Visual Inspection and Cleaning of Multimode and Singlemode Structured Cabling System Interconnect Components

READ ALL INSTRUCTIONS COMPLETELY BEFORE PROCEEDING

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1.0 Introduction

This document outlines the Panduit recommended procedures for visual inspection and cleaning of multimode and singlemode structured cabling system interconnect components (connectors and adapters) and specifies workmanship requirements, tools and best practices, to be utilized for end face inspections in the field.

Clean fiber optic components are a requirement for quality connections between fiber optic equipment. Cleaning of the fiber optic interfaces is one of the most basic and important procedures for maintaining fiber optic systems.

Defects due to workmanship in connectors such as pits, cracks, voids and scratches can result in high insertion loss and low return loss. In some instances, these can impact reliability when defects are severe enough or located in particularly sensitive areas of the end face. Connector assembly manufacturers and individuals performing on-site fiber terminations magnify and examine these end faces in an attempt to assess the quality of the polished surface and make corrections if required.

It is also possible for high power laser systems (up to 200-mW coupled power) to fuse contaminants present in the core area onto the fiber surface when the laser is powered on. This action may render the core non-cleanable and the fiber unusable.

Refer to IEC document 61300-3-35 for inspection test and measurement guidelines which presents visual inspection criteria and test methods. Standards created by inspection equipment manufacturers and connector manufacturers typically state tolerances concerning the locations and severity of the defects as well as specifying the magnification used for the inspection. The primary consideration that must be justified in any inspection process is that it must protect the end-user (customer) of the product from defects that could potentially lead to field failure. On the other hand, the process must also protect the manufacturer from discarding their product due to overly tight specifications which do not correlate with product performance and reliability.

When cleaning fiber components, procedures must be followed precisely in order to prevent dust accumulation or other forms of end face contamination. Clean connectors function properly; while contaminated connectors may transfer dirt and debris to other components or damage optical surfaces. Inspection and cleaning are critical steps that must be performed before making any fiber connection.

This document addresses inspection and cleaning issues by describing the impact of workmanship deficiencies in field assembly and test, performance problems caused by interconnect defects, and the fiber optic connector end face workmanship standards established by Panduit to ensure consistent high-quality interconnect systems.

2.0 Subject Connectivity Systems in Link Segments and Channels

All fiber connectivity in the cabling system shall be subject to inspection and cleaning according to the guidelines presented herein. For the purposes of this document, connectivity systems consist of the fiber connector and adapters connecting different segments of the network.

3.0 Safety Precautions

1. **Always check the connector with a power meter to ensure no power is present.**
2. **Never use unfiltered handheld magnifiers or focusing optics to inspect fiber connectors.**
3. **Never connect a fiber to a fiberscope while the system lasers are "ON".**

4.0 Defect Classification

Fiber optic connector end face workmanship is typically inspected for defects by magnified visual examination of the end face. When defects are visualized, they can typically be identified and categorized as follows:

Scratches
Scratches are surface defects. They act as reflection and scattering sites thereby increasing insertion loss and net reflectivity. Deep scratches have the potential of collecting debris that increase reflectance, absorption and scattering of light leading to further degradation of the optical path.

Scratches outside of the core area can possibility lead to debris collection that results in the impairment of the physical contact between the fiber cores. It is also possible that a scratch that has significant subsurface damage may enlarge under stress and cause a fiber break.

Cracks
Cracks in the fiber are fractures of the material that may appear as lines on the surface. Unlike a scratch, a crack can go deep into the fiber.

Cracks in the fiber can present the same types of problems as scratches, but cracks have the potential to grow under load. Cracks near the edge of the fiber can lead to edge chips. Edge chips can then become loose contamination and can affect the mating of the connector.

Fixed Contamination
Fixed contamination is material on the fiber end face surface that can be particularly stubborn to remove or cannot be removed at all. This material can be present in the form of cured epoxy, stains, or embedded particles.

This type of contamination can partially obscure light transmission and lead to higher than expected insertion loss. In addition, such contamination can sometimes be reflective in nature resulting in a low return loss.

The primary problem with fixed contamination present outside of the fiber core is that this material may prevent or limit physical contact of the fiber end faces and cause both high insertion and low return losses. Even if contamination of this type allows physical contact, separation of the end faces may occur during expansion and contraction due to temperature fluctuations and this form of contact may result in the damaging of the mated end face.

Loose Contamination
Loose contamination is debris on the surface of the connector that is not permanent and can be removed with practices outlined in this document. Loose debris may include oil, grease, loose fibers, or metallic particles.

This type of contamination can partially obscure light transmission and lead to higher than expected insertion loss.

Pits
Pits in the connector endface are permanent features in the fiber or ceramic ferrule substrate that are generally irregular shaped, where material has been removed due to polishing.

Pits can create the same problems as scratches. Significant pitting can increase insertion loss and decrease return loss possibly preventing physical contact of the fiber cores when the connector is mated.

Chips
Chips are areas were sizeable segments have broken out of the glass fiber (typically at boundary areas such as the clad edge). These flaws occur most during the polishing and cleaving processes and can negatively impact the optical characteristics of the connector by acting as a “dirt-trap” for contaminations.

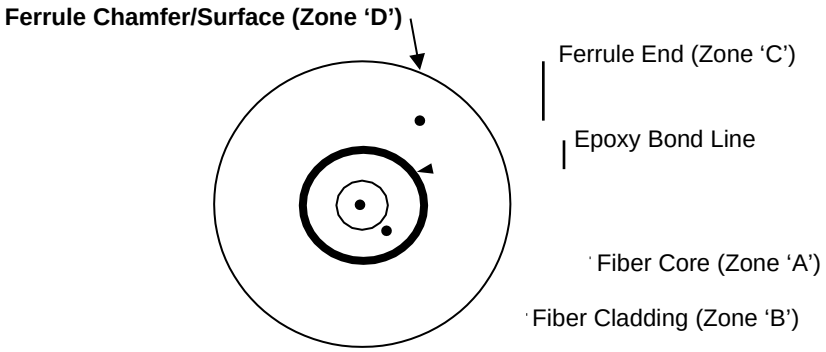
Chips within the core region can result in high insertion loss due to local refractive change and impair return loss due to chips being undercut with respect to the physical contact area creating areas of high **Fresnel loss**. Fresnel loss is the loss that takes place at any discontinuity of refractive index, especially at an air-glass interface such as a fiber end face, at which a fraction of the optical signal is reflected back toward the source.

Defect Location

Defects can be further investigated and classified by their location on the end face surface. The end face surface is defined as the mating surface of a fiber optic connector. It consists of a glass core and cladding, surrounded by a ferrule made of ceramic, plastic, or metal. It is critical to keep this entire area protected from damage at all times.

The locations of defects found during inspection are important because performance impairment is a function of location by zone on the end face. The core area, labeled Zone 'A' in Figure 1, is the light guiding portion of the fiber and is the most sensitive of all of these zones. Defects in Zone 'A' directly affect the light that is transmitted into an adjoining fiber; therefore, adversely affecting performance.

Figure 1 – Typical View of a Single Fiber Connector End Face



NOTE: In array type connectors (MPO or MTP*), boundaries between Zones C and D will usually not be visible due to the array type construction as seen in Figure 4 (page 8).

Defect Specification and Limits

In addition to defect type and location, defects must also be assessed by size and quantity within allowable specified limits. Workmanship standards should be used as a means to promote connector quality and should be validated by appropriate research so that proper inspection, corrective action and disposition can be made.

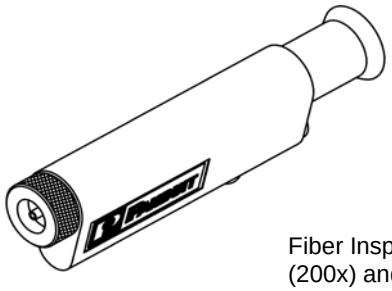
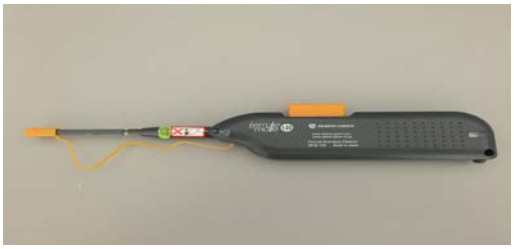
Unnecessarily stringent workmanship standards only serve to negatively impact installation yield for the person performing the connectorization. On the other hand, loose workmanship standards can adversely affect the user, resulting in higher insertion loss and inferior return loss along with lower overall reliability of the connection.

5.0 Equipment List

Connector Cleaning/Inspection Supplies

The following is the Panduit recommended list of equipment and consumable materials for inspection and cleaning of interconnection components.

Figure 2 –
Recommended Cleaning Equipment/Consumables for Single and Array Type Connectors

 Fiber Inspection Microscope (200x) and adapters Panduit P/N FSCOPEY	 Cleaning Swabs Panduit P/N FSWB-C
 Adapter inspection tool	 Electro-Wash PX by Chemtronics or similar
 Non-woven cloth wipes Panduit P/N FWP-C	 1.25mm Fiber Adapter Cleaner
 MTP* Fiber Connector Cleaning Tool Panduit P/N FMTPFCT (Female)	 2.5mm Fiber Adapter Cleaner
 MTP Fiber Adapter Cleaner Panduit P/N FIBCCT	 MTP* Fiber Conn Cleaning Tool Pan # FMTPMFCT (male)

6.0 Acceptable Visual Criteria and Cleanliness Standards

Perform an end face inspection BEFORE the cleaning process using a fiber inspection scope at 200x magnification.

Defects should be noted, classified and dealt with by the inspector according to defect type, size, severity and location per tables, below.

Tables 1 – 3: Visual Inspection Criteria at 200x Magnification for SM and MM Type Fiber

Table 1 – Visual requirements for single-mode PC polished connectors, RL ≥ 45 dB

Zone[a]	Scratches (maximum number of a given dimension)	Defects (maximum number of a given dimension)
A: core 0 µm to 25 µm	None	None
B: cladding 25 µm to 115 µm	No limit ≤ 3 µm None > 3 µm	No limit < 2 µm 5 from 2 µm to 5 µm None > 5 µm
C: adhesive 115 µm to 135 µm	No limit	No limit
D: contact 135 µm to 250 µm	No limit	None > 10 µm

[a] For multiple-fibre rectangular-ferrule connectors only the requirements of Zone A and Zone B apply.

NOTE 1 There are no requirements for the area outside the contact zone. Cleaning loose debris beyond this region is recommended good practice. This is of particular concern for multiple-fibre rectangular-ferrule connectors.

NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.

Table 2 – Visual requirements for single-mode angle polished (APC) connectors

Zone[a]	Scratches (maximum number of a given dimension)	Defects (maximum number of a given dimension)
A: core 0 µm to 25 µm	4 ≤ 3 µm	None
B: cladding 25 µm to 115 µm	No limit	No limit < 2 µm 5 from 2 µm to 5 µm None > 5 µm
C: adhesive 115 µm to 135 µm	No limit	No limit
D: contact 135 µm to 250 µm	No limit	None > 10 µm

[a] For multiple-fibre rectangular-ferrule connectors only the requirements of Zone A and Zone B apply.

NOTE 1 There are no requirements for the area outside the contact zone. Cleaning loose debris beyond this region is recommended good practice. This is of particular concern for multiple-fibre rectangular-ferrule connectors.

NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.

Table 3 – Visual requirements for multimode PC polished connectors

Zone[a]	Scratches (maximum number of a given dimension)	Defects (maximum number of a given dimension)
A: core 0 µm to 65 µm	No limit ≤ 3 µm None > 3 µm	4 ≤ 5 µm None > 5 µm
B: cladding 65 µm to 115 µm	No limit ≤ 5 µm None > 5 µm	No limit < 5µm 5 from 5 µm to 10 µm None > 10 µm
C: adhesive 115 µm to 135 µm	No limit	No limit
D: contact 135 µm to 250 µm	No limit	No limit < 20 µm 5 from 20µm to 30µm None > 30µm

[a] For multiple-fibre rectangular-ferrule connectors only the requirements of Zone A and Zone B apply.

NOTE 1 There are no requirements for the area outside the contact. Cleaning loose debris beyond this region is recommended good practice. This is of particular concern for multiple-fibre rectangular-ferrule connectors.

NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.

NOTE 3 The zone size for multimode fibres has been set at 65 µm to accommodate both 50 µm and 62,5 µm core size fibres. This is done to simplify the grading process.

7.0 General Inspection Guidelines

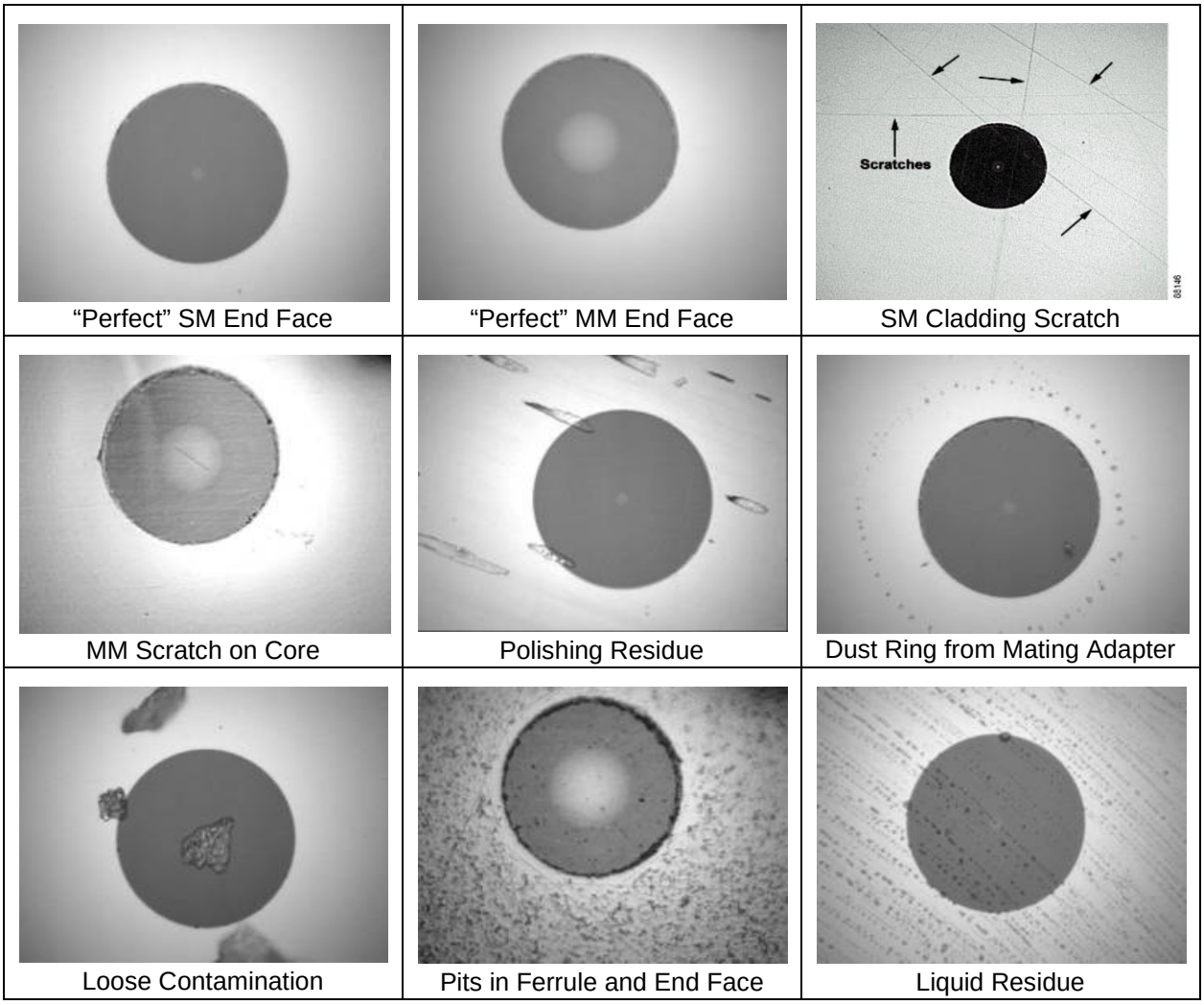
Visual microscopic inspection of the connector end face is the best way to determine the quality of the termination process and cleanliness of the connector. Connector end faces should be smooth, scratch-free and should not display cracks. Several different contamination types and workmanship flaws are shown in Figure 3 on the following page.

The proper magnification for viewing connectors is recommended to be 200x. At lower magnification, typical of an eye loupe or portable magnifier, adequate resolution is not provided. At high magnification, negligible defects at times look worse than they really are. Refer, for example, to Figure 4, where the MTP* connector is magnified at 400x and shows oil or debris on the ferrule end.

Panduit has found that heightened levels of workmanship standards do not provide proportional increases in interconnect performance. In general, if the defects aren't observed at 200x magnification, they do not significantly impact the optical performance of the connector. If workmanship standards are adhered to with inspection at this magnification, connector performance is relative to the cleanliness of the optical interface.

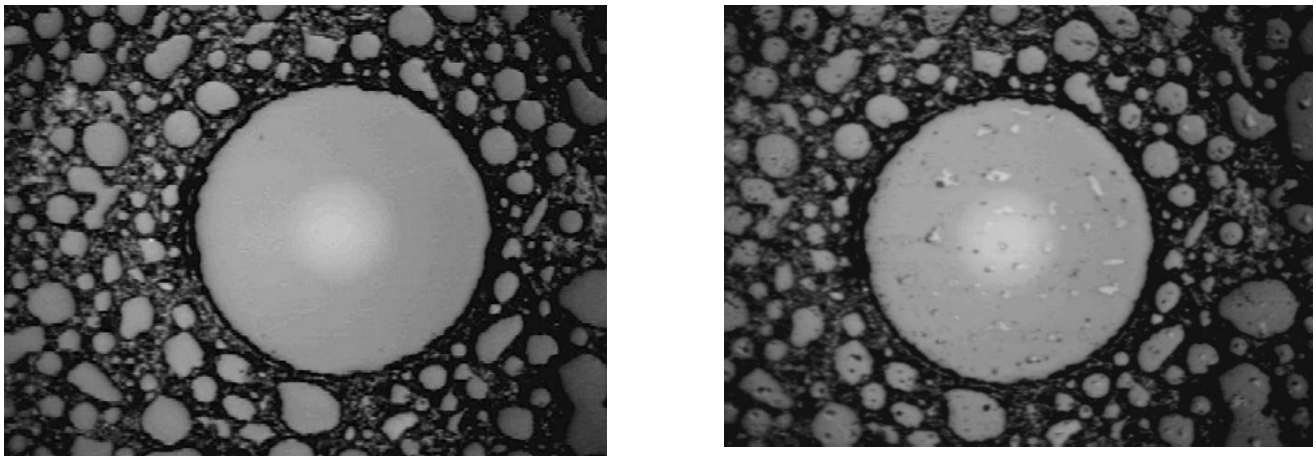
There is a tendency to be overly critical in connector end face inspection, especially at higher magnification(400x). Typically, only defects over the fiber core are a problem. Chipping of the glass around the outside of the cladding is not unusual and will have minimal effect on the ability of the connector to couple light in the core. Likewise, scratches on the cladding area will not cause significant loss problems.

Figure 3 – Typical Fiber End Face Views of a Single Connector at 200x Magnification



“Perfect” SM End Face	“Perfect” MM End Face	SM Cladding Scratch
MM Scratch on Core	Polishing Residue	Dust Ring from Mating Adapter
Loose Contamination	Pits in Ferrule and End Face	Liquid Residue

Figure 4 – Typical Single Fiber End Face View of an MTP* Connector at 400x Magnification



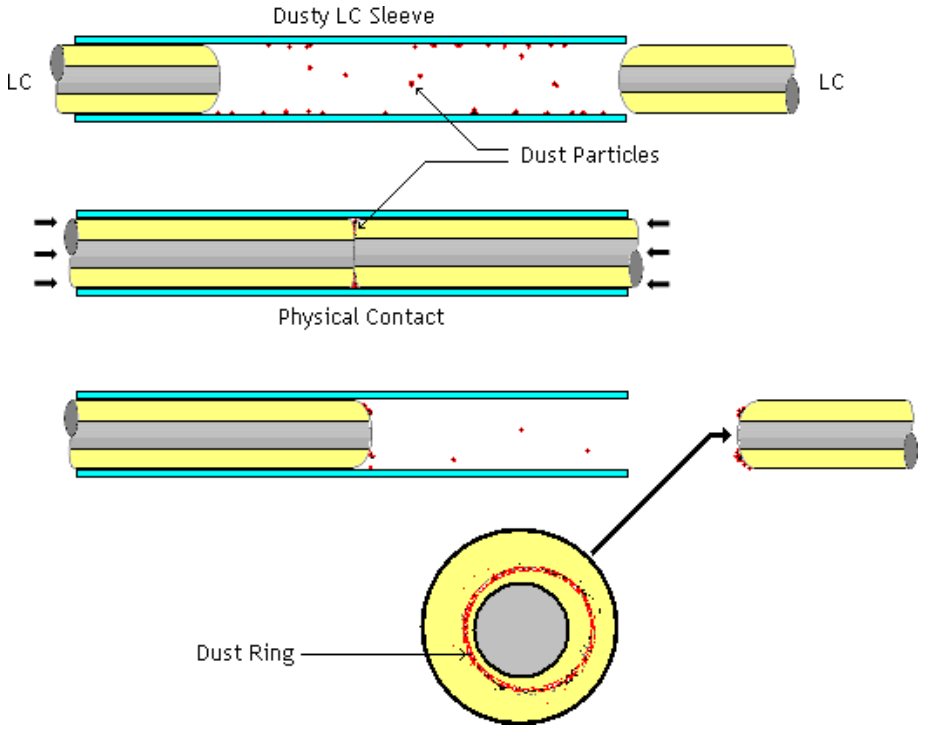
“Perfect” End Face in MTP* connector

Oil/Liquid residue on MTP* connector core and cladding

The most common form of adapter contamination appears in the form of a “Dust Ring”. See Figure 3 for typical end face examples and Figure 5 below for a visual explanation. The particles inside and on the walls of an adapter sleeve are pushed to the contacting surface by both ferrules. Once there, they are collected on the mating end faces of each of the ferrules. When the two ferrules are making physical contact, sub-micron dust particles are forced onto the contact surface. These particles form a ring, the circumference of which encircles the center of the physical contact area.

When there is excess moisture or alcohol present, it also forms similarly shaped rings. Clean adapters do not produce such a ring.

Figure 5 – Typical “Dust Ring” Formation



8.0 General Cleaning Procedures

For components that are suspect of being contaminated, the following cleaning procedures are recommended. Use the following definitions for each connector/adapter scenario described in the cleaning procedures section.

Utilized and accessible: The adapter has fiber connectors mated and both sides of the adapter can be reached.

Not utilized and inaccessible: One side of the adapter is connected and cannot be reached while the other side of the adaptor is not in use, but can be reached.

Utilized and inaccessible: The adapter has fiber connectors mated and only one side of the adapter can be reached.

*MTP is a registered trademark of US Conec Ltd

Fiber Inspection and Cleaning

Note: Per industry standards, Panduit fully supports the practice that all fiber connector end faces be inspected and if necessary, cleaned and re-inspected prior to mating.

Initial Inspection

1. Ensure that no laser or power source is present.
2. Remove any protective caps that may be present on the individual fiber you intend to test.
3. Inspect the connector end faces that are intended to be mated using a high quality **200 X magnification** (no larger) fiber inspection device designed for that purpose.
4. If upon inspection, the end faces prove to be free and clear of any contaminants, proceed to mate the connectors.

Cleaning Regimen A

5. If upon inspection, an end face appears dirty, proceed to clean the fiber with a reel type, micro fabric-based dry cleaner such as Panduit #FMTPMFCT (for Male MPO/MTP connectors) and #FMTPFCT (for all other connector types) or a 1.25mm, 2.5mm or MPO type Fiber Adapter Cleaner.
6. Re-inspect the fiber end faces with the fiber inspection device to determine whether dirt has been removed.
7. If any dirt remains, repeat steps 5 and 6.
8. If upon inspection, the end faces prove to be free and clear of any contaminants, proceed to mate the connectors.

Cleaning Regimen B – after Regimen A is deemed insufficient

9. If after 2 attempts, the dry cleaning procedure proves to be insufficient, proceed to a wet cleaning method.
    a. The wet cleaning method most commonly employed is the use of 90+% Isopropyl Alcohol, (99% preferable), applied to a cleaning swab - Panduit # FSWB-C.
    b. The swab is then rubbed over the entire face of the connector with moderate pressure to remove any remaining contaminants.
    c. Immediately dry the end face with the dry cleaner, as in step #5.
10. Re-inspect each fiber end face once again with the fiber inspection device to determine that all dirt has been removed.
11. If upon inspection, the end faces prove to be free and clear of any contaminants, proceed to mate the connectors.

Cleaning Regimen C – After both Regimen A and B are deemed insufficient

12. At this point, if material of any type remains on either end face, proceed to the use of a wet cleaning fluid such as Chemtronics Electro-Wash PX or equivalent.
    a. Apply Electro-Wash PX cleaner – (F.I.S. part #F1ES810) - to a cleaning swab, as in step #9.
    b. Rub swab over the entire end face of the dirty connector with moderate pressure to remove any remaining contaminants.
    c. Immediately dry the end face with the dry cleaner, as in step #5.
13. Repeat steps 12a, 12b and 12c until all visual contaminants are removed.
14. If upon inspection, the end faces prove to be free and clear of any contaminants, proceed to mate the connectors.
15. If after several attempts with cleaning regimen “C”, any end faces remain insufficiently free of contaminants, (Per IEC 61300-3-35 document) consider replacing the offending connector(s).

NOTES:

- For definition of acceptability based upon artifacts left on fiber end face, *refer to section 6 of the IEC 61300-3-35 document* (FO Interconnecting Devices – Basic Test and Measurement Procedures).
- When incorporating the use of 99% IPA, keep bottle closed at all times when not in use. 99% IPA is extremely volatile and prone to contamination from moisture in the air.
- At operator’s discretion, regimen “B” can be skipped and regimen “C” can be implemented immediately, once cleaning regimen “A” has proven to be insufficient.

9.0 Troubleshooting Unacceptable Interconnect Performance

Unacceptable interconnect performance due to cleanliness issues of the optical interfaces can be localized to certain areas of the network and can be grouped into assignable causes/locations for the degraded performance:

A. Permanent Link Related
These failures occur primarily in the patch field (permanent connector, patch cord or adapter). This could be caused by improper dressing of the jumpers and cables, improper keying/seating of connectors, contamination of the connection, or improper cable routing and localized damage (in the enclosure).

B. Equipment Related
Over/under driving the optical transmission will cause either total or intermittent failure. This can be caused by improper keying or seating of connectors into the transceivers, contamination of the patch cord connector, or contamination of the OSA (Optical Sub-Assembly) of the transceiver. Do not attempt to clean any equipment parts without consulting manufacturer’s specifications.

C. Installation Related
Installations occurring around previously installed fiber networks can also create failures due to lack of attention in dressing, termination issues and cable routing. These can be assigned to either the permanent link or the optics receptacles in the active equipment.

D. Construction/Maintenance Related
In local area networks; cuts through walls and ceilings, extensive pulling (resulting in tensile faults), mistakenly cutting cables, improper clamping, and breaking fibers at the connectors are examples of localized failures due to poor cable identification or lack of care by workers.

Inspection of connectivity for cleanliness and defects is the recommended place to start troubleshooting the physical network. Guidelines for recommended actions based on certain conditions are presented in Table 2 below.

Table 2 - Typical Fiber End Face Defects and Recommended Actions

Defect	Recommended Action
Epoxy bond line cracks	Replace connector.
Fiber “pistoning” - The axial movement of the fiber within the connector body/ferrule.	Positive pistoning - May be addressed by re-polishing. Negative pistoning – Replace connector.
Fiber protruding or convex - A surface irregularity caused by incomplete polishing.	May be fixable by additional re-polishing.
Fiber recessed or concave - A surface irregularity caused by excessive polishing.	Replace or re-terminate connector.
Ferrule Damage	Replace connector.
Surface Pits	Re-polish if in core (SM, MM and MPO/MTP*) or if present in cladding (SM).
Surface Cracks	Replace connector.
Fiber Edge Chips	May be addressed by re-polishing.
Surface Scratches	May be addressed by re-polishing.
Shattered - radial cracks in the core/clad	Replace or re-terminate connector.
Sub-Surface Cracks	Replace or re-terminate connector.

Note: For all Issues regarding visual inspection procedures of fiber optic connector end faces, refer also to the latest edition of the IEC document 61300-3-35.

10.0 Best Practices

1. Inspection and rework areas should be kept as clean as possible at all times to avoid risk of connector contamination. Fiber connectors and adapters under inspection should not be allowed to contact areas that have a high risk of connector contamination (e.g. floor, fingers, etc.).
2. It is recommended to utilize the dry-cleaning method first due to possibilities of contamination with misuse of the isopropyl alcohol. Wet cleaning should be used only when dry cleaning proves insufficient.
3. Panduit connectors and adapters are shipped with dust caps or plugs installed. These caps should remain in place at all times when the connectors are not in use, in order to avoid contamination and possible damage. Always keep dust caps on connectors, patch panels, and anything else within the signal path,until such time as these items are utilized.
4. **A connector removed from an adapter found to be contaminated indicates that the mating connector is also contaminated; therefore both connectors plus the adapter must be cleaned and inspected, before the connectors are re-mated.**
5. When inserting a connector into an adapter, ensure that the tip does not touch the outside of the adapter. This could cause the fiber end to contact unintended surfaces, producing scratches and creating contamination on the fiber end face.
6. Use lint-free, non-woven pads and dry reel cleaners to dry clean the connectors.
7. Use gun-type reel cleaners or a cleaning swab (Panduit Part Number FSWB-C) to clean adapters where one side of the adapter cannot be accessed.
8. Re-inspect connectors utilizing a 200x fiber microscope to ensure cleanliness before capping or reconnecting.
9. For cleaning connectors or adapters permanently affixed to the equipment, please consult the manufacturer’s specifications to minimize or eliminate the chance of damaging equipment.