8.4.5.5.3 Fusion Splice – Distortion (Surface) The outer diameter of the fused section is slightly distorted, reducing the effective outer diameter of the fiber.

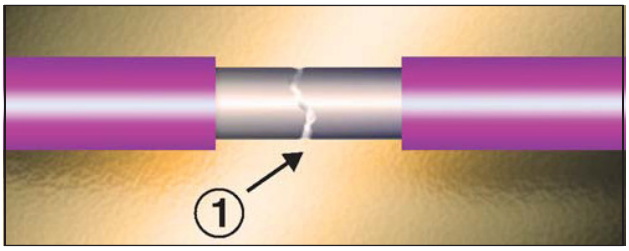


Figure 8-63 Surface Distortion (Fusion Splice)
1. D1D2D3: Distortion exceeds engineering specification.

Acceptable – Class 1, 2, 3
- Distortion is within engineering specification.
- No bubbles, boundary layer or diffraction zone.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Distortion exceeds engineering specification.
- Bubbles, boundary layer or diffraction zone.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.5.4 Fusion Splice – Angular Misalignment Misalignment of the mating fiber ends.

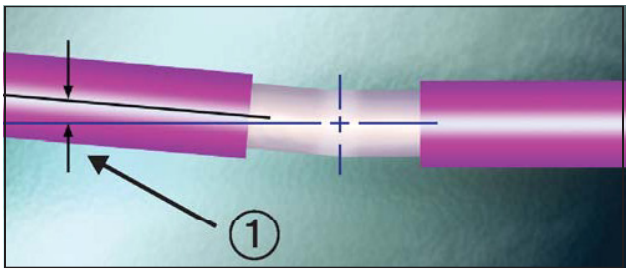


Figure 8-64 Angular Misalignment of Fibers (Fusion Splice)
1. D1D2D3: Angular misalignment exceeds specification.

Acceptable – Class 1, 2, 3
- Angular misalignment is within engineering specification.
- Completed splice will fit in splice closure/protector.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Angular misalignment exceeds specification.
- Completed splice will not fit in splice closure/protector.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.5.5 Boundary Layer/Diffraction Zone This is an indicator of an incomplete fusion process, improper cleave, and/or contamination within the fusion zone.

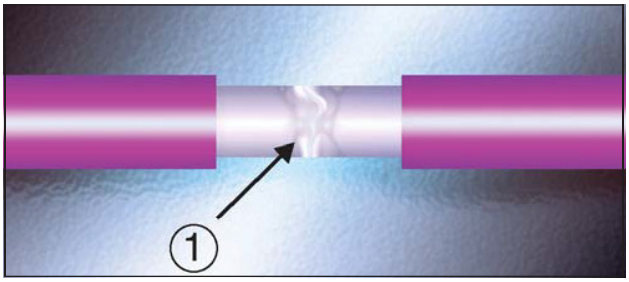


Figure 8-65 Boundary Layer/Diffraction Zone (Fusion Splice)
1. D1D2D3: Boundary layer/Diffraction zone exceeds engineering specification limits.

Acceptable – Class 1, 2, 3
- Boundary layer/Diffraction zone is within engineering specification limits.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.
- Test: Modal shift is within specification.

Defect – Class 1, 2, 3
- Boundary layer/Diffraction zone exceeds engineering specification limits.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.
- Test: Modal shift exceeds specification.

8.4.5.5.6 Fusion Splices – Bubbles Bubbles are an indicator of an incomplete fusion process, improper cleave and/or contamination.

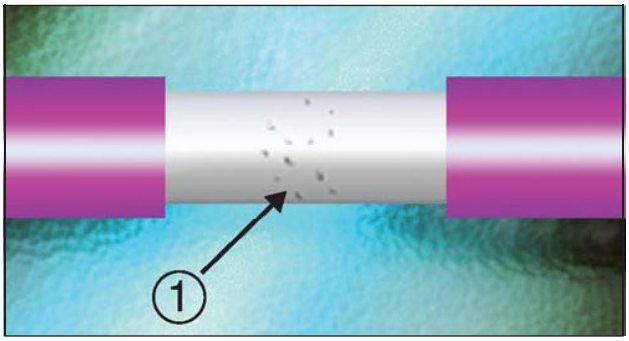


Figure 8-66 Bubbles (Fusion Splice)
1. D1D2D3: Bubbles are located in the core zone.

Acceptable – Class 1, 2, 3
- Bubbles are isolated and located in the cladding zone only.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Bubbles are touching.
- Bubbles are located in the core zone.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.5.7 Fusion Splice – Lateral Offset Lateral misalignment during the fusion process, resulting in high attenuation and poor mechanical properties.

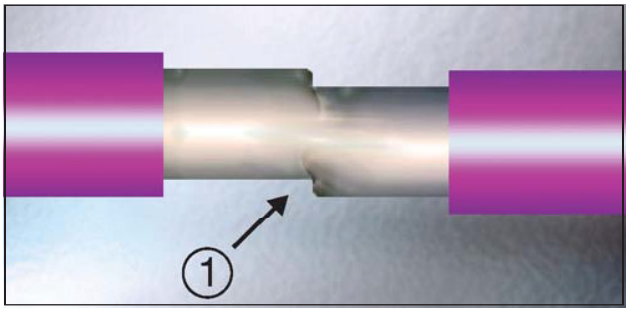


Figure 8-67 Lateral Offset (Misalignment) of Fibers (Fusion Splice)
1. D1D2D3: Lateral offset exceeds engineering specifications.

Acceptable – Class 1, 2, 3
- Lateral offset is within engineering specification.
- Completed splice will fit in splice enclosure/protector.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Lateral offset exceeds engineering specification.
- Completed splice will not fit in splice enclosure/protector.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.5.8 Mechanical Splice – Assembled

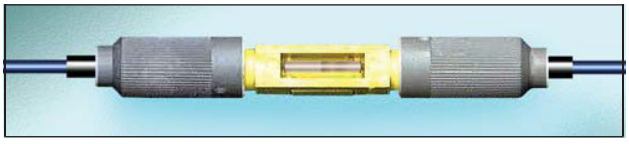


Figure 8-68 Mechanical Splice (Assembled)

Target – Class 1, 2, 3
- The fibers are properly inserted and aligned, and the end faces are in contact with each other.
- Splice housing is assembled per engineering specification.
- Strain relief features are set.
- Test: Attenuation (loss) is within link loss budget limit.

Note: Mechanical splices are not recommended for space-flight applications. See Appendix A for Space/Military Applications requirements.

8.4.5.5.9 Splice Closure/Protector

Figure 8-69 Splice Closure/Protector

Target – Class 1, 2, 3

- Splice closure is clean and undamaged.

8.4.5.5.10 Splice Closure/Protector – Butterfly

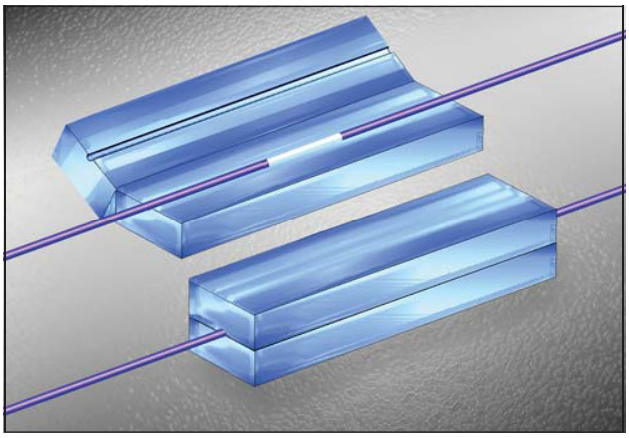


Figure 8-70 Butterfly Splice Closure/Protector

Target – Class 1, 2, 3

- Splice closure/protector is assembled per engineering specification.
- Strain relief features are set.
- Test: Attenuation (loss) is within link loss budget limit.

8.4.5.5.11 Splice Closure/Protector – Heat Shrink

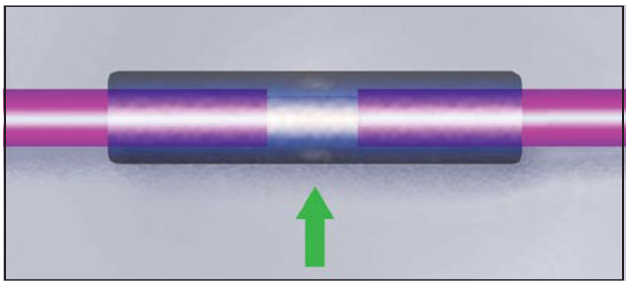


Figure 8-71 Heat Shrink Splice Closure/Protector (Assembled Fusion Splice)

Target – Class 1, 2, 3

- Splice closure/protector is properly located.
- Shrinkage is uniform, and strain-relief features are set.
- No evidence of scorching, burning or melting.

8.4.5.5.12 Mechanical Splice – Bubbles Bubbles in the matching gel cavity.

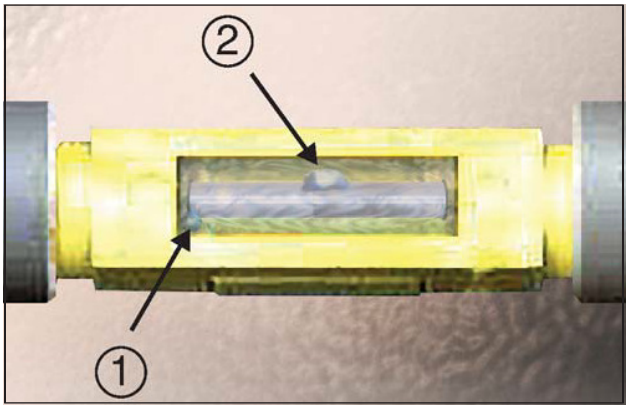


Figure 8-72 Bubbles in Index-Matching Gel (Mechanical Splice)
1. A1A2A3: Bubbles are isolated and do not contact fiber junction.
2. D1D2D3: Bubbles contact fiber junction.

Accept – Class 1, 2, 3
- Bubbles are isolated.
- Bubbles do not contact fiber junction.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Bubbles contact fiber junction.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.5.13 Mechanical Splice – End Face Separation Fiber ends are not in intimate contact, and/or the matching gel has been lost/removed.

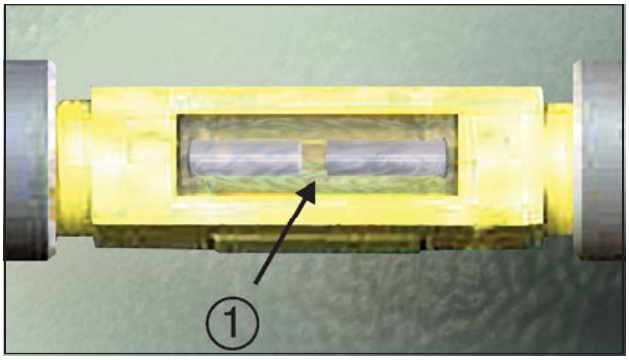


Figure 8-73 Fiber End Face Separation (Mechanical Splice)
1. D1D2D3: Splice assembly is not in compliance with drawing.

Defect – Class 1, 2, 3
- Splice assembly is not in compliance with drawing.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.
- Test: Dark fiber (no signal).

8.4.5.5.14 Splices, Core Mismatch The splicing of two differing fiber core sizes (e.g., 50/125 to 62.5/125), resulting in a power gain/loss, depending on the direction of transmission.

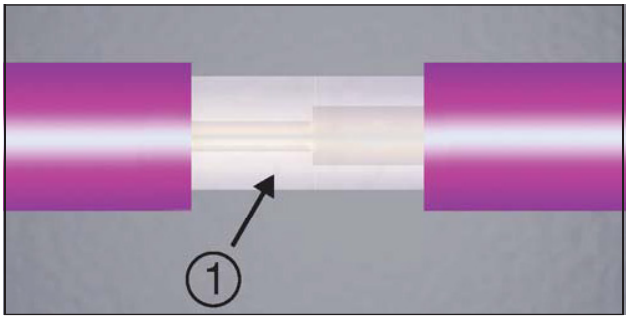


Figure 8-74 Core Mismatch (Fusion Splice)
1. D1D2D3: Splice assembly is not in compliance with drawing.

Note: Image is enhanced to highlight core sections.

Accept – Class 1, 2, 3
- Splice assembly is assembled in compliance with drawing.
- Test: Attenuation (loss) is within link loss budget limit.
- Test: Reflectivity is within link loss budget limit.

Defect – Class 1, 2, 3
- Splice assembly is not in compliance with drawing.
- Test: Attenuation (loss) exceeds link loss budget limit.
- Test: Reflectivity exceeds link loss budget limit.

8.4.5.6 Strain Relief/Strength Member Acceptability of the strength member **shall [D1D2D3]** conform to the following visual examples (at a minimum).

8.4.5.6.1 Strength Member

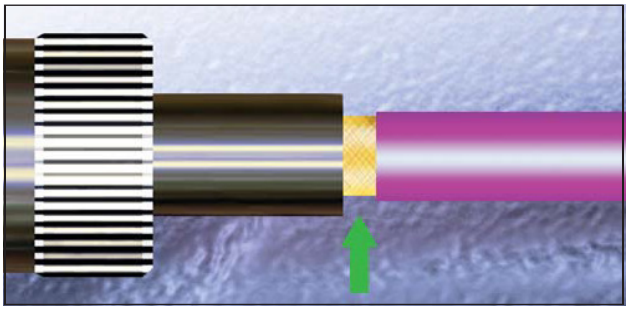


Figure 8-75 Strength Member

Target – Class 1, 2, 3

The strength member is uniformly distributed (dressed) and securely attached to the connector to prevent mechanical stress on the fiber.

Note: Figure 8-75 depicts a gap between the termination sleeve and the cable jacket for illustration purposes to show the proper insertion and dress of the strength member. This may not represent a typical configuration for some connector types.

8.4.5.6.2 Strain-Relief Device (Boot)

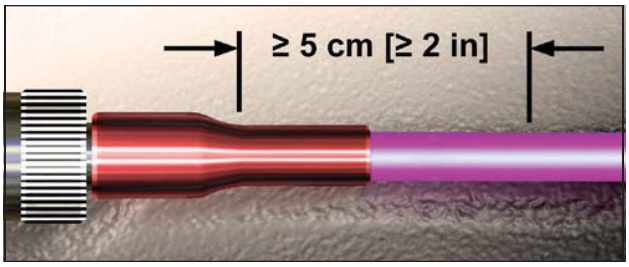


Figure 8-76 Strain-Relief Device (Boot)

Target – Class 1, 2, 3

- The strain-relief device (e.g., boot) is positioned and attached per engineering documentation.
- Strain relief is properly installed, straight, tight and damage-free.
- Axial alignment of the cable to the connector is maintained within 5 cm [2 in] of the exit from the connector body.

8.4.5.6.3 Strength Member – Protruding Fibers

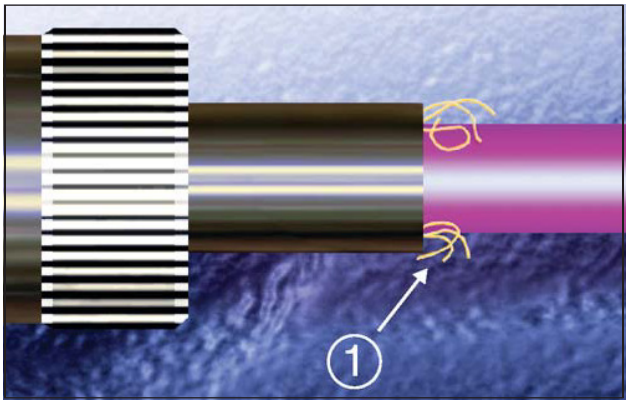


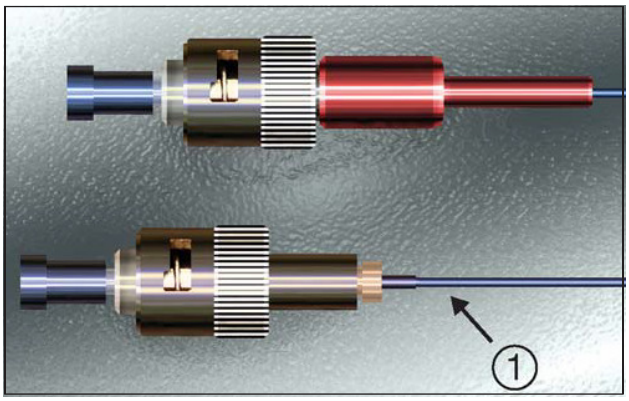
Figure 8-77 Strength Member – Protruding Fibers

1. D1D2D3: Assembly is not per engineering documentation.

Defect – Class 1, 2, 3

- Assembly is not per engineering documentation.
- Test: Attenuation (loss) exceeds link loss budget limits.

8.4.5.6.4 Improper Assembly – Missing Strain Relief



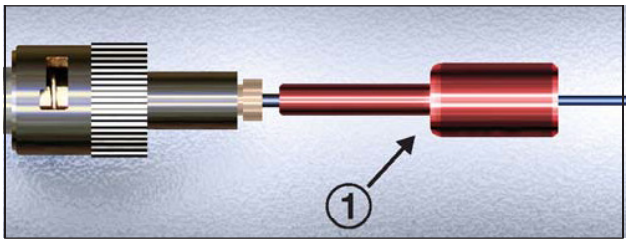
Defect – Class 1, 2, 3

- Assembly is not per engineering documentation.
- Test: Attenuation (loss) exceeds link loss budget limits.

Figure 8-78 Missing Strain-Relief Boot

1. D1D2D3: The strain-relief boot has not been installed (missing) per engineering documentation.

8.4.5.6.5 Improper Assembly – Strain-Relief Boot Installed Backwards



Defect – Class 1, 2, 3

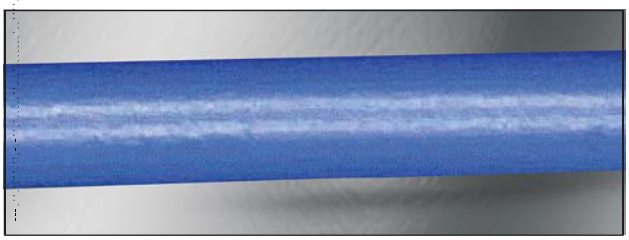
- Assembly is not per engineering documentation.
- Test: Attenuation (loss) exceeds link loss budget limits.

Figure 8-79 Improperly Installed Strain-Relief Boot

1. D1D2D3: The strain-relief boot has been installed backwards.

8.4.5.7 Insulation Jacket(s) Acceptability of the insulation jacket(s) of fibers and cables **shall [D1D2D3]** conform to the following visual examples (at a minimum).

8.4.5.7.1 Insulation Jackets



Target – Class 1, 2, 3

No damage (burns, cuts, tears, etc.), contamination or any other anomaly.

Figure 8-80 Example of Undamaged Insulation Jacket

8.4.5.7.2 Mechanical/Thermal Damage Mechanical/thermal damage includes abrasion, discoloration, gouging and scuffing.

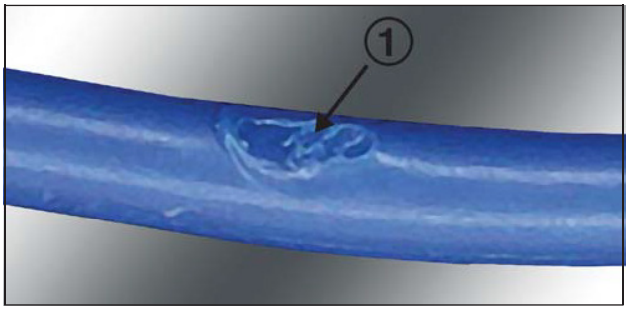


Figure 8-81 Acceptable Mechanical/Thermal Damage
1. A1A2A3: Damage does not exceed 20 % of outer jacket thickness.

Accept – Class 1, 2, 3
- Damage is ≤ 20 % of outer jacket thickness.
- Inner structures (fibers/strength member) are not exposed.
- Test: Attenuation (loss) is within link loss budget limits.

Defect – Class 1, 2, 3
- Damage exceeds 20 % of outer jacket thickness.
- Burns, charring or melt damage.
- Inner structures (fiber/strength member) are visible.
- Test: Attenuation (loss) exceeds link loss budget limits.

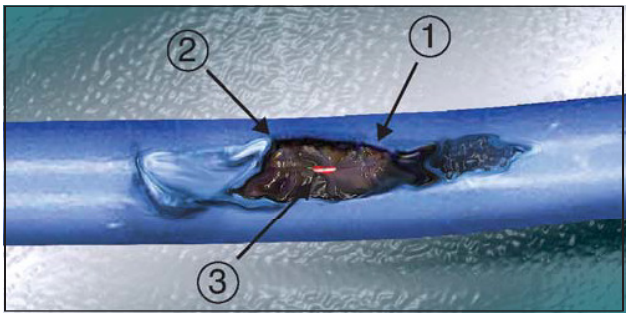


Figure 8-82 Unacceptable Mechanical/Thermal Damage
1. D1D2D3: Damage exceeds 20 % of outer jacket thickness.
2. D1D2D3: Charring and melt damage.
3. D1D2D3: Fiber is exposed.

8.4.5.7.3 Creasing/Ripples

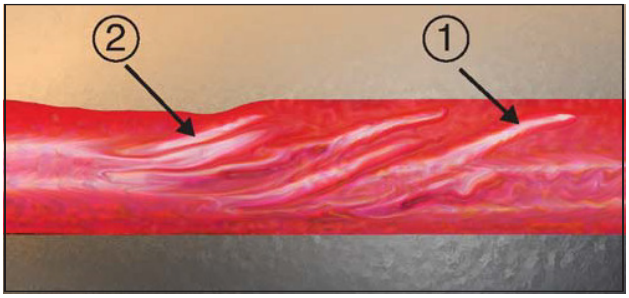


Figure 8-83 Creasing/Rippling of Outer Jacket
1. A1A2A3: Crease/ripple does not exceed insulation jacket thickness.
2. D1D2D3: Crease/ripple exceeds insulation jacket thickness.

Accept – Class 1, 2, 3
- Crease/ripple does not exceed insulation jacket thickness.
- Test: Attenuation (loss) is within link loss budget limits.

Defect – Class 1, 2, 3
- Crease/ripple exceeds insulation jacket thickness.
- Test: Attenuation (loss) exceeds link loss budget limit.

9 QUALITY ASSURANCE REQUIREMENTS – TEST

This section covers testing of individual fiber optic cables and for the overall fiber optic system (e.g., individual fiber optic cables, splices, connectors, termination boxes, cable ways, etc.) covered in this standard. The requirements herein are intended to verify the integrity of the optical transmission path.

Though some of the tests contained in this section may be used to qualify a product for its intended end-use or application, this section is not intended to specifically address all of the unique types of environmental and other testing performed/ required for that purpose.

9.1 Link Loss Budget Unless otherwise specified, the maximum allowable losses **shall [D1D2D3]** be as follows:

a. SM fiber (1550 nm): 0.2 dB/km
b. SM fiber (1310 nm): 0.35 dB/km
c. MM fiber (1300 nm): 1 dB/km
d. MM Fiber (850 nm): 3 dB/km
e. Splice (fusion): 0.05 dB
f. Splice (mechanical): 0.3 dB
g. Splitter (2:1): ≤ 3.5 dB (3 dB splitting loss, plus 0.5 dB excess loss)
h. Connector pair (mated): ≤ 0.75 dB (0.5 dB typ.)
i. Connector stability (mated): < 0.2 dB change over the temperature range of - 20 °C to 60 °C [- 4 °F to 140 °F].
j. Connector Repeatability (remated pair): ≤ 0.2 dB
k. Reflectance (LD transmitter): ≤ - 30 dB
l. Link optical return loss (ORL): ≥ 40 dB (total)
m. Terminator (Nonreflective): ≤ - 70 dB
n. Back-reflection: - 14 dB (unterminated fiber/glass-to-air interface, typ.)
o. Environmental effects loss: as specified by contract
p. Aging loss: as specified by contract
q. Unallocated margin (measured at the input of each receiver): ≥ 3 dB

References:

MIL-HDBK-415
MIL-STD-188-111
MIL-STD-2052

9.2 Test Conditions Unless specified otherwise, all measurements and tests **shall [D1D2D3]** be made at environmental conditions (e.g., temperature, RH, atmospheric pressure) and cleanliness levels that will ensure a proper reproduction and correlation of data. The environmental conditions specified for test may differ from the typical environmental conditions specified for the preparation and assembly of optical fiber, optical fiber cable and optical fiber assemblies in a CWA:

- Temperature: 18 °C to 30 °C [64.4 °F to 86 °F]
- RH: 30 % to 70 %
- Positive pressure: 1.27 mm [0.05 in] of water above the local (site) ambient atmospheric pressure

9.2.1 Standard Test Conditions Unless specified otherwise by engineering documentation or the specific test procedure, all measurements and tests **shall [D1D2D3]** be performed at standard test conditions, per Table 11-4.

9.2.2 Extended Test Conditions Unless specified otherwise by engineering documentation or the specific test procedure, all measurements and tests for critical application, Class 3 and/or Space products **shall [D1D2D3]** be performed at the extended test conditions, per Table 11-5.

9.3 Safety Precautions The following safety precautions **shall [D1D2D3]** apply:

a. Observe all written safety precautions given in the test procedure and the Supplier's safety-related procedures.
b. Observe all warning signs on equipment and all written safety precautions included in the equipment instruction manual.

c. The classification of a laser is based on the ability of the optical beam to cause damage to the eye. Under normal operating conditions, an optical fiber communication system (OFCS) is inherently an eye-safe system, but when an optical fiber connection is broken and optical viewing instruments are used, it is possible that hazardous energy can enter the eye. For this reason, four service group hazard classes have been devised (see 9.3.1) to indicate the degree of hazard and required hazard control measures. Refer to ANSI Z136.2 for a full technical definition.

9.3.1 Laser Service Group Definitions Simplified definitions of the service groups are as follows:

SG1 – No risk when the end of a fiber is viewed with a microscope, eye loupe or the unaided eye. The total output power is < 5 mW.

SG2 – Potentially hazardous when the end of the fiber is viewed for more than 0.25 seconds for a source that emits at wavelengths between 400 nm to 700 nm.

Note: This wavelength range is in the visible region and is outside the 850 nm or 1300 nm wavelength ranges used in United States Navy equipment.

SG3a – Hazardous when the end of the fiber is viewed with a microscope or eye loupe but is not hazardous when viewed with the unaided eye. The total output power of the source is between 5 mW and 50 mW.

Note: Most sources used in United States Navy systems or test equipment have output power significantly less than 5 mW.

SG4a – Hazardous when the end of the fiber is viewed under any condition unless protective eyewear is worn. The total output power of the source is between 50 mW and 500 mW.

9.3.2 Laser Safety Precautions Unless specified otherwise by engineering documentation, the following laser safety precautions **shall [D1D2D3]** apply:

a. Ensure personnel are familiar with the hazards and the required control measures associated with the applicable laser service group classification of the hardware being serviced prior to beginning work.

b. Ensure control measures and procedures prevent personnel from directly viewing the end of an optical fiber or cable connected to an active/powered LED or laser diode source.

Rationale: All optical fiber and cable must be treated as active until verified otherwise. Sources should be locked out to prevent unauthorized/unintended activation.

c. Ensure control measures and procedures prevent personnel from directly viewing the primary beam or a specular reflection from an OFCS with an optical microscope, eye loupe or other viewing instrument.

Rationale: The instrument may create an eye safety hazard due to its light-gathering capability.

d. Ensure personnel wear safety glasses designated for protection against direct and/or indirect exposure of visible/invisible laser radiation.

Rationale: Light generated by light-emitting diode (LED) and laser diode sources may not be visible but may still be hazardous to the unprotected eye.

9.3.3 Personnel Safety Precautions Unless specified otherwise by engineering documentation, the following personnel safety precautions **shall [D1D2D3]** apply when handling bare fibers or performing fiber terminations:

a. Ensure personnel wear approved safety glasses and other appropriate PPE.

Rationale: Always carefully handle optical fiber cable to avoid personal injury. The ends of optical fibers may be extremely sharp and can lacerate or penetrate the skin or cause permanent eye damage if made contact with the eye. If the fiber penetrates the skin, it most likely will break off, in which case the extraction of the fiber should be performed by trained medical personnel to prevent further complications.

b. Ensure personnel wear approved safety glasses when handling blown optical fiber tube (BOFT) connected to a pressurized air/gas source.

Rationale: Debris and objects transported through a pressurized tube can exit the tube with sufficient velocity to cause injury to unprotected eyes/skin.

c. Ensure personnel do not eat or drink in the vicinity of bare optical fibers and that they wash their hands after handling bare fibers or performing fiber terminations.

Rationale: Ingested optical fiber may cause serious internal injury.

d. Ensure personnel comply with all warning signs and procedures when handling solvents and epoxies.

9.4 Acceptance and Qualification Testing The acceptance and qualification criteria for optical fiber, optical fiber cable and optical fiber assemblies **shall [N1D2D3]** be the satisfactory completion of all contractually imposed acceptance tests and inspections.

a. Nondestructive tests (procedure/parameters/stimuli/fixtures) **shall [N1D2D3]** be selected and implemented in a manner that does not cause damage to the component under test.

b. Any deviation from or additions to the default requirements contained within this standard **shall [N1D2D3]** be noted on the drawing and approved by the User.

9.4.1 Receiving and Inspection Optical fiber cable of all types, and associated components (e.g., connectors, splices, termination boxes, etc.) making up the fiber optic system **shall [D1D2D3]** undergo visual inspection and optical performance testing upon receipt.

a. The cable **should** be tested while still on the shipping reel to ensure it is mechanically and optically sound.

b. The associated fiber optic components **should** be subjected to visual examination only.

9.4.2 Acceptance Test Acceptance and qualification tests **shall [N1D2D3]** be specified to conform to the product classification in this standard.

9.4.2.1 Testing Prior to Installation Visual inspection and testing of the fiber optic cable **should** be conducted just prior to installation in the cableways or end-item unit to verify the cables are still mechanically and optically sound.

9.4.2.2 Installation Tests

a. After installation into the cableways, or end-item, the tests prior to installation **should** be repeated to verify that fibers were not broken or damaged when the cable was pulled through the cableways or installed into the end-item unit.

   1. See Appendix A for Space/Military Applications requirements.

b. Additional testing **shall [D1D2D3]** be conducted after installation of connectors or splices to ensure the optical losses induced by these components are within acceptable limits and that the continuity of each fiber between interconnection devices has been maintained.

9.4.2.3 Tests After Installation After all fiber optic systems have been installed, tests **shall [D1D2D3]** be conducted to verify the end-to-end attenuation of each link in the system is within specified link loss budget limits.

9.4.3 Testing After Rework or Repair In the event a rework or repair action takes place, any tests/inspections that were previously performed **shall [D1D2D3]** be repeated in their entirety for the product that was affected by the rework or repair.

9.4.4 Test Discrepancy/Failure If a test discrepancy occurs during an acceptance test, the test **shall [N1D2D3]** be interrupted and the discrepancy verified.

a. The disposition of the discrepancy **should** be completed before the testing resumes.

b. If the discrepancy is dispositioned as due only to the test setup, test cables or to a failure in the test equipment, the test being conducted at the time of the failure may be continued after the discrepancy is corrected, *provided* it can be verified the discrepancy did not result in an overstress test condition or latent damage.

c. If an overstress test condition occurred, or if the discrepancy is dispositioned as a failure in the hardware under test, the preliminary failure analysis and appropriate corrective action **shall [N1D2D3]** be completed in accordance with the established procedures for handling nonconforming supplies.

d. The acceptance test in which the failure occurred, and any previous test whose results could possibly have induced the failure, or whose validity was comprised by the corrective action, **shall [N1D2D3]** then be entirely repeated.

9.4.5 Qualification When required by contract, qualification may be partially or totally satisfied by the testing of higher levels of assembly that include the optical fiber/cable/harness assembly.

a. Qualification tests **shall [N1D2D3]** be conducted to approved test plans that indicate which tests and test procedures will be conducted at which levels of assembly.

b. Applications having constraints on allowable outgassing **shall [N1D2D3]** qualify to that requirement either by test, or by analysis using applicable materials test data to determine the estimated total mass loss and the estimated loss of volatile condensable materials for each wiring harness during its service life.