a separate test fiber with the same cable type and length, but without an inserted connector.

5. Crosstalk calculations.
   a. Test equation parameters. The parameters for the equations to calculate the near end and far end crosstalk for both cable and for connecting devices inserted into cable are as follows:

      (1) Where the parameters for cable are as follows:

P_r Output power of cable (i.e., power of the active channel measured at the output/far end)
$P_{b[j]}$ Near end output power of the test fiber channel [j]
$P_{b[k]}$ Near end output power of the test fiber channel [k]
$P_{f[j]}$ Far end output power of the test fiber channel [j]
$P_{f[k]}$ Far end output power of the test fiber channel [k]

(2) Where the parameters for Multi Terminus Connector (DUT) are as follows: (and DUT = connecting device inserted, designated by subscripts "bi" or "fi" where "i" stands for "inserted" and is not an incremented variable)

P_b Near end output power of the test fiber (with no DUT inserted)
P_f Far end output power of the test fiber (with no DUT inserted)
$P_{bi[j]}$ Near end output power of the test fiber with DUT channel [j]
$P_{bi[k]}$ Near end output power of the test fiber with DUT channel [k]
$P_{fi[j]}$ Far end output power of the test fiber with DUT channel [j]
$P_{fi[k]}$ Far end output power of the test fiber with DUT channel [k]
P_r Output power of DUT (i.e., power of the active channel measured at the output/far end)

(3) And where the crosstalk variants are designated as follows:

CT_f Inherent far end crosstalk of the cable sample
CT_b Inherent near end crosstalk of the cable sample
CT_{fi} Far end crosstalk of the DUT
CT_{bi} Near end crosstalk of the DUT

b. The crosstalk should be calculated, using the TIA parameter designations, as follows:

(1) For cable: The far end crosstalk between any two fibers shall be not greater than minus 60 dB below the active fiber optical output level.

Implementation: Determine the far end crosstalk of each passive channel relative to the designated active channel separately. Equations below illustrate how to perform the calculations for two of the channels in the cable.

Far end crosstalk of the cable sample:
Far end crosstalk of channel [j] = $CT_{f[j]}$ (dB) = -10 $\log_{10}$ [($P_{f[j]}$)/P_r]
Far end crosstalk of channel [k] = $CT_{f[k]}$ (dB) = -10 $\log_{10}$ [($P_{f[k]}$)/P_r].
The requirement is that $CT_{f[j]}$ (dB) and $CT_{f[k]}$ (dB) separately must not be greater than –60 dB.
There is no near end crosstalk requirement for the cable sample.

(2) For cable with a connecting device (connector/splice): When connectors with more than 3 channels are tested, the signal power levels, or sum of levels of the passive channel or channels, shall be below the signal level of the active channel by at least 60 dB.

Implementation: Test all other channels in the DUT (i.e., the passive channels) relative to the active channel. Determine both the far end and the near end crosstalk of two passive channels, per crosstalk calculation, relative to the designated active channel and to the test fiber.

Far end crosstalk of each channel in the DUT: CT_{fi} (dB) = $-10 \log_{10} [(P_{fi} - P_f)/ P_r]$
Near end crosstalk of each channel in the DUT: CT_{bi} (dB) = $-10 \log_{10} [\{(P_{bi} - P_b)/P_r]$

Far end crosstalk of two passive DUT channels ([j] & [k]) relative to an active DUT channel:
$CT_{fi[j,k]}$ (dB) = $-10 \log_{10} [\{(P_{fi[j]} - P_f)+(P_{fi[k]} - P_f)\}/ P_r]$
Near end crosstalk of the DUT:
$CT_{bi[j,k]}$ (dB) = $-10 \log_{10} [\{(P_{bi[j]} - P_b)+(P_{bi[k]} – P_b)\}/ P_r]$

6. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list:
   a. Each measured optical power value.
   b. Each channel (identifying each DUT, position, etc.).
   c. The calculated crosstalk values required.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section VI

Optical Signal Discontinuity

Applicable military specifications: MIL-PRF-24623, MIL-PRF-29504, MIL-C-28876, MIL-C-83522, MIL-PRF-85045

Requirements (pass/fail criteria).

1. Optical performance:

   a. MIL-PRF-24623: No discontinuity shall occur. A discontinuity is considered to be a reduction in optical transmittance of 0.3 dB or more for a duration of 50 microseconds or longer.
   b. MIL-PRF-28876, MIL-PRF-29504: No discontinuity shall occur. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 50 microseconds or longer for termini with multimode fiber. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 100 milliseconds or longer for termini with single mode fiber.
   c. MIL-C-83522: No discontinuity shall occur.
      (1) Multimode, top & back impacts. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 50 microseconds or longer for connectors with multimode fiber tested for the top and back impacts.
      (2) Multimode, side impacts. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 500 microseconds or longer with multimode fiber tested for the side impacts.
      (3) Single mode; top, back & side impacts. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 1 seconds or longer for connectors with single mode fiber.
   d. MIL-PRF-85045: No discontinuity shall occur. A discontinuity is considered to be a reduction in optical transmittance of 0.5 dB or more for a duration of 50 microseconds or longer for fiber optic cable with multimode fiber. A discontinuity is considered to be a reduction in optical transmittance of 0.3 dB or more for a duration of 50 microseconds or longer for fiber optic cable with single mode fiber.

Conductance of test.

1. General.
   a. General remark. This test is not a "stand-alone" test, but it is one optical type measurement performed during a vibration test or a mechanical shock test.
   b. Test methods. The optical signal discontinuity measurements shall be performed in accordance with EIA-455-32 using test equipment having a time resolution sufficient to resolve discontinuities of duration not less than 50 **µ**s. For tests of extended duration (i.e., some vibration tests), optical signal discontinuity measurements may be made at discrete times during the test as approved by the qualifying activity.
2. Test sample configuration. See Section II, General Requirements.
   a. Minimum channels/samples to monitor. A minimum or four DUTs or four channels of a multiple channel DUT are to be monitored for optical signal discontinuity during the specified vibration/shock test.
   b. Fiber optic cable. For the mechanical shock test, a minimum test sample length of 1meter is to be mounted to the shock test fixture.
3. Setup.
   a. Generic representation.
      (1) Optical signal discontinuity: One approach for detection measurement. See figure VI-1.

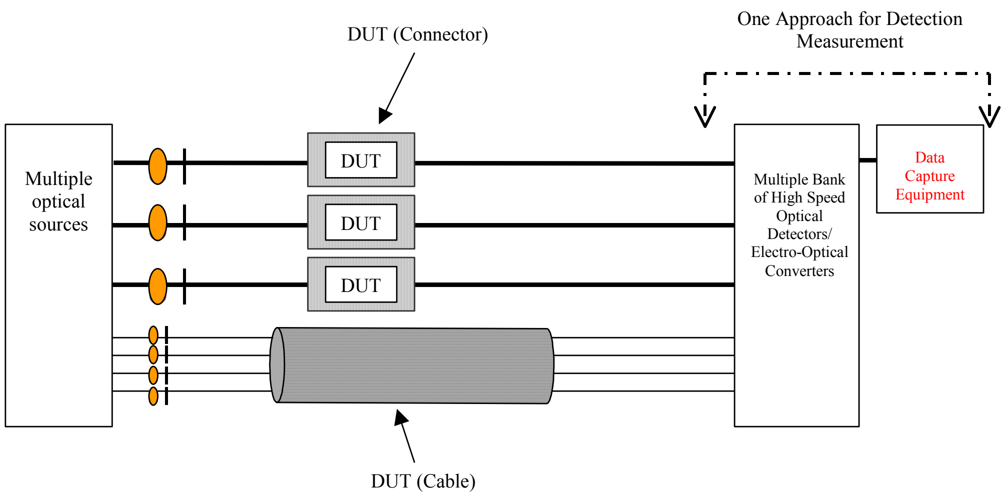


Figure VI-1. Optical Signal Discontinuity

b. No switches. For optical signal discontinuity measurements, the optical source and detector are to be connected directly to each DUT/DUT channel to permit multiple monitoring of at least four DUTs or four channels of a DUT. No intermediary devices, such as switches, that do not allow a direct optical path from the optical source through the DUT to the detector are to be used.
c. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test.
d. Test equipment. Requirements for test equipment compliance are listed in Section X.
  (1) Instrumentation used in the performance of the optical signal discontinuity test is to be verified for optical stability (see verification requirements in Section X). This verification is to be done and submitted for approval prior to start of testing. The test procedure must list the test equipment to be used. Verification must be submitted for optical stability of the test instrumentation.
  (2) Launch conditions. Requirements for launch conditions are listed in Section XI.
    (a) Multimode configuration. The restricted launch condition is to be used.
    Note: Although 3.1.1 of TIA/EIA-45-32 states that testing should be done using overfilled launch conditions, the individual fiber optic military specifications state that the restricted launch condition is to be used for the mechanical and environmental tests for components tested with multimode fiber.
    (b) Single mode configuration. The 30 mm mandrel specified is applicable for this application
  (3) Light source(s). Requirements for parameters specified for the change in optical transmittance and insertion loss tests shall apply.
    (a) Optical source wavelength. Measurements are to be taken at 1310 nm for single mode fiber and at 1300 nm for multimode fiber unless otherwise specified.
    Note: For aircraft designated components, the following optical source wavelength constraints shall be used. Single mode fiber optic components shall be tested using optical sources at both the 1310 nm and the 1550 nm wavelengths. Multimode fiber optic components can be tested using an optical source at either the 850 nm or the 1300 nm wavelength. Current preference is to use the 850 nm wavelength.

Note: For single mode, a different loss mechanism dominates each window. Connection losses are greater at the 1310 nm wavelength. Microbend sensitivity losses dominate the l550 nm wavelength. For multimode, difference in loss at the 850 nm and 1300 nm wavelength are cable length dependent. This loss is greater at the 850 nm wavelength.

(b) Optical source type. The insertion loss test for components with multimode fiber is to be done using an optical source with non-coherent light. Coherent light source (LD) is preferred for components with single mode fiber.
Note: The military specifications state the optical source wavelength (1300 nm window) to use, but not the source type (LED, LD, VCSEL, etc.). Some TIA standards specify the use of a non-coherent or non-monochromatic source. In general, an LED source should be used for components tested with multimode fiber. A laser diode (LD, Fabry Perot type) source is to be used for components with single mode fiber. An LED source used for testing a component with single mode fiber would provide a more conservative result and is not indicative of the way the component would be used in service. If the component passes using this latter configuration, then the test is valid. If the component fails, then the test would need to be repeated using a LD to determine if it is indeed a failure. Also, a LD source provides too optimistic of a result for components tested with multimode fiber and may lead to unacceptable noise in measurements. For consistency in a multiple component test procedure, it is preferable to state the use of an LED source for components tested with multimode fiber and a laser diode (LD) source for components with single mode fiber.

(4) Power meter. Requirements for parameters specified for the change in optical transmittance and insertion loss tests shall apply (see Section X) except for an additional requirement for using test equipment having a time resolution sufficient to resolve discontinuities of duration not less than 50 **μ**s.

e. Use of a monitor fiber.
   (1) Monitoring fiber for optical signal discontinuity. The measurement method may include the use of a monitoring fiber. This method for optical signal discontinuity is an acceptable method; however, the use of a monitoring fiber may be waved for this measurement if the optical source stability is shown to be sufficiently stable and the monitoring fiber is not used to establish the trigger level.
   (2) Monitoring fiber for change in optical transmittance. For shock and vibration testing, of some components, the change in optical transmittance after the test is required in addition to the optical signal discontinuity during the test. An optical measurement system with multiple channel switches may be used for any channel in which only the change in optical transmittance is obtained. In short, the monitoring fiber is not needed strictly for an optical discontinuity measurement. The monitoring fiber can be used as part of the data needed to calculate the change in optical transmittance.

f. Verifications.
   (1) Verify conformance to requirements for optical light sources and power meter parameters (see Section X).
   (2) Verify conformance to requirement for equipment used shall have a resolution sufficient to resolve discontinuities of duration not less than 50 microseconds or as otherwise specified. Verification of sufficient detector response, per 3.2.1.2 of TIA/EIA-455-32 must be provided.
   (3) Verify requirement of accelerometer used to monitor shock testing. Per A2.3 of EIA/TIA-455-14 (or 2.2.3 or MIL-STD-1344 Method 2004), the transducer (accelerometer) used to monitor the shock pulse must be calibrated over an expanded frequency range. The accuracy of the calibration method must be at least $\pm$ 5 percent over the frequency range of 2 to 5,000 Hz. The amplitude of the transducer being calibrated must be $\pm$ 5 percent over the frequency range of 4 to 5000 Hz.

4. Test procedure.
   a. Specific to type of equipment to detect and capture optical power levels (transients) outside of specified limits. Setup and test procedures must be detailed and specific to the test equipment used. Various methods of detection/capture/recording may be used. Items b and c below are provided in lieu of a test synopsis.
   b. Items to inspect/verify prior to test.
      (1) No splicing should be done as part of the optical discontinuity measurement.

(2) End faces clean. Verify that all fiber optic connection end faces are clean prior to mating or interface with the optical source, detector, etc.
(3) Seating. Verify that connectors are seated properly in their adapters and termini within the connector. A weak optical power level may be a function of improper seating, other misalignment or end face contamination.
(4) Saturation. Ensure that no saturation of the optical trace has occurred. Flat horizontal lines in the signal trace close to optical signal peaks are an indication of amplifier saturation.
(5) Reduce optical power between source and optical-electric converter. Place a jumper between the source and optical-electric converter. Obtain a trace measurement. Perform at least 5 wraps of the jumper around a 0.25 inch mandrel. If the optical power level does not change, then the amplifier is overdriven.
(6) Verify that the optical source is transmitting in the external power (un-modulated) or continuous power mode of operation.
(7) Marking position of tightening/fastening mechanisms. Mark place where DUT is tightened/fastened to determine if any optical signal discontinuities are due to movement by the fastening mechanism.

c. Items to inspect/verify during the test.
(1) Look at data after each axis (vibration) or impact (shock). Verify that no optical signal discontinuities occurred prior to proceeding to the next portion of the test.
(2) Post axis/impact results in optical power gain above insertion loss value.
Note: Power level cannot increase beyond that of an uncut fiber (one in which a DUT was not inserted).
a. Determination. Data is invalid. Redo axis/impact.
b. Corrective measures. Inspect for improper seated connectors, large particles/dirt on end face, etc.

5. Calculations.
a. Equation to set the threshold for the trigger. To obtain the threshold from an initial detector voltage from the DUT, the equation is $-0.5 = -10 \text{ Log } (V_{trigger}/V_{DUTinitial})$. From this equation the trigger should be set at 0.9 (or more precisely 0.8912) of $V_{DUTinitial}$. The above equation assumes that there is zero power at zero volts (V_0). If not, then the following equation must be used $-0.5 = -10 \text{ Log } [(V_{trigger} - V_0)/(V_{DUTinitial} - V_0)]$. In the electrical usage, $P_{electrical} = V^2/R$. In the optical usage the $P_{optical}$ is linear with the voltage. In terms of decibels $P_{optical} = -10 \text{ Log } (V_{measured}/V_{reference})$, where as $P_{electrical} = -20\text{Log } (V_{measured}/V_{reference})$.
b. Chart showing duration of optical signal discontinuity. Objective evidence that test requirements were achieved whether it is recorded on a plot/chart, stored data on disk or by other means approved by the Qualification Activity. Any stored data must be retained and made available at Government request. A plot of the variation in optical signal level during each mechanical shock pulse is desired to verify compliance with the optical signal discontinuity requirement in the applicable test specification.
(1) Chart duration. The chart provided must display sufficient duration to see the full extent of the optical discontinuity.
(2) Chart threshold. The chart threshold power should be displayed as “0” and not “1” or other base value.
(3) Chart resolution. Resolution must be sufficient to verify pass/fail criteria.

6. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list:
a. Record/checklist to verify adjustment required by detection equipment were performed properly.
b. Calibration data of detection system if not done on a routine calibration cycle.
c. Recorded voltages and calculated optical transmittance (discontinuity) values if not automated.
d. Sign convention for optical values recorded. State the sign convention for the optical signal discontinuity on the data sheet. For instance, an increase in the optical power level, i.e., optical transmittance, is recorded as + dB. Similarly in this case, a decrease in optical transmittance (decreasing power) is recorded as – dB.

Section VII

Optical Return Loss

Applicable military specifications: MIL-PRF-24623, MIL-PRF-29504, MIL-C-28876, MIL-C-83522, MIL-PRF-85045

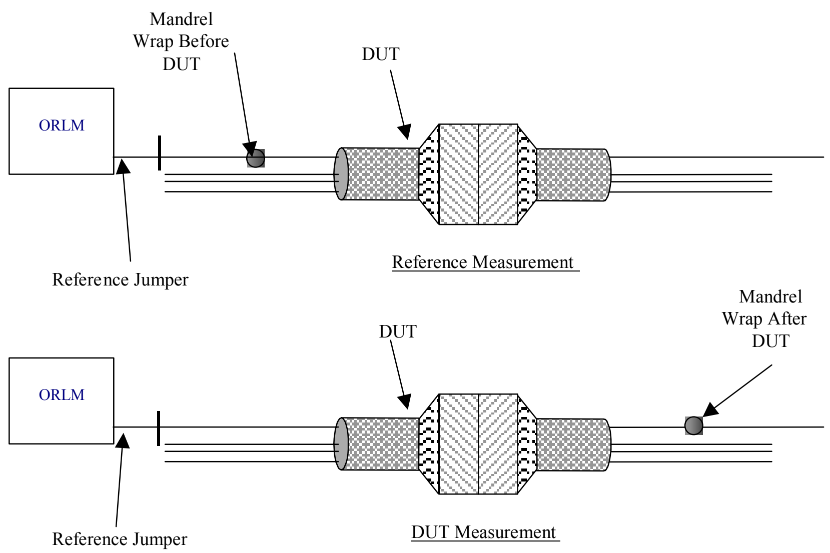
Requirements (pass/fail criteria).

1. Optical performance:

    a. MIL-PRF-24623: The return loss of a multimode or single mode optical terminus shall be not greater than -30 dB.
    b. MIL-PRF-28876, MIL-PRF-29504: The return loss of a multimode or single mode optical terminus shall be not greater than -30 dB. The return loss of an enhanced polish single mode optical terminus shall be not greater than -40 dB.
    c. MIL-C-83522: The return loss of a multimode or single mode optical terminus shall be not greater than -30 dB. Planned addition to specification: The return loss of an enhanced polish single mode optical terminus shall be not greater than -40 dB.

Conductance of test.

1. General.
    a. Test methods. The return loss shall be measured in accordance with TIA/EIA-455-107 or by an equivalent method (for a continuous wave measurement).
    b. Sequence in testing. The return loss measurement is usually performed prior to the start of a mechanical or environmental test sequence (initial return loss test under Group I Optical tests). Once this sequence is concluded, a second return loss measurement (a subsequent return loss or return loss verification test) is performed. Other specifications require return loss measurements after selected tests in the test sequence as opposed to only one measurement after the sequence.
    c. Applicable fiber type. The return loss measurement is performed only on test samples with single mode fiber. Testing for return loss on test samples with multimode fiber is not required, if single mode sample testing is being performed.
2. Test sample configuration. See Section II, General Requirements.
3. Setup.
    a. Generic representation.
        (1) Optical return loss: Test using ORLM. See figure VII-1.
        (2) Optical return loss: Test using coupler. See figure VII-2.



FigureVII-1. Optical Return Loss: Test Using ORLM (Optical Return Loss Meter)

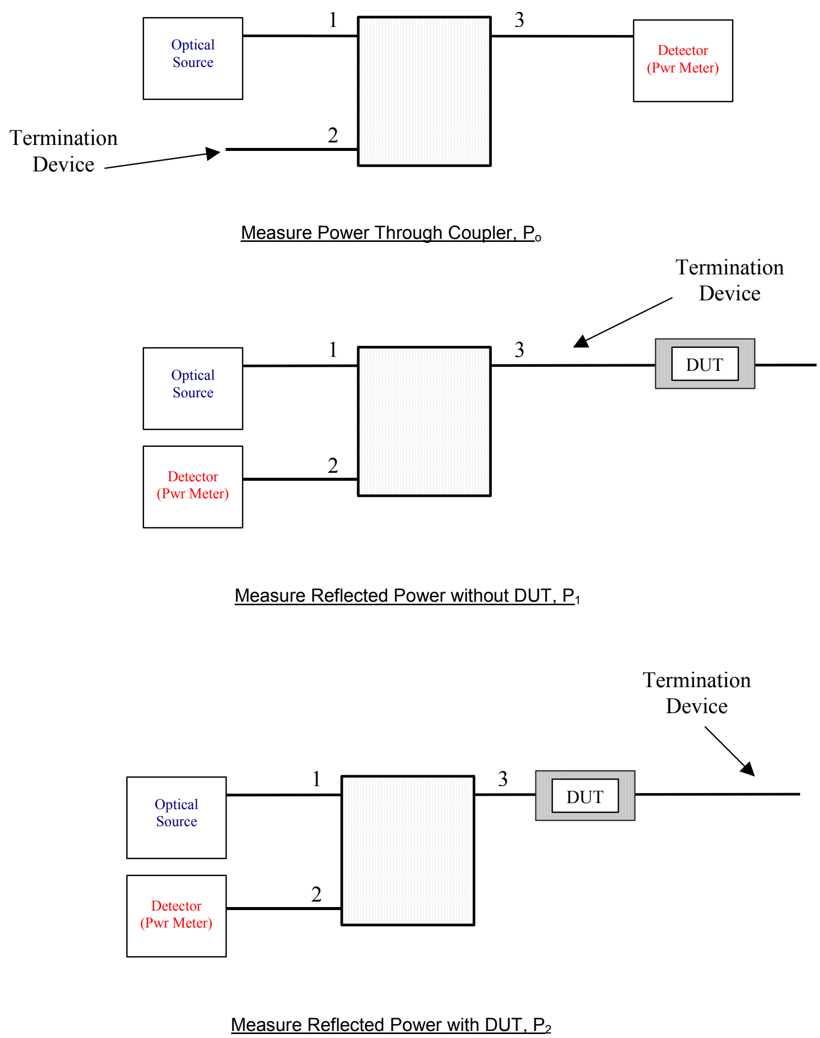


Figure VII-2. Optical Return Loss: Test Using Coupler

b. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test. This disconnection is not allowed once the source end of the DUT is attached to a measurement system for optical monitoring during a series of mechanical or environmental tests.
c. Systems with switches. The return loss test is to be performed from the detector end only, on test samples, when measurements require that the optical path be disconnected for attachment to a return loss meter. No source end test sample removal from the test instrumentation is permitted. Mandrel wrapping during the measurement is to occur without disconnecting any optics at the test sample source end. Disconnecting the optics at the detector end are a source of error for succeeding change in optical transmittance measurements when the detector end is not connected directly to an optical power meter. Errors may be caused, by changing the optical conditions at the detector end, with either of the following instrumentation:
   (1) When a switching system is used.
   (2) When connecting directly to a detector with optics (such as a Grin lens) between the connector and photocell.
d. Test equipment (continuous wave measurements).
   Note: The requirements listed below for the optical source and detection system are applicable when either an Optical Return Loss Meter (ORLM) is used or an equivalent method using an optical source, three port (1x2) coupler (splitter) and power meter is used.
   (1) Light source(s).
      (a) Optical source wavelength. Measurements are to be taken at 1310 nm for single mode fiber and at 1300 nm for multimode fiber unless otherwise specified.
      Note: For aircraft designated components, the following optical source wavelength constraints shall be used. Single mode fiber optic components shall be tested using optical sources at both the 1310 nm and the 1550 nm wavelengths. Multimode fiber optic components can be tested using an optical source at either the 850 nm or the 1300 nm wavelength. Current preference is to use the 850 nm wavelength.
      Note: For single mode, a different loss mechanism dominates each window. Connection losses are greater at the 1310 nm wavelength. Microbend sensitivity losses dominate the l550 nm wavelength. For multimode, difference in loss at the 850 nm and 1300 nm wavelength are cable length dependent. This loss is greater at the 850 nm wavelength.
      (b) Optical source type. The optical discontinuity measurement for components with multimode fiber is to be done using an optical source with non-coherent light. Coherent light source (LD) is preferred for components with single mode fiber.
   (2) Launch conditions. Requirements for launch conditions are listed in Section XI.
      (a) Multimode configuration. The restricted launch condition is to be used. (This is normally achieved through the use of a single mode launch using a ORLM for single mode fiber.)
      Note: Unless otherwise specified, a return loss measurement is not required for components tested with multimode fiber.
      (b) Single mode configuration. Launch conditions are not controlled.
   (3) Detection system.
      (a) Measured reflectance range: 10 to 55 dB minimum.
      (b) Resolution: 0.1 dB minimum.
      (c) Accuracy: $\pm$ 0.5 dB minimum at a return loss of 55 dB.
      (d) Detector size: sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it.
      (e) Detector stability: $\leq$ 0.1 dB/hr.
      (f) Ambient light susceptibility (recommended). Affects of ambient light into the detector need to be controlled.
   (4) Coupler. If an equivalent method with a separate (standalone) coupler is used, the coupler insertion loss shall be determined from methods listed in TIA/EIA-455-180. Separate test procedure for determining the insertion loss for the coupler must be submitted to the Government for approval.

e. Time of flight measurements (other types of test equipment/measurement approaches). Determination of the initial return loss must be done using test equipment and the method that complies with TIA/EIA-455-107. Other technologies (such as OTDR based measuring technique, i.e., time of flight measurements) will be permitted, if approved by the Preparing Activity, with the following constraint. As previously stated, the initial return loss must be first be done using test equipment and the method that complies with TIA/EIA-455-107. Next, the initial return loss must be redone using the other technique. If the measurements are within 1 dB, then the other technique can be used for subsequent return loss measurements.
f. Termination device. Between 5 to 10 turns or wraps around a specified mandrel diameter (usually 6 to 10 mm) is one acceptable method to provide a non-reflective termination. Mandrel diameter and number of wraps must be sufficient to provide a minimum attenuation level required by the measurement (usually 40 dB). Index matching material/gel may be used as a termination device, but is less preferred due to potential cleaning/contamination problems.
g. Verifications.
   (1) Verify conformance to requirements for optical light sources and detection system parameters listed above.
   (2) Verify conformance to TIA/EIA-455-107 test method. If an Optical Return Loss Meter (ORLM) is used, then the internal measurement system must be equivalent to using an optical source, three port (1x2) coupler (splitter) and power meter.
   (3) Verify conformance when alternative measurement approaches (such time of flight) are used. When an OTDR is used, verify measurement compatibility to an ORLM as stated in 4.d above.

4. Test procedure.
   a. Methods for continuous wave measurements. Test performed using an ORLM is the preferred test method
      (1) When using an equivalent method to TIA/EIA-455-107, method A (using two detectors) is more straightforward. Method B (using one detector) reduces one variable. Either method may be used. Method 1 in annex A (using one detector and mandrel wrapping) is acceptable also.
      (2) A time of flight measurement approach (OTDR, etc.) may be used for subsequent return loss measurements provided that the requirements in part d under setup are met.
   b. Reference reflectors are discouraged for use in this test.
   c. When an ORLM is used to make the measurement, no splicing should be done from the ORLM to the mandrel wrap after the DUT.
   d. Test synopsis.
      (1) Test using ORLM.
         (a) Perform the reference measurement. Mandrel wrap before the DUT and reference the ORLM. Verify reference measurement is in acceptable range. Undo mandrel wrap.
         (b) Perform DUT measurement. Mandrel wrap after the DUT with sufficient turns that the measurement is stable. Record the measurement as the value for return loss.
      (2) Test using equivalent method (optical source, coupler, power meter).
         (a) Measure optical power transmitted through the coupler, measurement P_o. Attach optical source at port 1of coupler and the detector to port 3. Place a termination device at port 2.
         (b) Measure optical power reflected back to the input port without a DUT attached at port 3, measurement P_1. Measure the reflected power at port 2 by placing the power meter at this port. The optical source remains at port 1 and a termination device is placed at port 3.
         (c) Measure optical power reflected back to the input port with a DUT attached at port 3, measurement P_2. Measure the reflected power at port 2 with the power meter at this port. The optical source remains at port 1. One end of the DUT is placed at port 3. A termination device is placed at the other end of the DUT.

5. Calculations.
   a. Equation when using equivalent method.
      $L_R = -10 \text{ Log } [(P_2 - P_1)/P_o] - L_C$
      Where:
         L_R = Optical Return Loss (ORL)

L_C = Coupler Insertion Loss found using method in TIA/EIA-455-180
P_2 = Optical power reflected back to the input port when a DUT is attached at port 3 (reflected power at port 2 from optical source at port 1 and the DUT followed by a termination device at port 3).
P_1 = Optical power reflected back to the input port without a DUT attached at port 3 (reflected power at port 2 from optical source at port 1 and a termination device at port 3).
P_0 = Optical power transmitted through the coupler (from optical source at port 1 to detector at port 3 with a termination device at port 2).
Note: Ports 1 and 2 are on one side of the coupler (input ports) and port 3 is on other side (output port).

7. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list:
   a. Termination device (for mandrels, include mandrel diameter and number of wraps used).
   b. Sign convention for optical values recorded. State the sign convention for the measurement performed for each parameter on the data sheet. For instance, Optical Return Loss is recorded as + dB. Similarly reflectance measurement is recorded as – dB.

Section VIII

Attenuation Rate

Applicable military specifications: MIL-PRF-49291, MIL-PRF-85045

Requirements (pass/fail criteria).

1. Optical performance. The attenuation rate shall not exceed the values specified in table VIII-1. The change in attenuation for fiber optic cable shall not exceed the values specified in table VIII-2. For initial qualification, the pass/fail criteria include both the attenuation rate and the attenuation change. For Group A testing, only the attenuation rate is required.

Table VIII-1. Attenuation Rate.

Device Under Test (DUT) (Optical Fiber, Cable)	Maximum Allowable Attenuation Rate (dB/km) at Wavelength (nm) to be Measured			
	Single mode		Multimode	
	dB/km at 1310 +/- 20 nm	dB/km at 1550 +/- 20 nm	dB/km at 850 +/- 20 nm	dB/km at 1300 +/- 20 nm
MIL-PRF-49291	0.4	0.3	3.5	1.0
MIL-PRF-85045 General	1.0	1.0	4.5	2.0
MIL-PRF-85045/13	1.0	1.0	4.5	2.0
MIL-PRF-85045/15	1.0	1.0	4.5	2.0
MIL-PRF-85045/16	1.0	1.0	4.5	2.0
MIL-PRF-85045/17	1.5	1.5	4.5	2.0
MIL-PRF-85045/18	1.5	1.5	4.5	2.0
MIL-PRF-85045/19	1.0	1.0	4.5	2.0
MIL-PRF-85045/20	1.5	1.5	5.6	2.0
MIL-PRF-85045/21	2.0	2.0	4.5	2.0
MIL-PRF-85045/22	1.0	1.0	4.5	2.0
MIL-PRF-85045/23	2.0	2.0	4.5	2.0
MIL-PRF-85045/24	2.0	2.0	4.5	2.0
MIL-PRF-85045/27	0.75	0.75	3.75	1.25
MIL-PRF-85045/29	0.75	0.75	3.75	1.25

Table VIII-2. Change in Attenuation.

Device Under Test (DUT) (Optical Fiber, Cable)	Maximum Allowable Change in Attenuation (dB/km) at Wavelength (nm) to be Measured			
	Single mode		Multimode	
	dB/km at 1310 +/- 20 nm	dB/km at 1550 +/- 20 nm	dB/km at 850 +/- 20 nm	dB/km at 1300 +/- 20 nm
MIL-PRF-85045, Multiple fiber cable, tight buffer, Shipboard	0.5	0.5	1.0	1.0
MIL-PRF-85045 Multiple fiber cable, tight buffer, Tactical	0.3	0.3	0.5	0.5
MIL-PRF-85045, single fiber cable, tight buffer	0.5	0.5	1.0	1.0

Conductance of test.

1. General.

a. Test methods.
  (1) Initial qualification: attenuation rate, spectral attenuation measurement. Attenuation rate is to be performed in accordance with TIA-455-46 for test samples with multimode fiber and in accordance with EIA/TIA-455-78 for those with single mode fiber. The measurement is to be performed using a 30 mm mandrel for single mode and a 70/70 restricted launch condition for multimode fiber optic cable. Spectral attenuation shall be performed at a sufficient number of wavelengths to cover the applicable optical transmission windows and sources for attenuation. Sufficient coverage includes the optical transmission windows (850, 1300, 1310 and 1550 nm), ultraviolet absorption band (600 to 870 nm), Rayleigh scattering losses (800 to 1200 nm), OH impurity absorption peaks (945, 1249 and 1383 nm) and infrared absorption (1600 to 1700 nm). Use of a source and power meter to perform this measurement is not acceptable.
  (2) Quality conformance testing: attenuation rate at specified wavelength, Optical Time Domain Reflectometer (OTDR) measurement. Attenuation rate may be performed on multimode or single mode, fiber optic cable in accordance with TIA/EIA-455-61 using an OTDR in lieu of a spectral attenuation measurement. The measurement is to be performed using a 30 mm mandrel for single mode and a restricted launch condition for multimode fiber optic cable. This method of measurement is acceptable only when attenuation rate measurement is restricted to the transmission window of interest.

2. Test sample configuration. See Section II, General Requirements.
  a. Optical fiber. Unless otherwise specified, minimum length of the test sample is 1.0 km.
  b. Cable. Unless otherwise specified, minimum length of the test sample is 0.5 km.
  c. Quality Conformance (Group A) testing. Specified minimum lengths apply to qualification samples. Allowances are given on production lengths when specified on customer orders.
3. Setup.
  a. Generic representation.
    (1) Spectral attenuation rate. See figure VIII-1.
    (2) Group A attenuation rate using OTDR. See figure VIII-2.

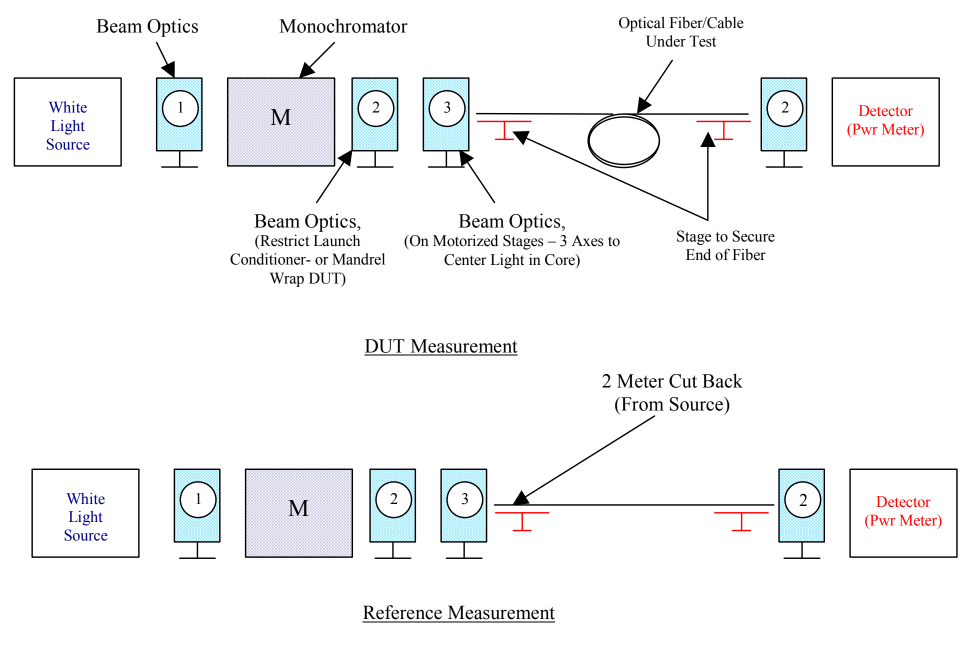


Figure VIII-1. Spectral Attenuation Rate

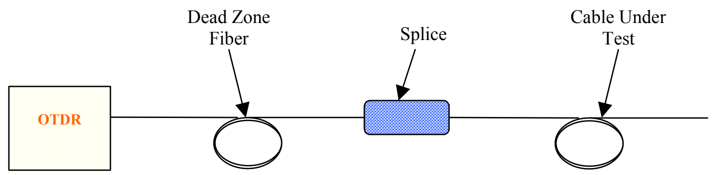


Figure VIII-2 Group A: Attenuation Rate Using OTDR

b. Connection at source end. No disconnection of the source end of the test sample from the source is permitted during this test.

c. Test equipment (spectral attenuation measurements).
   (1) Light source(s). Spectrally broad non-coherent light source is to be used with sufficient stability in optical power output and wavelength over the time the measurement is performed. A white light source, with a tungsten-halogen lamp or a xenon arc lamp, is an example of an acceptable light source.
   (2) Launch conditions. Requirements for launch conditions are listed in Section XI.
      (a) Multimode configuration. The restricted launch condition is to be used.
      (b) Single mode configuration. The 30 mm mandrel specified is applicable for this application
   (3) Monochromator. Able to tune monochromator in 10 nm increments over the wavelength range specified. Requirement to verify that monochromator is tuned to correct wavelength.
   (4) Detection system.
      (a) Optical noise floor: Sufficient to detect optical power from the DUT at wavelength being measured. A detector system with a –90 dB noise floor is most likely not sufficient for this measurement.
      (b) Resolution: 0.01 dB minimum.
      (c) Accuracy: 0.25 dB minimum.

         Note: A percent accuracy equates to a dB conversion as follows, using 5 % accuracy as an example. Think of the 5 % as the whole number 100 $\pm$ 5 % = 0.95 to 1.05.
         Take 10 log 0.95 = -0.22 dB
         Take 10 log 1.05 = +0.21 dB
         Therefore, specify the accuracy as $\pm$ 0.22 dB.

      (d) Linearity: $\leq$ 5 % or $\leq$ 0.22 dB over the range of optical power being measured.
      (e) Detector size: sufficient active area and placed sufficiently close to the end of the fiber or geometric optical system (one using lenses to couple light into the fiber under test) to detect all the radiation emitted from it.
      (f) Detector stability: $\leq$ 0.1 dB/hr.
      (g) Ambient light susceptibility (recommended). Affects of ambient light into the detector need to be controlled.
   (5) Fiber interface with test equipment.
      (a) Launch end: Core alignment maximization. On the launch end, the light entering the core of the optical fiber must be uniformly overfilled, then a method used to deplete power from the higher order modes (for multimode optical fiber) or attenuate power in the second and third order modes (for single mode optical fiber).

1 Active alignment using beam optics. Active alignment using beam optics is one method to achieve a uniformly overfilled launch in the center of the core. Motorized stages (in three axes) optimize light entering the core to be uniformly overfilled. Either beam optics or other methods (such as mandrel wrapping per TIA/EIA-455-34, see Section XI) may be used to obtain the required mode depletion/attenuation. Some automated optical benches for optical fiber parameter characterization, such as the Net Test (formerly Photon Kinetics) Model PK2500 do active alignment using beam optics. When using an alternate method, then verification technique to ensure acceptable alignment must be documented and employed.

2 Alternative methods. Optical fiber alignment to test equipment with a fiber optic pigtail is an alternative approach. The pigtail fiber typically has core diameter and numerical aperture matched to the test fiber. A larger fiber may be used; a smaller one may not. The pigtail fiber should be overfilled. In this approach a mechanical splice is used to align the optical fiber with the fiber optic pigtail. A guide tube, v-groove or other type alignment mechanism is used to align the two ends of the optical fiber. (An alignment method that presses the end faces of the two fibers together is referred to as butt-joint connection.) Index matching gel, is used to inhibit reflection from the end faces of the optical fiber.

3 Potential optical losses with alternative methods. With active alignment using beam optics, inspection of a cleaved fiber end face occurs. Poorly cleaved fibers are redone. Dirt on a cleaved fiber end face is observed and corrected. Verification techniques for cleave quality, cleanliness, and optimal fiber alignment must be performed when an alternate method is used. It should be noted that elevated losses are obtained with poor quality cleaves and dirt. Likewise, a very underfilled launch will excite lower order mode that may result in attenuation (typically higher) which may be significantly different than otherwise would have been recorded. . These verification techniques must be a part of the test procedure/setup.

(b) Detector end: Complete light impingement onto detector active area. On the detector end, all light exiting the optical fiber must fall onto the active area of the detector. Items to ensure this occurrence include cleave quality, cleanliness and optical path to the detector. When active alignment with beam optics is not used, then other means for verification techniques must be employed.

1 Cleave quality and cleanliness. As on the launch end, verification techniques to ensure acceptable cleave quality and degree of cleanliness must be employed.

2 Light detection. Also, verification must be provided that all light exiting the fiber does fall onto the active area of the detector. If an optical fiber pigtail is used, then the optical path to the detector may include a mechanical splice (to join the optical fiber under test to the fiber optic pigtail) and a connector interface at the detector. A larger core fiber for the fiber pigtail is one means, that can be used to capture the light exiting the fiber under test. Use of a wide area detector is one method to ensure impingement/detection of all exiting light (see Section X to verify sufficient detector surface area). Use of a power meter module with a grin lens interface to the fiber pigtail is not preferred.

d. Calibration of optical test bench, spectral attenuation measurement. Calibration of the optical test bench used in the spectral attenuation measurement is required. One approach that may be taken to do the calibration is to use standard test reels. A standard test reel is one with “known values” that the optical fiber manufacturer recorded for that specific reel of optical fiber. The same two meter pieces may be reused to simulate the cut-back. The calibration is performed by comparing values between the optical fiber manufacturer with those of the optical test bench being calibrated. One advantage of using this approach is that the other optical parameters of the optical test bench may be calibrated with the same standard test reel. Other calibration methods may be used contingent upon Government approval.

e. Verifications.

(1) Verifications required for spectral attenuation.

(a) Noise floor of photo-detector/power meter. Spectral attenuation measurement is obtained at a low power level for each wavelength. A photo-detector/power meter with a low noise floor must be used.

(b) Spectral resolution and wavelength. Monochromator resolution (10 nm minimum) and range for both single mode and multimode fibers must be provided. Means must be provided to verify that correct wavelength is obtained.

(c) Spatial and angular properties.

1 Single mode. The mode launch condition used and the means to obtain that launch condition must be provided. If a geometric optical system (one using lenses to couple light into the fiber under test) is not used, then the fiber/equipment interface must be provided.

2 Multimode. The multimode launch condition used and the means to obtain that launch condition must be provided. If a geometric optical system (one using lenses to couple light into the fiber under test) is not used, then the fiber/equipment interface must be provided. Also, the methods must be specified that are used to verify/produce a beam to control spot size and numerical aperture and to center the launch spot on the fiber core.

(2) Verifications required for Attenuation rate at specified wavelength using an OTDR.

(a) Wavelength. Wavelengths for the OTDR modules used.

(b) Dynamic range. Verification that the OTDR can cover the dynamic range for the minimum and maximum fiber/cable lengths to be measured.

(c) Launch conditions. Methods employed to obtain both single mode and multimode light launch conditions.

(d) Group delay index. A table of the group delay index of the optical fiber being tested or a procedure to determine the group delay index for each optical fiber.

4. Test procedure.

a. Initial qualification. A spectral attenuation test shall be performed for attenuation rate that covers the wavelength range from 800 to 1550 nm. A table of wavelength versus attenuation shall be provided. The intent is to have an initial record of the cable performance/characteristics throughout the specified measurement range. Use of a source and power meter to perform this measurement is not acceptable.

(1) Multimode.

(a) Background. Test was to be performed per TIA-455-46, procedure B (using beam optics) to obtain the restricted launch condition as shown in figure 1. The light launch conditions shall be made in accordance with TIA/EIA-455-50, light launch conditions for spectral attenuation measurements, using beam optics to obtain the specified restricted launch condition (method B). The other method (method A) in TIA/EIA-455-50 uses beam optics to obtain an overfilled condition followed by a mandrel wrap mode filter to obtain the specified restricted condition. Note: TIA/EIA-455-50 was withdrawn and replaced by TIA-455-78B in June 2003. A.1.3.2 of TIA-455-78B cites using beam optics to obtain the specified restricted launch condition. TIA-455-46A was withdrawn in January 2003.

(b) Current requirements. Test is to be performed per TIA-455-78, method A or annex A (equivalent method in TIA-455-46, procedure B). Light launch conditions for the spectral attenuation measurements may be performed using beam optics to attenuate the transient modes to steady state (see limited phase space launch). As an alternative, beam optics may be used to obtain a launch with excited modes followed by a mandrel wrap mode filter to attenuate the transient modes to steady state.

(2) Single mode. Test is to be performed per TIA-455-78, method A or annex A (equivalent method in EIA/TIA-455-78, the version replaced by TIA-455-78, and the equivalent method as in TIA-455-46, procedure B for multimode fiber). Light launch conditions for the spectral attenuation measurements is to be performed at a wavelength greater than or equal one in which the fiber is single mode. One means of removing higher order modes is cited by specifying EIA/TIA-455-77 (withdrawn in January 2003). The higher order mode filter consists of a mandrel or other device that keeps the fiber being tested in a controlled bend. The diameter of the bend and number of turns are the two key parameters. TIA-455-78 cites another example of a higher order mode filter (single loop of radius sufficiently small to shift cut-off wavelength below the minimum wavelength of interest).

b. Quality conformance inspections (Group A testing). The test for attenuation rate at the wavelengths of operation (850 nm and 1300 nm for multimode, 1310 nm and 1550 nm for single mode) may be provided in lieu of a spectral attenuation test.
   (1) Test standard. TIA-455-61 had been withdrawn in August 2003 and replaced by TIA-455-78B. TIA-455-78A included only the spectral attenuation test using beam optics using a cut back. TIA-455-78B is a shared IEC standard (IEC 60793-1-40) that includes tests using:
      (a) beam optics with a 2 meter cut back (cut-back method, method A),
      (b) beam optics with a 2 meter substitution fiber instead of a destructive cut back (insertion loss method, method B),
      (c) an OTDR (backscattering, method C).
   (2) Use of OTDR for Group A attenuation test. Method C of TIA-455-78B can be used with single mode fiber when launch conditions for the attenuation measurement is done as listed under method A using a 30 mm mandrel. Likewise, method C can be used with multimode fiber when launch conditions for the attenuation measurement is done as listed under method A of EIA-455-50 (mandrel wrap mode filter) or as stated in the section under launch conditions.

c. Limited scope.
   (1) Group A only. The attenuation procedure submitted should contain a note that the OTDR method employed is limited to use for Group A inspections only. This method is not to be used for initial qualification.
   (2) Single mode and multimode. This procedure is valid for Group A inspections for both single mode and multimode fiber.

d. Group delay index. The group delay index of the optical fiber is required to perform the OTDR measurement accurately. A procedure for determining the Group delay index when it is not known should be included in the procedure.

e. Test synopsis.
   (1) Spectral attenuation using cut-back method.
      (a) Verify suitable optical alignment and launch conditions.
      (b) Set monochromator for next wavelength in which test is to be performed.
      (c) Perform DUT measurement. Mandrel wrap the DUT (reel of fiber or cable), after interface with the launch end beam optics, with sufficient turns to obtain specified launch condition. Record the value of P_B, the optical power of the DUT.
      (d) Perform the reference measurement. Maintain connection interface at the launch end and the mandrel wrap. Cut-back the DUT (reel of fiber or cable) to a 2 +/- 1 meter length from the launch end and connect to detector. Record the value of P_A, the optical power of the 2 meter length.
      (e) Calculate the attenuation rate for that particular wavelength.
      (f) Repeat test for other wavelengths of light required.
   (2) Attenuation rate at wavelength using OTDR (i.e., backscattering method, Method C per TIA-455-78). Note: See Section XII for a sample of an OTDR attenuation measurement per MIL-STD-2042.
      (a) Insert applicable source module into OTDR for next wavelength in which test is to be performed.
      (b) Connect dead zone fiber to OTDR source module. (Ensure dead zone fiber size is compatible to the DUT).
      (c) Enter correct fiber parameters (including Group Delay Index).
      (d) Mandrel wrap the DUT (reel of fiber or cable), after interface with the dead zone fiber, with sufficient turns to obtain specified launch condition (if not already done).
      (e) Perform DUT measurement.
      Note: Some varieties of OTDR do this measurement automatically, with others cursor movements are required to obtain values for calculating parameters of interest. Step-by-step measurement process must be part of the test procedure.
      (f) Record the value of attenuation rate and length of DUT Calculate the attenuation rate for that particular wavelength if not done so automatically.
      (g) Repeat test for other wavelengths of light required.

5. Calculations.

a. Spectral attenuation for each wavelength.
$A(\lambda) = -10 \text{ Log } [(P_B(\lambda)/P_A(\lambda)]$
Where:
$A(\lambda)$ = Spectral attenuation at wavelength λ.
P_B = Optical power of the DUT (i.e., measurement with a reel of fiber optic cable or optical fiber).
P_A = Optical power after the reel of cable/fiber has been cut back to 2 +/- 1 meter (6.6 +/- 3.3 feet) from the optical source end (i.e., measurement with the 2 meter, cutback length).

b. Spectral attenuation coefficient for each wavelength.
Note: EIA/TIA-455-46 terminology for this parameter is attenuation coefficient. In the military specifications this same parameter is referred to as the attenuation rate.
$\alpha(\lambda) = [A(\lambda)/L]$
Where:
$\alpha(\lambda)$ = Spectral attenuation coefficient (or spectral attenuation rate) at wavelength λ
$A(\lambda)$ = Spectral attenuation at wavelength λ.
L = Length of the DUT in kilometers.

6. Data sheet. In addition to the items for the standard data sheet listed in Section IX, the data sheet is to list:
a. Qualification.
(1) Attenuation rate table. At a minimum, a table of wavelength versus attenuation rate shall be provided.
(2) Length. Length of each DUT for which the attenuation rate is provided.
(3) Attenuation rate plot (optional). The attenuation rate at the specific wavelengths plotted against wavelength.
b. Quality Conformance (Group A).
(1) Attenuation rate. At a minimum, the attenuation rate at each wavelength specified shall be provided.
(2) Length. Length of each DUT for which the attenuation rate is provided.

Section IX

Test Procedures

Test procedure minimum requirements. Minimum requirements for test procedures are listed in this section. Information must be in the test procedure as opposed to referencing the military specification or commercial standard for particular information such as figures, tables or calculations. Data sheet layout for each optical test performed and sample calculations are not included in the procedures submitted. Data sheet should be specific with respect to items such as pass/fail criteria. Operators/test laboratory personnel are expected to make a judgement if the item passed or failed. For purposes of testing to a military specification, the items either passed or failed. No other classification, such as "deviation", or other category/terminology is to be used. A phrase, such as "or as specified by the vendor" is not appropriate for a qualification to a military specification and should be included in any test procedure. Test procedures to military specifications are specific and "interpretations" by other parties are not permitted. Any clarifications required is to be addressed through DSCC. Data sheet for each optical test should list those items not covered on any general data sheet provided for each test.

Test procedures (including inspection procedures) must be specific to the equipment/instruments used to perform the test, must have sufficient detail so that someone with minimal training can "step in" and perform the test and must include:

(1) Setup procedure or sufficiently detailed schematic, as appropriate.
Note: Preference is to be very specific with the figure(s), diagram(s), drawing(s), etc. so that less detail is needed in description (words) to do the setup. Unique features of the setup may need to be more descriptive.

(2) Step-by-step test method specific to the equipment/instruments to be used and to the component(s) being tested.

(3) Pass/fail criteria (specification requirements).

(4) Equipment list or specific reference to one.

(5) Reference documentation must be listed. Also, latest version of military and commercial specifications cited in the component specification must be available and shown during the audit.

(6) Sample calculations for these methods where mathematical equations are used to determine the results.
Note: This requirement is waived if calculations are performed by the instrumentation or if data is entered into a spreadsheet for calculations to be performed.

(7) Data sheet where standard data sheet is not used or appropriate. Data sheet is to include the following information: test performed, performed by, start date, end date, start time, end time, test sample description, test sample model number, test sample serial number (if applicable), test sample manufacturer, lab temperature during test, lab humidity during test, test procedure used, test requirements (pass/fail criteria), reference specifications, test equipment (manufacturer, model number, serial number, equipment accuracy, calibration due date), remarks (space to record discrepancies, unexpected events, etc.), test data, indication of pass/fail, the data.
Note: Items other than the data may be summarized on a separate sheet or referenced to other sections of the test report.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section X

Optical Test Instrumentation Requirements
Change in Optical Transmittance and Insertion Loss

1. Optical instrumentation for insertion loss and change in optical transmittance measurements. Optical sources are to be used to generate the optical signal and an optical power meter is to be used to detect the optical power transmitted through the test sample.

   Note: The output power from a laser source specified is that launched from a source, into a 9/125 um fiber (such as the Corning SMF-28) then into a power meter.
   Note: The output power from a LED source specified is that launched from a source, into a 62.5/125 um fiber (graded index) then into a power meter.
   Note: Dynamic range is the difference between the output power from an optical source (laser or LED) to the sensitivity of the detector (power meter optical noise floor). A reduced laser source output power and/or a reduced noise floor limit will decrease the dynamic range. The acceptable level of the signal would then be reduced at both source and receiver! The Government concern is that these reductions will lead to increased noise for change in optical transmittance, increasing ambiguity in test results. A reduction in the dynamic range will be considered if it is demonstrated that at least 20 dB of signal to noise remains after accounting for all optical losses through the optical system (switches, test jumpers, mode conditioners, DUT, etc.). The requirements for optical source output power and power meter noise floor result in an implied dynamic range of 50 dB for single mode systems (with laser sources), 40 dB for multimode systems (with LED sources).

The optical sources and power meters used are to meet the following requirements:

a. LED Source (for use with 62.5/125 and 50/125 micron fiber sizes)
   (1) Wavelength: 1300 ± 20 nm.
   (2) Power output: -20 dBm minimum for multimode.
   (3) Spectral width: 170 nm maximum.
   (4) Optical power stability: ≤ 0.1 dB/hr.
   (5) Coupled Power Ratio (CPR).
      (a) Requirement: range of 20.5 to 22.5 dB.
      (b) Test procedure: MIL-STD-2052, Appendix A with conditions/apparatus per TIA/EIA-525-14, Annex A.
   (6) Mechanical stability of connector interface/port.
      (a) Requirement: Repeated matings with the same unit (using units with both ST and FC interfaces) shall result in a measured change in the optical launch power of ≤ 0.1 dB between any two of the matings.

b. LED Source (for use with 100/140, 62.5/125 and 50/125 micron fiber sizes, aircraft applications)
   (1) Wavelength: 850 ± 20 nm.
   (2) Power output: -20 dBm minimum for multimode.
   (3) Spectral width: 170 nm maximum.
   (4) Optical power stability: ≤ 0.1 dB/hr.
   (5) Mechanical stability of connector interface/port.
      (a) Requirement: Repeated matings with the same unit (using units with both ST and FC interfaces) shall result in a measured change in the optical launch power of ≤ 0.1 dB between any two of the matings.
   (6) Launch condition for the 100/140 micron fiber size: Must meet ASA-100 (see Section XI).

c. LD (Laser Diode) Source.
   (1) Wavelength: 1310 +20/-30 nm for single mode.

(2) Power output: -10 dBm minimum.
(3) Spectral width: 5 nm maximum.
(4) Optical power stability: $\leq$ 0.1 dB/hr.
(5) Mechanical stability of connector interface/port.
(a) Requirement: Repeated matings with the same unit (using units with both ST and FC interfaces) shall result in a measured change in the optical launch power of $\leq$ 0.1 dB between any two of the matings.

d. LD (Laser Diode) Source.
(1) Wavelength: 1550 +20/-30 nm for single mode fiber sizes for aircraft applications.
(2) Power output: -10 dBm minimum.
(3) Spectral width: 5 nm maximum.
(4) Optical power stability: $\leq$ 0.1 dB/hr.
(5) Mechanical stability of connector interface/port.
(a) Requirement: Repeated matings with the same unit (using units with both ST and FC interfaces) shall result in a measured change in the optical launch power of $\leq$ 0.1 dB between any two of the matings.

e. Power meter.
(1) Optical noise floor: - 60 dB minimum.
(2) Resolution: 0.01 dB minimum.
(3) Accuracy: $\pm$ 0.25 dB maximum.
Note: A percent accuracy equates to a dB conversion as follows, using 5 % accuracy as an example. Think of the 5 % as the whole number 100 $\pm$ 5 % = 0.95 to 1.05.
Take 10 log 0.95 = -0.22 dB
Take 10 log 1.05 = +0.21 dB
Therefore, specify the accuracy as $\pm$ 0.22 dB.
(4) Linearity: $\leq$ 5 % or $\leq$ 0.22 dB over the range of optical power from – 60 dBm to 3 dBm.
(5) Detector size: sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it.
(6) Detector stability: $\leq$ 0.1 dB/hr.
(7) Measurement repeatability: less than 3 percent variation.
(8) Ambient light susceptibility (recommended). Affects of ambient light into the detector need to be controlled.

2. Verifications required.

a. Verify conformance to requirements for optical light sources and power meter parameters.

b. Verify optical transmittance instrumentation stability. Two stability tests are to be performed on the optical test instrumentation used to monitor the change in optical transmittance. The first test should consist of measuring the transmitted power through each channel once every minute for a four hour period. The second test should consist of measuring the transmitted power through each channel once every 30 minutes for a 96 hour period. The data for each channel should be analyzed to determine average transmittance, minimum and maximum transmittance, the standard deviation of the transmittance, and the minimum and maximum percent deviation of the transmittance. Stability is acceptable if the observed change is less than one tenth of the optical performance requirement.

c. Verify detector surface area is sufficient.
(1) Intent. Ensure that the entire cone of light from the ferrule end face strikes the active area of the detector. Provide an analysis to show that the distance from the connector ferrule end face to the detector surface is sufficient to provide complete light coverage over the active area of the selected detector without missing any higher order modes.

(2) Sample calculation.

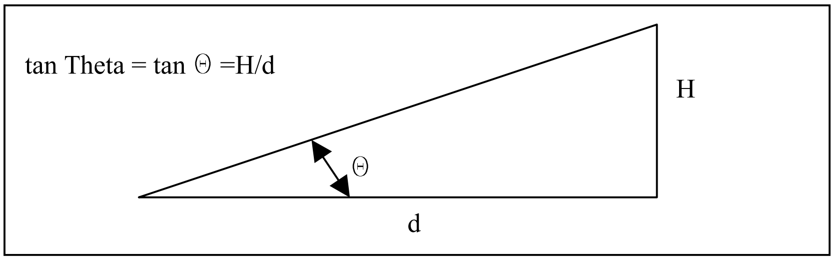


Figure showing sides and angle for trigonometric tangent designations.

Given: NA = 0.275 and distance d between the ferrule end face and detector surface = 1.825 mm.
Calculations: Theta = ARCSIN NA = ARCSIN .275 = .279
tan Theta = H/d; H = d tan Theta = (1.825 mm) x 0..286 = .523mm
Result: Need a detector with an active surface diameter of at least 0.523 x 2 = 1.05 mm

d. Verify Coupled Power Ratio (CPR) for multimode optical sources with tests using 62.5/125 micron fiber.

(1) Test equipment. Optical power meter, optical source, one 62.5/125 micron multimode jumper cable with near nominal core size and NA, one single mode jumper cable (sinlge mode at the source wavelength) and near nominal mode field diameter, one cable jumper-to-cable jumper adapter (such as an ST-to-ST adapter). The jumper cables should be sufficiently long (at least 1 meter) that all launch cladding mode power is completely attenuated.

(2) Test setup. Allow sufficient warm up time for the optical source and power meter. Clean the optical connectors on the ends of the cable jumpers and the optical connector interface ports at the optical source and power meter.

(3) CPR measurement.

(a) Connect one end of the multimode jumper cable to the optical source and the other end to the power meter.

(b) Observe the power meter display. When the value in the display is sufficiently stable, record the value (P_{MM}) in dBm.
Note: If the power meter value fluctuates more than 0.4 dB (peak-to-peak), a reading should not be taken. Either the optical source is not sufficiently stable or the optical power level is too low for the optical power meter.

(c) Disconnect the multimode jumper cable from the power meter and place a ST-to-ST adapter (or the appropriate adapter) onto that end of the multimode jumper cable.

(d) Select the appropriate single mode jumper cable with respect to the optical source output wavelength.

(e) Connect one end of the single mode jumper cable to the adapter (on the output end of the multimode jumper cable).

(f) Connect the other end of the single mode jumper cable to the power meter.

(g) Observe the power meter display. When the value in the display is sufficiently stable, record the value (P_{SM})in dBm.

Note: If the power meter value fluctuates more than 0.4 dB (peak-to-peak), a reading should not be taken. Either the optical source is not sufficiently stable or the optical power level is too low for the optical power meter.

(h) Disconnect the single mode and multimode jumper cable and clean the connectors and the cable ends.

(i) Repeat steps a through h until five stable readings have been recorded both with and without the single mode jumper cable.

(4) CPR calculations.

(a) For each repetition of steps a through g, calculate the logarithmic ratio of the optical power coupled into the multimode optical fiber (P_{MM}) to the optical power coupled into the combined single mode and multimode optical fibers (P_{SM}) using the equation:

$$R_S = P_{MM} - P_{SM}.$$

(b) Calculate the average of the five values for R_S to obtain the CPR.

Section XI

Launch Conditions

1. Launch conditions requirements.

a. Single mode.

(1) Purpose. Single mode cable is mandrel wrapped to increase the attenuation coefficient in the second and third order modes.

(2) Launch end mandrel wraps. Mandrel wraps attenuate power in the second and third order modes launched into the test sample by the source.

(3) Detector end mandrel wraps. Mandrel wraps attenuate power in the second and third order modes introduced into the test sample cable assembly by the test sample. If the loss of the test sample is low, then higher order modes are not being generated in the test sample. Detector end mandrel wraps are usually not necessary since a few meters of fiber also attenuate the second and third order modes.

(4) Mandrel diameter. Unless otherwise specified by the applicable test specification, a mandrel diameter shall be used as the means of mode conditioning to filter out higher order modes. The technique of wrapping the fiber around a mandrel shall be performed as specified see 3.5 of TIA/EIA-455-34.

Note: It is acknowledged that it is optimum to use the largest possible mandrel size that produces repeatable results. In this manner, bending loss is minimized. Smaller than optimum mandrel sizes were selected that will provide measurement consistency while more conservatively ensuring adequate mode conditioning for covering products from different vendors. Additional optical loss from bending will occur.

(a) 9/125 micron fiber size. A diameter of 30 mm shall be used with 3 complete turns of the fiber wrapped around the mandrel.

(b) 5.8/125 and 7.5/125 fiber sizes. A diameter of 60 mm shall be used with 1 complete turn of the fiber wrapped around the mandrel.

Note: The first fiber has a specified mode field diameter of 5.8 microns at the 1550 nm wavelength. The equivalent mode field diameter at 1310 nm transmission wavelength is 5.1 microns. Likewise, the second fiber has a specified mode field diameter of 7.5 microns at the 1550 nm wavelength.

b. Multimode.

(1) Purpose. Multimode cable may be wrapped to deplete power from the higher order modes with the result of minimizing transient effects from causing variations in the optical power level.

(2) Multimode overfilled launch condition. This is a more conservative launch condition and the vendor assumes a risk by using it. Measurements, using an overfilled launch condition, are required only for the initial insertion loss test. Power meter measurements, using the overfilled launch condition, includes the higher order, loosely guided modes.

(3) TIA mode filter diameter and the 70/70 restricted launch condition.

(a) 62.5/125 micron fiber size.

1 70/70 restricted launch condition. Use of a 50/125 micron fiber with a minimum length of 2 meters may be placed in front of each channel of the Device Under Test to simulate a 70/70 restricted launch condition.

2 Mode filter diameter launch condition. Place a 20 mm mandrel at the launch end of each channel of the Device Under Test to simulate the TIA restricted launch condition.

(b) 50/125 and 100/140 micron fiber sizes.

1 More restricted (such as 70/70) launch condition. Use of a specialty fiber (such as 42/125 micron fiber for the 50/125 micron fiber size) with a

minimum length of 2 meters may be placed in front of each channel of the Device Under Test to simulate a more restrictive launch condition. Near field and far field measurements are to be performed to verify conformance to restricted launch specifications on any specialty fiber used. Restricted launch condition shall not be more restrictive than that for a 70/70 launch condition.

2 Mode filter diameter launch condition. Place a 25 mm mandrel at the launch end of each channel of the Device Under Test to simulate the TIA restricted launch condition. This mandrel size applies to both 50/125 and 100/140 micron fiber sizes.

(4) Comparison of restricted launch conditions. The launch conditions resulting from a 20 mm mandrel wrap for the 62.5/125 micron fiber size falls somewhere between an overfilled and a 70/70 restricted launch condition (closer to the overfilled). With a 20 mm mandrel wrap, a non worst-case, value is obtained. Using a 20 mm mandrel wrap, the transient loss and loss due to highest order modes in the connector/test sample will not be observed.

(5) Mandrel wrap requirements. Mandrel wrap each cable with five closely wound turns around the mandrel, with no crossovers, while applying a minimal amount of tension. The diameter of the mandrel selected is to account for the outer diameter of the cable. For the case of a 62.5/125 micron fiber in a 2mm diameter cable, the diameter of the 20 mm mandrel should be reduced to 18 mm (subtract the diameter of the outer cable jacket from the specified 20 mm mandrel diameter). This will result in the fiber being in a 20 mm coil around the mandrel.

c. Coupled Power Ratio (CPR) for multimode, 62.5/125 fiber size launch conditions and 1300 nm wavelength.

(1) Overfilled launch condition. CPR = 22.5. For purposes of performing a CPR measurement for optical source acceptability, an acceptable overfilled launch condition is one within the range with a CPR from 20.5 to 22.5.

(2) 20 mm mandrel wrap launch condition. CPR = 21.0.

(3) Typical laboratory grade LED launch condition. CPR = 20.5 to 22.5.

d. Loss of mandrel wrap. If the mandrel wrap becomes undone during testing, a determination must be made if the data is valid. If there is no difference in the optical power, with and without the mandrel, then the test data is valid. If the change in optical transmittance is less than 0.1 dB, there is no concern. If the change in optical transmittance approaches 0.5 dB, then a determination cannot be made if the test sample passes, fails or is borderline. The test should be redone with a mandrel wrap.

e. Recommendation for purchasing a new source. Purchase LED optical sources with an overfilled launch condition and place mandrel wraps on the launch end of the cable assemblies under test. This configuration will allow for maximum flexibility of different launch condition requirements.

2. Launch condition specifications.

a. Acceptable shipboard and general applications limits for restricted multimode launch conditions.

(1) Power distribution. Numerical Aperture (NA) is defined in terms of a worst case (overfilled) far field, power intensity distribution. Core diameter is defined in terms of a worst case (overfilled) near field, power intensity distribution. If the launch condition is not specified in the component specification or applicable test standard, a 70/70 restricted launch condition (70 % of core diameter and 70 % of the NA) may be used. Restricted launch condition shall not be more restrictive than that for a 70/70 launch condition. The compliance for a 70/70 restricted launch condition is evaluated at the minimum and maximum tails of the intensity curve at 5 percent of the peak intensity (see table below).

(2) Launch condition tolerance for a 70/70 restricted launch. Use a tolerance of +10/-5 % to obtain upper and lower limits for the tolerance.

(3) Example of a 70/70 restricted launch condition tolerance for 62.5/125 micron (um) optical fiber.

(a) Near field.
Use a tolerance of +10/-5 % to obtain lower and upper limits of 40.6 to 50.0 um for core diameter.
Calculations:
70 % - 5% of core diameter = 0.65 x core diameter = 0.65 x 62.5 um = 40.6 um.
70 % + 10% of core diameter = 0.8 x core diameter = 0.8 x 62.5 um = 50 um.

(b) Far Field.
Use a tolerance of +/-5 % to obtain upper and lower limits of 0.18 to 0.22 for NA.
Calculations:
Where the NA for a far field, overfilled launch condition is 0.275.
70 % - 5% of NA = 0.65 x NA = 0.65 x 0.275 = 0.178 ~ 0.18.
70 % + 10% of NA = 0.8 x NA = 0.8 x 0.275 = 0.22.

Table for 70/70 Restricted Launch Tolerances

Pattern Type	Intensity Level (from peak value)	Minimum Tolerance	Maximum Tolerance	Measurement Procedure
Far Field	5 %	0.18	0.22	EIA/TIA-455-47
Near Field	2.5 %	40.6	50.0	TIA/EIA-455-176

(4) Methods to reduce launch conditions.

(a) Use beam optics with a spot restrictor and a NA restrictor.

(b) For 62.5/125 micron optical fiber, use a 1 meter minimum length of 50/125 micron optical fiber with a 0.2 NA.

1 A 50/125 micron optical fiber has an 80 % aperture of the 62.5/125 micron optical fiber, but it has a parabolic versus constant transmittance over the cross-sectional area. Additional constraints applied to the 50 micron fiber (e.g. mandrel wraps) tend to restrict the launch conditions beyond acceptable limits.

b. Acceptable launch conditions for U.S. military aerospace applications.

(1) Single mode. Ensure that there is a 2 meter minimum length of fiber between the optical source and the test sample. Mode conditioning for filtering out higher order modes shall be performed by mandrel wrapping as stated in 1.a(4).

(2) Multimode 50/125 micron fiber size. A restricted launch condition shall be standardized using a 42/125 micron, stepped index fiber (i.e., uniformly doped core with a pure silica cladding and acrylate coating). The selection of the parameters for this fiber was an engineering choice that produces results that are more conservative than that of a 70/70 restricted launch condition. The nominal value of the 42 micron core diameter was obtained by taking 70 percent of the core diameter for a 62.5/125 micron fiber. The nominal value for the numerical aperture was obtained by taking 70 percent of 0.20, the numerical aperture for the 50/125 micron fiber. The numerical aperture is measured at the 50 percent intensity levels as is typical for a SI (stepped index) fiber versus at the 5 percent intensity levels for a GI (graded index) fiber. A tolerance of +/- 5 % is used for the core diameter and +/- 8 % for the numerical aperture. Compliance for this restricted launch condition is evaluated at the indicated percent of the peak intensity as shown in the table below for the 50/125 micron fiber size.

(3) Multimode 62.5/125 micron fiber size. Launch condition shall be a 70/70 restricted launch. Use a tolerance of +10/-5 % to obtain upper and lower limits for the tolerance. The compliance for a 70/70 restricted launch condition is evaluated at the minimum and

maximum tails of the intensity curve at the indicated percent of the peak intensity. Restricted launch tolerances is shown in table below for a 62.5/125 micron fiber size.

(4) Multimode 100/140 micron fiber size. A restricted launch condition shall be standardized using the ASA-100 launch condition. Compliance for this restricted launch condition is evaluated as indicated in the table below for 100/140 micron fiber size.

Table of Restricted Launch Tolerances for 50/125 micron fiber size with a NA of 0.20.

Pattern Type	Intensity Level (from peak value)	Minimum Tolerance	Maximum Tolerance	Measurement Procedure
Far Field	50 %	0.125	0.155	EIA/TIA-455-7
Near Field	50 %	39	48	TIA/EIA-455-58

Table of 70/70 Restricted Launch Tolerances for one common 62.5/125 micron fiber size with a NA of 0.275.

Pattern Type	Intensity Level (from peak value)	Minimum Tolerance	Maximum Tolerance	Measurement Procedure
Far Field	5 %	0.18	0.22	EIA/TIA-455-47
Near Field	2.5 %	40.6	50.0	TIA/EIA-455-176

Table of ASA-100 Restricted Launch Tolerances for 100/140 micron fiber size with a NA of 0.29.

Pattern Type	Intensity Level (from peak value)	Minimum Tolerance	Maximum Tolerance	Measurement Procedure
Far Field	5 % 15 % 75 %	0.245 0.210 0.100	0.255 0.225 0.120	EIA/TIA-455-47
Near Field	5 % 15 % 75 %	80 70 30	95 85 45	TIA/EIA-455-176

ASA-100 launch condition was identified previously as the M80 launch condition.
Far Field skewing requirement for ASA-100 launch condition. The difference in the angle at the 5% points is not to exceed 3^{o} when the far field intensity scan is performed in two, 90^{o} radial orientations of the optical fiber.
Near Field core eccentricity requirement for ASA-100 launch condition. The difference in the diameter at the 5% points is not to exceed 3 microns when the near field intensity scan is performed in two, 90^{o} radial orientations of the optical fiber.

c. Definition and tolerances for overfilled launch conditions.

(1) Far field/near field distributions. Paragraph 5.1.1 of TIA/EIA-455-50 provides a definition for the overfilled launch condition. An overfilled launch condition is one the produces a nominal launch spot of diameter greater than or equal to the nominal core diameter of the test fiber and a nominal launch condition numerical aperture (NA) greater than or equal to the nominal NA. Due to measurement precision, a tolerance of +/- 5 percent may be applied to this definition.

(2) Coupled Power Ratio (CPR). Annex A of TIA-526-14 specifies the CPR limits for overfilled launch conditions (i.e., category 1) of multimode fibers.

3. Other considerations.

a. Disconnects. The light launch conditions at the optical source end must be maintained throughout the test (no disconnects permitted) for all measurements taken with that fiber as the active channel.

b. Centerline wavelength. The centerline wavelength of the optical source used shall be 1300 +/- 20 nm. Some tests in the military specifications contain a typographical error that states 1330 +/- 20 nm.

c. Overfilled launch, multimode. Launch conditioning cables are not commonly used to provide an overfilled launch condition. Launching from a larger core into a smaller core does not necessarily provide an overfilled launch if the optical source has a restricted launch condition. The launch condition from the optical source should be obtained and provided in the test procedure or with the list of test equipment.

d. Simulating overfilled launch conditions, multimode. There are several cases where overfilled or less restrictive launch conditions are required than available with existing test instrumentation. One case is where a transition from smaller to larger core fiber is required (such as when using an existing source switch on a multimode measurement system pigtailed with 50 micron fiber to test 100 micron fiber). Another is when the optical source does not provide an overfilled launch condition or this launch condition is not maintained through the measurement/switching system. Launch conditioning cables with larger core fiber may be used to simulate the required launch condition with the constraints noted in this section. Launch conditioning cables with mixing may be required to achieve the required launch condition (smaller to larger requires mixing with a mode scrambler versus filtering by a mandrel). Verification of achieving the proper launch condition by acceptable methods stated in the section (Coupled Power Ratio or near field/far field distribution) must be performed. In cases where profiles for near field/far field distributions are given, approval for compliance only with a specified point on that profile must be obtained. It is the responsibility of the test activity to determine the launch conditioning cable to be used (with mandrel size if wrapping is necessitated to achieve an overfill without being overly conservative or a desired, less restrictive launch). Note that the launch condition verification must be done using the fiber under test. Any measures taken on the launch conditioning cable only are not appropriate.

e. Launch into smaller fiber sizes, single mode. An optical source with a standard 9/125 micron fiber pigtail may be used to launch light into a fiber with a smaller single mode core size. This will incur a loss, but the single mode should reestablish itself in the smaller mode field diameter fiber. It should be noted that care needs to be taken on the output end to ensure that all of the light exiting the test sample be captured by the detection system. The numerical aperture of some small mode field diameter fiber designs may be larger than the acceptance angle of the detection system or that of standard multimode fiber that might be used as pigtails on the detector. Light from a single mode fiber with a smaller mode field diameter cannot be transmitted to the detector through single mode fiber with a larger mode field diameter. From the smaller core fiber, no detector end switch, switch-to-detector jumper or detector with a larger core fiber pigtail can be used. The preference is to not do the mismatch on the detection end. Alternately, it is possible for development of a system that performs accurate measurements with a mismatch present, but this requires careful implementation and characterization before test results should be considered acceptable.

4. Launch condition verification.

a. General.

(1) CPR (Coupled Power Ratio). The CPR is one acceptable method to determine/verify the launch condition.

(2) Near Field and Far Field optical power distributions. This is an alternative, acceptable method to determine/verify the launch condition.

b. Single mode. No verification is required if a mandrel is used in conjunction with a Fabry Perot type laser source.

c. Overfilled launch, multimode. Vendor certification (using CPR or Near Field/Far Field power distributions) or measurements done to obtain CPR or Near Field/Far Field power distributions.

d. Restricted launch, multimode.

   (1) Verify how the adjustments to the optical setup will be done to provide the required restricted launch condition for specific tests to be performed. Both mandrel wrap and restricted launch cables are listed as acceptable approaches.

      (a) Mandrel wrap. The mandrel diameters listed will not provide a 70/70 restricted launch nor will any other practical mandrel wraps. The mandrel diameters listed in TIA/EIA-455-34 provide a more conservative launch condition than the 70/70 restricted launch. These mandrel diameters are acceptable for use. No verification for Near Field and Far Field optical power distributions of restricted launch conditions are required as long as the optical source used provides an overfilled launch condition.

      (b) Launch cables. Launch cables with the fiber sizes listed as a suitable alternative means to provide a restricted launch condition. No verification, such as using for Near Field and Far Field optical power distributions, are required as long as the optical source used provides an overfilled launch condition.

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section XII

Synopsis of OTDR Attenuation Measurement

1. Summary of method:
   a. Setup OTDR per Figure 6B1-3 of MIL-STD-2042.
      (1) Connect a 50 meter dead zone cable to the OTDR optical port.
      (2) Place a ST-to-ST adapter on the other end of the dead zone jumper.
      (3) Set the OTDR parameters as follows:
         (a) Pulse width: use 20 ns pulse width.
         (b) Dynamic range: 1 km.
         (c) Group (refractive) index: 1.491
         (d) Back scatter coefficient: -74 (for 1300 nm, 62.5/125 micron fiber).
         (e) Time for average measurement mode: 1 minute.
   b. Prepare one fiber on the cable end using procedure I, Method 6B1 of MIL-STD-2042.
         Note: Strip lengths may vary depending on the bare fiber adapter used.
   c. Place the bare fiber adapter on the end of a stripped fiber.
      Note: Clean bare fiber end using tape.
         Note: Examine end face under 400X microscope to verify that end face is clean and not shattered.
   d. Connect ST-to-ST adapter on end of dead zone jumper to the bare fiber adapter.
      Note: Ensure that the setup is not disturbed during the OTDR average measurement.
      Note: Ensure that the fiber existing the bare fiber adapter is not placed in a tight bend.
   e. Actuate the OTDR for the average measurement mode (as opposed to placing in the real time mode).
      Caution: LASER will be actuated for the duration of the average measurement (1 minute). Observe LASER safety precautions.
      Note: If waveform drops several dB after Z_3, then fiber is shattered (or there is a poor fiber cleave). Re-cleave fiber and repeat measurement.
   f. Find and record the cable lengths by placing cursors A and B on locations Z_1 and Z_2.

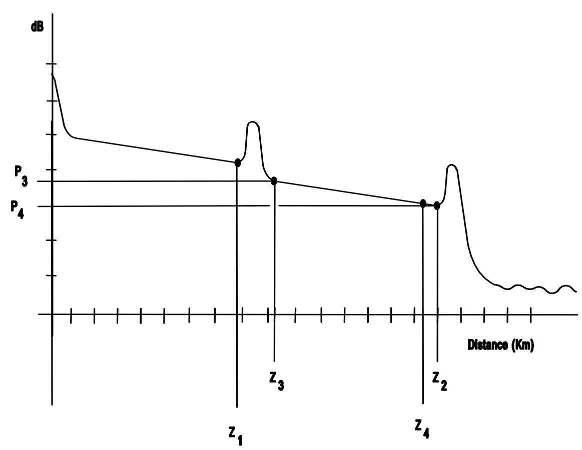


Figure 6B1-3 of MIL-STD-2042

g. Find and record the attenuation in dB for the length $Z_4 – Z_3$.
Note: $Z_4 – Z_3$ is the linear portion of the trace for the cable under test.
Note: If the OTDR does not display cable attenuation, then calculate attenuation using the following formula: Attenuation (dB/km) = B =$(P_3 – P_4)/(Z_4 – Z_3)$ per figure 6B1-3. Multiply the result by the cable length in km.
Note: If the OTDR displays the attenuation for $Z_2 – Z_3$, then that value may be recorded in lieu of the attenuation for $Z_4 – Z_3$.

2. Specific application requirements:
   a. Optical attenuation. The cable is considered satisfactory if the maximum measured attenuation for each fiber does not exceed the maximum allowable attenuation specified in MIL-PRF-85045 (2 dB/km for multimode fiber at 1300 nm wavelength).

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Section XIII

Checklist Of Minimum Essentials

There is an independent checklist of minimum essentials for each test. This independence results from potential utilization of different test equipment, test locations and other testing variables (equipment break-down, etc.) in addition to slight variations in some requirements.

Insertion Loss

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length:		
		Connectors & splices	10 meters minimum (13 m if to do 3 cut-backs)	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	23 ± 5°C/73 ± 9°F & 20 to 70% RH	
		Controlled Ambient	23 ± 2°C/73 ± 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters ≥ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	LED Source	Wavelength	1300 ± 20 nm (variation for aircraft)	
		Power output	-20 dBm minimum for multimode	
		Spectral width	170 nm maximum	
		Optical power stability	≤ 0.1 dB/hr.	
		Coupled Power Ratio (CPR), see CPR test	range of 20.5 to 22.5	
		Mechanical stability of connector interface/port	≤ 0.1 dB between any two of the matings	
6	LD Source (LD = Laser Diode, Fabry Perot type)	Wavelength	1310 + 20/-30 nm	
		Power output	-10 dBm minimum	
		Spectral width	5 nm maximum	
		Optical power stability	≤ 0.1 dB/hr.	
		Mechanical stability of connector interface/port	≤ 0.1 dB between any two of the matings	
7	Power meter	Optical noise floor	- 60 dB minimum	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Linearity: over the range of optical power from – 60 dBm to 3 dBm.	≤ 5 % or ≤ 0.22 dB (see Section X for conversion)	
		Detector size (see detector verification test, Section X) If do cut-back or simulated cut-back, wide area detector used (5 mm dia min)	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	≤ 0.1 dB/hr.	
		Measurement repeatability	Less than 3 percent variation	
		Ambient light susceptibility (recommended)	Detector unit sealed to extent that not exposed to ambient light (ports covered completely)	
	Launch Conditions			
8	Multimode	Overfilled launch (initial OIL only)		
		100/140	Not/Applicable (N/A), do ASA-100 only	
		62.5/125	CPR range: 20.5 to 22.5 or do Near F/Far Field	
		50/125	Use source with 62.5/125 launch	
9		Restricted launch (initial & all subsequent OIL)		
		100/140	M80	
		62.5/125	20 mm mandrel @ 5 wraps or 50/125 jumper	
		50/125	25 mm mandrel @ 5 wraps or 42.5/125 jumper	
10	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
11	Test Setup	Items to inspect for compliance	No switching system (source-DUT-detector)	
			No splicing of cable assembly	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
			Restricted launch at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			In line mate/demate connection for mates	
			Use of substantial fixtures (no wobbling, etc.)	
12	Test procedure	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Measurement after DUT insertion	Ten mates & de-mates performed	
		Simulate cable: pre-DUT insertion	Cut-back (use bare fiber adapter or how do?)	
			or simulated cut-back (if config permits)	
13	Calculation	Equation to give value in dB	Verify proper method if operator performed	
		Sign convention	Recorded as positive value	
14	Data Sheet	Approved data sheet	Compliance with Section IX	
			Method used to do restricted launch condition	
15	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Change in Optical Transmittance

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length: Connectors & splices	10 meters minimum (13 m if to do 3 cut-backs)	
		Optical fiber	1000 meters minimum	
		Fiber Optic cable	500 meters minimum	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	23 $\pm$ 5°C/73 $\pm$ 9°F & 20 to 70% RH	
		Controlled Ambient	23 $\pm$ 2°C/73 $\pm$ 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters $\geq$ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	LED Source	Wavelength	1300 $\pm$ 20 nm (variation for aircraft)	
		Power output	-20 dBm minimum for multimode	
		Spectral width	170 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Coupled Power Ratio (CPR), see CPR test	range of 20.5 to 22.5	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
6	LD Source (LD = Laser Diode, Fabry Perot type)	Wavelength	1310 + 20/-30 nm (variation for aircraft)	
		Power output	-10 dBm minimum	
		Spectral width	5 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
7	Power meter	Optical noise floor	- 60 dB minimum	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Linearity: over the range of optical power from – 60 dBm to 3 dBm.	$\leq$ 5 % or $\leq$ 0.22 dB (see Section X for conversion)	
		Detector size (see detector verification test, Section X)	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	$\leq$ 0.1 dB/hr.	
		Measurement repeatability	Less than 3 percent variation	
		Ambient light susceptibility (recommended)	Detector unit sealed to extent that not exposed to ambient light (ports covered completely)	
8	Switching system	Repeatability, each switch	$\leq$ 0.03 dB either random or sequential switching	
		Drift relative to monitor channel	0.06 dB for ten days	
		Fiber size in switch	$\geq$ fiber size of DUT	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
		Launch end switch, when use restricted launch	MM: restricted launch device @ ea. output port	
		Launch end switch, single mode	Higher order mode filter @ ea. output port	
		Launch end switch, jumper: source-to-switch	Fiber size same: jumper & switch	
		Detector end switch, jumper: switch-to-detector	Fiber size same: jumper & switch	
9	Monitor fiber	Fiber size	Same as DUT cable assembly	
		Configuration	Source sw.-to-det. sw, same amb, no bends, etc.	
10	Verify stability	Optical system: 4 hour & 96 hour stability tests	See Section X (measure repeat < 3%, etc.)	
	Launch Conditions			
11	Multimode	Restricted launch only		
		100/140	M80	
		62.5/125	20 mm mandrel @ 5 wraps or 50/125 jumper	
		50/125	25 mm mandrel @ 5 wraps or 42.5/125 jumper	
12	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
13	Test Setup	Items to inspect for compliance	Setup: (source-S sw.-DUT-d. sw.-detector)	
			Splicing of cable assembly: to sw./instr. only	
			Restricted launch at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			No sharp bend in cable from DUT	
			Use of substantial fixtures (no wobbling, etc.)	
		Splicing allowance	Affix DUT cable assembly to switch	
			Do not disturb from pre-test to post test	
			Verify ea. splice is low loss & stable	
14	Test procedure	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Maintain pre-test baseline	No de-mate during test	
		Perform pre-test (baseline) measurement	Prior to mechanical/environmental conditions	
		Perform measurements during (when specified)	@ specified interval, if not see Section IV	
		Perform post test measurement after test	Do after conditions are stable (wait up to 24 hr)	
15	Calculation	Equation to give value in dB	Verify proper method if operator performed	
		Normalize for length (environ for cable & fiber)	Units in dB/km (normalized for 1 km length)	
		Sign convention	Recorded as + value, if increase in optical pwr.	
16	Data Sheet	Approved data sheet	Compliance with Section IX	
			Method used to do restricted launch condition	
			Each DUT/channel/position identified	
			All during/after measurements calculated on sht.	
17	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Crosstalk

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length: Connectors	10 meters minimum (13 m if to do 3 cut-backs)	
		Fiber Optic cable	500 meters minimum	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	23 $\pm$ 5°C/73 $\pm$ 9°F & 20 to 70% RH	
		Controlled Ambient	23 $\pm$ 2°C/73 $\pm$ 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters $\geq$ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	LED Source	Wavelength	1300 $\pm$ 20 nm (variation for aircraft)	
		Power output	-20 dBm minimum for multimode	
		Spectral width	170 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Coupled Power Ratio (CPR), see CPR test	range of 20.5 to 22.5	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
6	LD Source (LD = Laser Diode, Fabry Perot type)	Wavelength	1310 + 20/-30 nm (variation for aircraft)	
		Power output	-10 dBm minimum	
		Spectral width	5 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
7	Power meter	Optical noise floor (see Section V pwr. mtr.)	- 60 dB minimum above noise floor (do calc)	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Linearity: over the range of optical power from – 60 dBm to 3 dBm.	$\leq$ 5 % or $\leq$ 0.22 dB (see Section X for conversion)	
		Detector size (see detector verification test, Section X)	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	$\leq$ 0.1 dB/hr.	
		Measurement repeatability	Less than 3 percent variation	
		Ambient light susceptibility (recommended)	Detector unit sealed to extent that not exposed to ambient light (ports covered completely)	
	Launch Conditions			
8	Multimode	Overfilled launch		
		100/140	Not/Applicable (N/A), use ASA-100 launch	
		62.5/125	CPR range: 20.5 to 22.5 or do Near F/Far Field	
		50/125	Use source with 62.5/125 launch	
		Restricted launch	Not Applicable (N/A) for this test	
9	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
10	Test Setup	Items to inspect for compliance	No switching system (source-DUT-detector)	
			No splicing of cable assembly	
			Restricted launch at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			In line approach to & from connection for mates	
			Use of substantial fixtures (no wobbling, etc.)	
11	Test procedure, general	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Use correct detector (Power meter = pwr mtr)	Verify - 60 dB min above noise floor (do calc)	
		Designate source & detector ends of DUT	Source = near end (near), detector = far end (far)	
12	Test procedure, cable	Measure optical pwr of active channel	Source @ near, detector @ far of channel	
		Measure far end opt pwr, all other channels	move detector to measure ea. "passive" channel,	
			Leave source @ "active" channel	
		Calculate crosstalk of ea. passive channel	Calc near & far end relative to active channel	
			Separate calc for ea. ch near & ea. ch far	
		Repeat process	Minimum of 3, random selected, active fibers	
13	Test procedure, connectors (multiple termini)	Measure optical pwr of active channel	Source @ near, detector @ far of channel	
		Measure far & near opt pwr, all other channels	move detector to measure ea. "passive" channel,	
			Leave source @ "active" channel	
		Calculate crosstalk of two passive ch	Far & near end relative to active ch & test fiber	
			Far end & near end done in separate calculations	
		Repeat process	Minimum of 3, random selected, active fibers	
14	Calculation	Equation to give value in dB	Verify proper method if operator performed	
		Each channel listed	Far & if specified near end crosstalk calculated	
15	Data Sheet	Approved data sheet	Compliance with Section IX	
16	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Optical Signal Discontinuity

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length:		
		Connectors & Splices	10 meters minimum (13 m if to do 3 cut-backs)	
		Fiber Optic cable	500 meters minimum	
2	Room Ambient	Standard Ambient (if test equipment built to	23 $\pm$ 5°C/73 $\pm$ 9°F & 20 to 70% RH	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
	Environmental Condition	operate in this range, if not-then controlled amb)		
		Controlled Ambient	23 $\pm$ 2°C/73 $\pm$ 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters $\geq$ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	LED Source	Wavelength	1300 $\pm$ 20 nm (variation for aircraft)	
		Power output	-20 dBm minimum for multimode	
		Spectral width	170 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Coupled Power Ratio (CPR), see CPR test	range of 21 to 22	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
6	LD Source (LD = Laser Diode, Fabry Perot type)	Wavelength	1310 + 20/-30 nm (variation for aircraft)	
		Power output	-10 dBm minimum	
		Spectral width	5 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
7	Power meter	Detector response: resolution to resolve signal	$\geq$ 50 microseconds	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Linearity: over the range of optical power from – 60 dBm to 3 dBm.	$\leq$ 5 % or $\leq$ 0.22 dB (see Section X for conversion)	
		Detector size (see detector verification test, Section X)	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	$\leq$ 0.1 dB/hr.	
		Ambient light susceptibility (recommended)	Detector unit sealed to extent that not exposed to ambient light (ports covered completely)	
		Measurement repeatability	Less than 3 percent variation	
8	Accelerometer	Accuracy	$\pm$ 5 % from 5 to 5000 Hz	
		Amplitude calibration	$\pm$ 5 % from 4 to 5000 Hz	
	Launch Conditions			
9	Multimode	Restricted launch only		
		100/140	ASA-100	
		62.5/125	20 mm mandrel @ 5 wraps or 50/125 jumper	
		50/125	25 mm mandrel @ 5 wraps or 42.5/125 jumper	
10	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
11	Test Setup	Items to inspect for compliance	No switching system (source-DUT-detector)	
			No splicing of cable assembly	
			Restricted launch at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			In line approach to & from connection for mates	
			Attachment to fixture adequate (no wobble, etc)	
12	Test procedure	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Use correct detector (Power meter = pwr mtr)	Response adequate, resolve $\geq$ 50 microseconds	
		Optical connections of DUT	No splicing near DUT	
		Acceptable connections	Cleaned and properly seated (power level o.k.)	
		Data capture signal level set properly	Not saturate (flat close to peak value)	
			amp not overdriven (level changes if attenuated)	
		Verify if movement at connection	Mark joint where DUT is tightened	
			Observe if movement during test	
		Optical source transmission	Continuous power mode	
		Observe if no discontinuities during test (if data capture equipment permits)	Shock: Verify after each impact	
			Vibration: Verify after each axis	
		Observe data for optical power gains above Value of insertion loss (that of uncut fiber)	If occurs, data is invalid	
			Clean, reseat, etc., then redo axis/impact, etc.	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
13	Calculation	Equation to trigger threshold in dB (see Sec VI)	Verify proper method if operator performed	
		Method to store data	Plot/chart, stored data on disk, other Gov't apr	
14	Data Sheet	Approved data sheet	Compliance with Section IX	
		Adjustments to detection system	Record/checklist that done properly	
		Detection system calibration	Verification if not done on routine cycle	
15	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Return Loss

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length: Connectors & splices	10 m minimum (13 m if insertion loss cut-back)	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	23 $\pm$ 5°C/73 $\pm$ 9°F & 20 to 70% RH	
		Controlled Ambient	23 $\pm$ 2°C/73 $\pm$ 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters $\geq$ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	LD Source (LD = Laser Diode, Fabry Perot type) (ORLM or separate source)	Wavelength	1310 + 20/-30 nm	
		Power output	-10 dBm minimum	
		Spectral width	5 nm maximum	
		Optical power stability	$\leq$ 0.1 dB/hr.	
		Mechanical stability of connector interface/port	$\leq$ 0.1 dB between any two of the matings	
6	Detector (ORLM or separate detector)	Measured reflectance range	10 to 55 dB minimum	
		Resolution	0.1 dB minimum	
		Accuracy	$\pm$ 0.5 dB minimum at return loss of – 55 dB	
		Detector size	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	$\leq$ 0.1 dB/hr.	
		Measurement repeatability	Less than 3 percent variation	
7	Coupler	If equivalent method where stand-alone coupler (not use ORLM)	Do coupler insertion loss per TIA/EIA-455-180	
			Verify separate procedure to do insert loss exits	
8	OTDR or time of flight type measurement	Approach for acceptance for a non-continuous wave measurement method for optical return Loss (ORL) – using time of flight measurement	Do ORL, useTIA/EIA-455-107method -ORLM	
			Do ORL to time of flight method	
			If both within 1 dB of ea. other, o.k. to use time of flight for subsequent ORL measurements	
9	Termination device	Acceptable methods to do non-reflective terminations	Mandrel (6-10 mm dia.), 5 to 10 turns/wraps	
			Index matching gel (less preferred – messy!)	
			Either way, must do min attenuation level 40 dB	
	Launch Conditions			
10	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
11	Test Setup	Items to inspect for compliance	No switching system (ORLM or source-cpl-det)	
			No splicing of cable assembly	
			Hi order mode fil at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			In line approach to & from connection for mates	
			Use of substantial fixtures (no wobbling, etc.)	
12	Test procedure (test using ORLM)	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Perform reference measurement	Mandrel wrap before DUT, reference ORLM	
		Perform DUT measurement	Mandrel wrap after DUT with turns so stable	
			Record measurement as the return loss	
13	Test procedure (test using	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
	equivalent method, i.e., source-coupler-power meter)	Measure optical power thru coupler, P_0	Port1=source,port2=terminator,port3=detector	
		Measure reflected pwr to port2 w/o DUT	Port1=source,port2=detector,port3=terminator	
		Measure reflected pwr to port2 with DUT	Port1=source,port2=detector,port3=DUT, then terminator	
		Calculate return loss	Verify correct calculation, see Section VII	
14	Calculation	Equation to give value in dB	Verify proper method if operator performed	
		Sign convention	Recorded as positive value	
15	Data Sheet	Approved data sheet	Compliance with Section IX	
		Type of termination device used	If mandrel, diameter & # of wraps	
		Sign convention	Return loss, record as + dB	
16	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Attenuation Rate, Spectral (for Initial Qualification)

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length:		
		Optical fiber	1000 meters minimum	
		Fiber Optic cable	500 meters minimum	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	23 ± 5°C/73 ± 9°F & 20 to 70% RH	
		Controlled Ambient	23 ± 2°C/73 ± 4°F & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters ≥ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
5	Light Source (white light)	Source type: broad spectrum, non-coherent	white light: tungsten-halogen or xenon arc lamp	
		Optical power stability	≤ 0.1 dB/hr.	
6	Detector	Optical noise floor	Must detect optical pwr at each wavelength	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Linearity: over the range of optical power measured	≤ 5 % or ≤ 0.22 dB (see Section X for conversion)	
		Detector size	sufficient active area and placed sufficiently close to the end of the fiber to detect all the radiation emitted from it	
		Detector stability	≤ 0.1 dB/hr.	
		Measurement repeatability	Less than 3 percent variation	
		Ambient light susceptibility (recommended)	Detector unit sealed to extent that not exposed to ambient light (shielded as practicable)	
7	Monochromator	Use over specified wavelength range	Tune in 10 nm increments or less	
		Tuned to correct wavelength	Verify method that correct wavelength obtained	
8	Calibration of Attenuation rate measurement	One approach for acceptance:	Use standard reels with "known" values	
			Same 2m piece may be used for cut-back, but only for standard reel (not DUT test)	
			Other methods: need Government approval	
	Launch Conditions			
9	Single mode	If geometric system not used	Fiber/equipment interface must be provided	
			Method to determine spatial & angular properties provided	
10	Multimode	Method used must be provided	Obtain launch condition	
			Control spot size & NA	
			Center launch spot on fiber core	
		If geometric system not used	Fiber/equipment interface must be provided	
			Method to determine spatial & angular properties provided	
11	Test Setup	Items to inspect for compliance	No switching system	
			No splicing of cable assembly	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
			Hi order mode fil at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			In line approach to & from connection for mates	
			Use of substantial fixtures (no wobbling, etc.)	
12	Test procedure (spectral)	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Optical alignment & launch conditions	Verify suitability (per procedure)	
		Set monochrmator to next wavelength in test	Verify correct wavelength (if required)	
		Perform DUT measurement	Mandrel wrap DUT, source end, with sufficient Turns to obtain launch condition, record value	
		Perform reference measurement	Maintain source end connection interface	
			Cut-back 2m from launch end, record measurement for 2m length	
		Calculate attenuation rate	For that particular wavelength	
		Repeat test	For each wavelength to be measured	
13	Calculation	Equation to give value in dB/km	Verify proper method if operator performed	
		Sign convention	Recorded attenuation as positive value	
14	Data Sheet	Approved data sheet	Compliance with Section IX	
		At minimum, provide table	Attenuation rate versus wavelength	
		Record length	Length of DUT for attenuation rate provided	
		Attenuation rate plot (optional)	Attenuation rate plotted against wavelength	
15	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Attenuation Rate, OTDR Measurement (Only for Quality Conformance – Group A)

Item	Category	Item	Requirement	Compliance
1	Test Sample Configuration	Cable assembly length:		
		Optical fiber	1000 meters minimum	
		Fiber Optic cable	500 meters minimum	
2	Room Ambient Environmental Condition	Standard Ambient (if test equipment built to operate in this range, if not-then controlled amb)	$23 \pm 5^{o}C/73 \pm 9^{o}F$ & 20 to 70% RH	
		Controlled Ambient	$23 \pm 2^{o}C/73 \pm 4^{o}F$ & 45 to 55% RH	
3	Test Condition	Test setup cable routing	Bend diameters $\geq$ min long term bend dia	
			Sharp twists & bends avoided	
			Avoid protrusions/other obstacles	
4	Environmental Chamber Charts	Temperature & humidity profiles recorded	Chart, stored data on disk,other approved means	
			Includes chamber model & serial, date of test	
	Test Equipment			
6	OTDR	Optical noise floor	Must detect optical pwr at each wavelength	
		Resolution	0.01 dB minimum	
		Accuracy	0.25 dB minimum	
		Measurement repeatability	Less than 3 percent variation	
	Launch Conditions			
9	Multimode	Restricted launch only		
		100/140	ASA-100	
		62.5/125	20 mm mandrel @ 5 wraps or 50/125 jumper	
		50/125	25 mm mandrel @ 5 wraps or 42.5/125 jumper	
10	Single mode	Reduce higher order modes	30 mm mandrel @ 5 wraps/(2 m length)	
11	Test Setup	Dead zone fiber reel	Same fiber size as DUT	
			Splicing o.k. to attach dead zone fiber to DUT	
			Launch condition at source end of ea DUT/ea ch	
		Items to minimize variation in test	Secure/tie down cables (no move @ instr. ports)	
			Group Delay Index found, if not known	
			Fiber parameters entered correctly into OTDR	
12	Test procedure (spectral)	Approved test procedure	Compliance with Section IX	
		Maintain setup during test (source end)	No detachment of DUT cable from source	
		Insert applicable source module into OTDR	Correct wavelength (MM: 850/1300, SM: 1310/1550 nm)	
		Attach dead zone fiber to OTDR & DUT	Splice/index matching gel o.k. @ DUT interface	

OPTICAL TEST MEASUREMENT GUIDE,
TEST SUITABILITY FOR FIBER OPTIC CABLE TOPOLOGY COMPONENTS

Item	Category	Item	Requirement	Compliance
		Verify launch condition	Mandrel wrap DUT, source end	
		Perform measurement	If not automatic, perform cursor operations to obtain parameters for calculation	
		Calculate attenuation rate	For that particular wavelength	
		Repeat test	For each wavelength to be measured	
13	Calculation	Equation to give value in dB/km	Verify proper method if operator performed	
		Sign convention	Recorded attenuation as positive value	
14	Data Sheet	Approved data sheet	Compliance with Section IX	
		At minimum, at each wavelength specified	Usually MM: 850, 1300; SM: 1310, 1550 nm	
		Record length	Length of DUT for attenuation rate provided	
15	Pass/fail criteria	Proper criteria specified	Conforms with MIL-SPEC parameters & values	
		Proper criteria implemented	Test operators knows if fail & to verify result	

Section XIV

Laser Safety

1. Laser Classification Overview: The classification of a laser is based on the ability of the optical beam to cause damage to the eye. Under normal operation an optical fiber communication system (OFCS) is inherently an eye safe system, but when an optical fiber connection is broken and an optical viewing instrument is used, it is possible that hazardous laser energy can enter the eye. For this reason four service group hazard classes (Class 1, 2, 3 (a & b), and 4) have been devised to indicate the degree of hazard and required hazard control measures. Refer to ANSI Z136.2 for a full technical definition and preventive measures.

2. Laser Safety Precautions:

    a. Observe and adhere to all Warning/Caution/Advisories/Notes in the applicable Type/ Model/Series aircraft manuals for repair of and operational verification.
    b. Ensure personnel are familiar with the degree of hazard and the required control measures for the laser in use.
    c. Light generated by light emitting diodes (LED's) and laser diodes may not be visible, but may still be hazardous to the unprotected eye. Never stare into the end of an optical fiber connected to an LED or laser diode and do not stare into broken, severed or disconnected optical cables.
    d. Do not view the primary beam or a specular reflection from an OFCS with an optical microscope, eye loupe or other viewing instrument. The instrument may create an eye hazard due to its light gathering capability.

3. Fiber Optics Safety Precautions:

    a. Keep all food and beverages out of the work area. If fiber particles are ingested they can cause internal injury.
    b. Do not smoke while working with fiber optic systems.
    c. Always wear safety glasses with side shields. Treat fiber optic splinters the same as you would glass splinters.
    d. Never look directly into the end of fiber cables until you are positive that there is no light source at the other end. Use a fiber optic power meter to make certain the fiber is dark.
    e. Do not touch the ends of the fiber, as they may be razor sharp. Rinse hands thoroughly under running water to rinse away any glass shards.
    f. Contact wearers must not handle their lenses until they have thoroughly rinsed and then washed their hands.
    g. In the event glass shards enter the eye or penetrate the skin seek medical attention immediately. **Do not rub your eye. Only authorized medical personnel should attempt removal of glass shards from the eye. <u>Do not attempt removal of glass from the eye yourself</u> !**
    h. Do not touch your eyes while working with fiber optic systems until your hands have been thoroughly cleaned.
    i. Clean hands thoroughly first by rinsing hands under running water to rinse away any glass shards after handling and repairing fiber. Then wash normally. Wear protective gloves if at all possible.
    j. Keep all combustible materials safely away from heat sources.
    k. Ultraviolet (UV) safety glasses shall be worn when using the UV curing lamp.
    l. Only work in well-ventilated areas.
    m. Avoid skin contact with epoxies.