



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).

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 and in some cases can impact reliability when these defects are severe enough or are located in particularly sensitive areas of the endface. Connector assembly manufacturers and individuals performing on-site fiber terminations magnify and examine these endfaces 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.

At present, there are no published industry standards or guidelines with which to compare 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. This document aims at establishing *PANDUIT* workmanship requirements, tools and best practices, to be used for inspections in the field.

When cleaning fiber components, procedures must be followed precisely and carefully with the goal of eliminating any dust or contamination. Clean connectors function properly; while contaminated connectors may transfer contamination 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 endface 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 should be the subject of 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. **Inspecting connectors in operating fiber optic links can be very dangerous if high power levels are present.**
2. **Always check the connector with a power meter to ensure no power is present.**
3. **Never use unfiltered handheld magnifiers or focusing optics to inspect fiber connectors.**
4. **Never connect a fiber to a fiberscope while the system lasers are “ON”.**

4.0 Defect Classification

Fiber optic connector endface workmanship is typically inspected for defects by magnified visual examination of the endface. 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 possibly 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 significance 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 surface that cannot be removed. 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. On the other hand, such contamination can sometimes be reflective 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 endfaces and cause both high insertion and low return loss. Even if contamination of this type allows physical contact, separation of the endfaces may occur during temperature fluctuations and the contact may result in the damaging of the mated endface.

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.

Chip

Chips are areas where sizeable segments have broken out of the glass fiber (typically at boundary areas such as the clad edge). They 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.

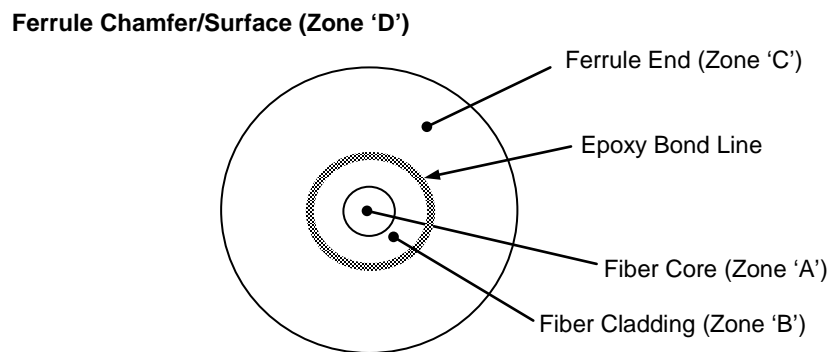
Chips within the core region can result in high insertion loss due to local refractive change and impair return loss due to chips being undercut with respect to the physical contact area creating areas of high Fresnel loss.

Defect Location

Defects can be further investigated and classified by their location on the endface surface. The endface 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 endface. The core area, labeled Zone 'A' in Figure 1 on the next page, 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 Endface



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 on Page 6. As of the date of this publication, there is not any magnifying inspection equipment that will allow the user to view all fibers in the MPO or MTP* connector at one time for cleaning purposes. Each fiber needs to be viewed individually using an MPO/MTP* adapter and the entire endface of the array needs to be cleaned if one fiber is contaminated.

Defect Specification and Limits

In addition to defect type and location, defects must also be assessed by size and quantity of the defect within allowable limits specified for size and quantity given the defect type and location. Workmanship standards should be used as a means to promote connector quality, and should be validated by 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. Loose workmanship standards can adversely affect the user resulting in higher insertion and return loss along with lowering the reliability of the connection.

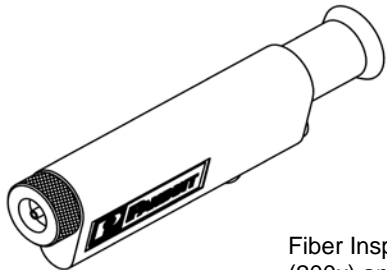
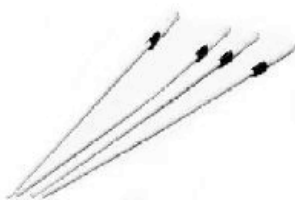








5.0 Equipment List

Connector Cleaning/Inspection Supplies

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

NOTE: As of the date of this publication, there is no available MPO or MTP* connector for the microscope that will allow one to view all of the fibers at one time; one has to examine each endface individually.

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

 <p>Fiber Inspection Microscope (200x) and adapters</p>	 <p>Cleaning Swabs Panduit P/N FSWB-C</p>
 <p>Adapter inspection tool</p>	 <p>Typical Universal adapter for 200x Microscope and typical MTP* type adapter</p>
 <p>Non-woven cloth wipes Panduit P/N FWP-C</p>	 <p>1.25mm Fiber Adapter Cleaner</p>
 <p>Single Connector Cleaning Tool Panduit P/N FMPFCT (Female)</p>	 <p>2.5mm Fiber Adapter Cleaner</p>
 <p>MTP* Fiber Adapter Cleaner Panduit P/N FIBCCT</p>	 <p>MTP* Fiber Connector Cleaning Tool Panduit P/N FMPFCT (Female) and Panduit P/N FMPMFCT (Male)</p>

6.0 Acceptable Visual Criteria and Cleanliness Standards

Perform an endface inspection after 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 Table 1 on the following page.

Table 1 – Visual Inspection Criteria at 200x Magnification for SM, MM and MTP* Type Fiber

Location	Fiber Type	Scratches	Cracks	Contamination		Pits	Chips
				Fixed	Loose		
Fiber Core (Zone 'A')	SM	Rework	Scrap	Rework	Clean	Rework	Scrap
	MM	Rework	Scrap	Rework	Clean	Rework	Scrap
	MPO/MTP*	Rework	Scrap	Rework	Clean	Rework	Scrap
Fiber Cladding (Zone 'B')	SM	OK	Scrap	Rework	Clean	OK	OK
	MM	OK	Scrap	OK	Clean	OK	OK
	MPO/MTP*	OK	Scrap	OK	Clean	OK	OK
Ferrule End (Zone 'C')	SM	OK	NA	Rework	Clean	OK	OK
	MM	OK	NA	OK	Clean	OK	OK
	MPO/MTP*	OK	NA	OK	Clean	OK	OK
Ferrule Chamfer/Surface (Zone 'D')	SM	NA	NA	OK	Clean	NA	NA
	MM	NA	NA	OK	Clean	NA	NA
	MPO/MTP*	NA	NA	NA	Clean	NA	NA

7.0 General Inspection Guidelines

Visual microscopic inspection of the connector endface is the best way to determine the quality of the termination process and cleanliness of the contact. Connector endfaces 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 magnifications, small, ignorable defects look worse than they really are. This is shown in Figure 4, on the following page, where the MTP* connector is magnified at 400x and shows oil or liquid defects in 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 junction.

There is a tendency is to be overly critical in connector endface inspection, especially at high magnification. 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 Plate Views of a Single Connector at 200x Magnification

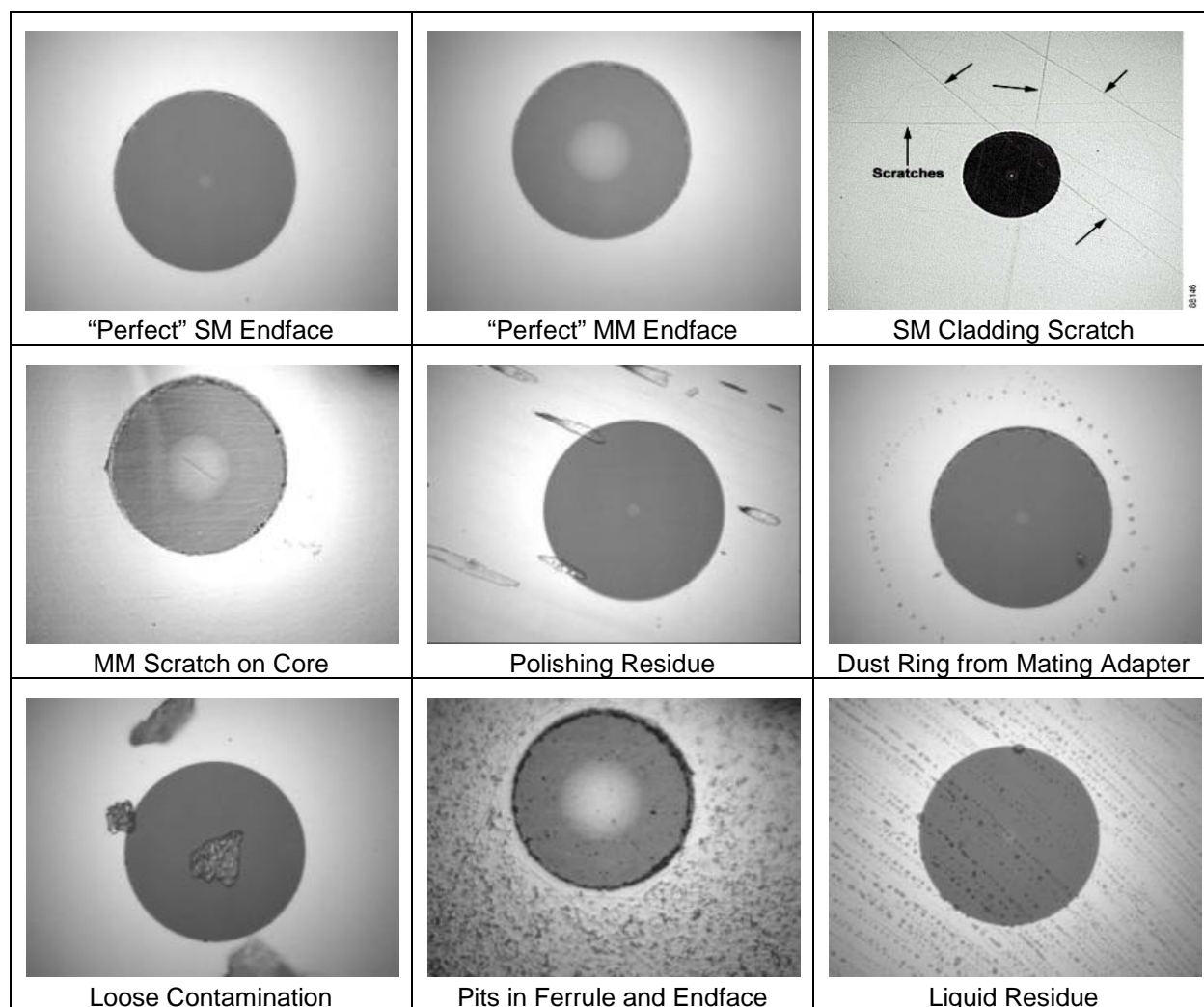
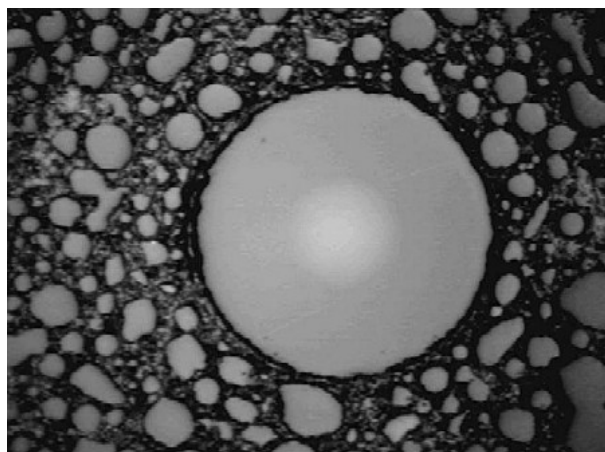
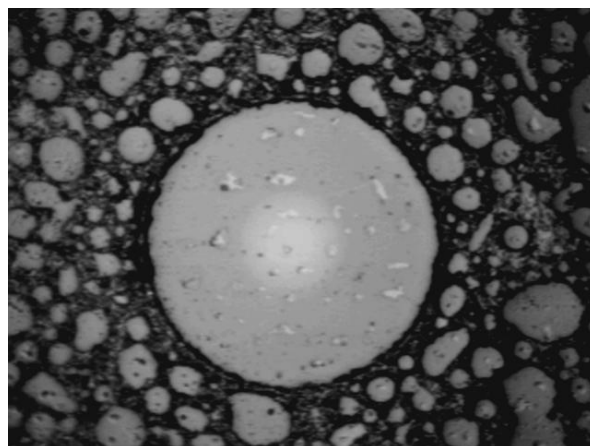


Figure 4 – Typical Single Fiber Endface View of an MTP* Connector at 400x Magnification

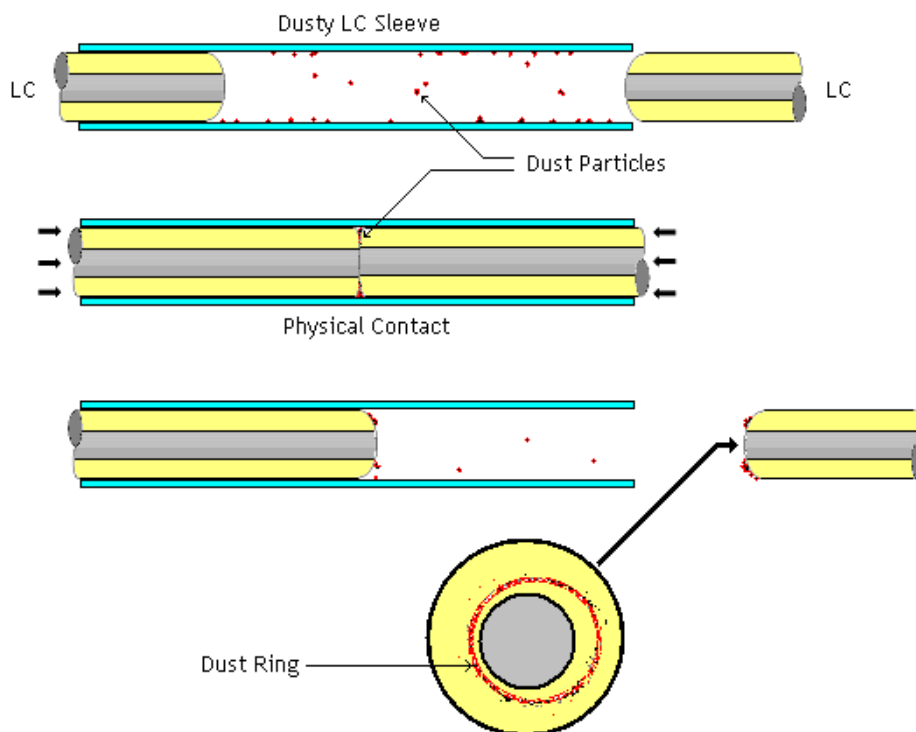
"Perfect" Endface in MTP* connector



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 on the previous page for endface typical and Figure 5 below for visual explanation. The particles inside and on walls of an adapter sleeve are pushed to the contacting surface by both ferrules. Once there, they are collected on the mating endfaces of each of the ferrules. When the two ferrules are making physical contact, sub-micron dust particles are forced out of the contact surface. The particles form a ring, center of which unveils the center of the contact.

When there is moisture or alcohol, it also forms similarly shaped ring. 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/adaptor 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.

A. Cleaning Procedure for Single Fiber Optic Connectors

1. Ensure that the laser source is not present.
2. Remove the protective cap (if present).
3. Inspect the connector with an inspection microscope.
4. Gently wipe the fiber end with a lint-free non-woven cloth wipe (Panduit P/N FWP-C). If it is a reel type, micro fabric based cleaners are utilized (Panduit P/N FMTPFCT is recommended). Follow the instructions provided.
5. Re-inspect the fiber end with an inspection microscope to ensure cleanliness.
6. If the defect is still present, repeat Step 3.
7. Re-inspect fiber end with a fiber microscope to ensure cleanliness.
8. If the connector is not immediately deployed, replace the protective cap.

B. Cleaning Procedures for Single Fiber Optic Adapters

Utilized and accessible:

1. Ensure that the laser source is not present.
2. Remove the fiber connectors from both sides of the adapter.
3. Gently slide cleaning swab (Panduit P/N FSWB-C) thru adapter or utilize Ferrule Mate P/N SFM-125 or SFM-250 (per manufacturer's instructions).
4. Ensure that the fiber connector is clean by following the procedures outlined in Section A above (*Cleaning Procedure for Single Fiber Optic Connectors*).
5. Reconnect the fiber connector to the adapter.

Not utilized and inaccessible:

1. Remove the protective cap.
2. Inspect the adapter with an adapter inspection tool, if available.
3. Utilize a fiber adapter cleaner (Ferrule Mate P/N SFM-125 or SFM-250 is recommended - refer to Section 4.0) per manufacturer's instructions.
4. Re-inspect the adapter.
5. Replace the protective cap.

Utilized and inaccessible:

1. Ensure that the laser source is not present.
2. Remove the fiber connector from the adapter.
3. Inspect the adapter with an adapter inspection tool, if available.
4. Utilize a fiber adapter cleaner (Ferrule Mate P/N SFM-125 or SFM-250 is recommended - refer to Section 4.0) per manufacturer's instructions.
5. Re-inspect the adapter.
6. Ensure that the fiber connector is clean by following the procedures outlined in Section A above (*Cleaning Procedure for Single Fiber Optic Connectors*).
7. Reconnect the fiber connector to the adapter.

C. Cleaning Procedure for MPO or MTP* Array Fiber Optic Connectors

1. Ensure that the laser source is not present.
2. Remove the protective cap, if present.
3. Inspect the fiber with a fiber microscope, and MPO/MTP* adapter, if available.
4. Gently clean the fiber with a micro fabric based cleaner. Panduit P/N FMTPFCT (female connector) or MTPMFCT (male connector) Cleaner Tools are recommended. Follow the instructions provided (PN433^).
5. Re-inspect the fiber for cleanliness.
6. If connector is not immediately deployed, replace the protective cap.

D. Cleaning Procedures for MPO or MTP* Array Fiber Optic Adapters**Utilized and accessible:**

1. Ensure that the laser source is not present.
2. Remove the fiber connectors from both sides of the adapter.
3. Utilize a fiber adapter cleaner, such as Panduit P/N FIBCCT, following instructions provided (PN433^).
4. Ensure that the connectors are clean, following the procedures outlined in Section C above (*Cleaning Procedure for MPO or MTP* Array Fiber Optic Connectors*).
5. Replace fiber connectors into adapter.

Not utilized and inaccessible:

1. Remove the protective cap.
2. Inspect the adapter with an adapter inspection tool, if available.
3. Utilize a fiber adapter cleaner, such as Panduit P/N FIBCCT, following instructions provided (PN433^).
4. Replace the protective cap.

Utilized and inaccessible:

1. Ensure that the laser source is not present.
2. Remove the fiber connector from the adapter.
3. Inspect the adapter with an adapter inspection tool, if available.
4. Utilize a fiber adapter cleaner, such as Panduit P/N FIBCCT, following instructions provided (PN433^).
5. Re-inspect the adapter for cleanliness
6. Ensure that the connector is clean, following procedures outlined in Section C above (*Cleaning Procedure for MPO or MTP* Array Fiber Optic Connectors*).
7. Reconnect the fiber connector to the adapter.

9.0 Troubleshooting Unacceptable Interconnect

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 and 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 Endface 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.

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 alcohol. Wet cleaning should be used as a last resort.
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 everything else that is going to be involved in a connection until utilized.
4. A connector removed from an adapter found to be contaminated indicates that the mating connector is also contaminated; therefore both connectors and 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 endface.
6. Use lint-free, non-woven pads and dry reel cleaners to clean the connectors.
7. Use gun-type reel cleaners 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 danger of damaging the equipment.