CONNECTOR INSPECTION AND MAINTENANCE

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One of the first tasks to perform when designing fiber-optic networks is to evaluate the acceptable budget loss in order to create a product that will meet application requirements. To adequately characterize the budget loss, the following key parameters are generally considered:

- Transmitter: launch power, temperature and aging
- Fiber connections: connectors and splices
- Cable: fiber loss and temperature effects
- Receiver: detector sensitivity
- Others: safety margin and repairs

When one of the above-listed variables fails to meet specifications, the performance of the network can be greatly affected or worse, the degradation can lead to network failure. Unfortunately, not all the variables can be controlled with ease during the deployment of the network or the maintenance stage; however, there exists one component–the connector–that is too-often overlooked, sometimes overused (test jumpers) but that can be controlled using the proper procedure.

The Inspection Phase

Connectors are key components that interconnect the entire network elements, which is why maintaining them in good condition is essential to ensure that all the equipment operates to their maximum performance–to avoid catastrophic network failure. Since connectors are susceptible to damage that is not immediately obvious to the naked eye–the inspection phase is vital.

Components

When proceeding with the inspection of connectors, there are two main components to inspect: the connector itself and the ferrule.

The Connector

One of the advantages with connectors is that when connector failure occurs, it can be rapidly dealt with since its main cause is often traced to the end-face (also called the “ferrule”) or the mechanical section of the connector. Connector failure is most frequently the result of a dirty or damaged end-face. Figure 1 illustrates the parts of a SC-type fiber optic connector.

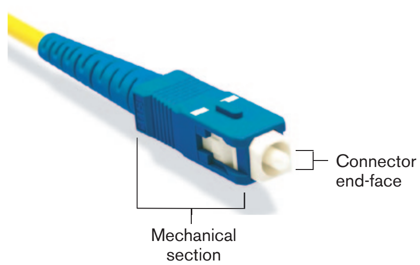


Figure 1. Fiber-optic connector: SC type

EXPERTISE REACHING OUT

The Ferrule

In the connector, the element that holds the fiber and provides the alignment positioning is the ferrule. The ferrule is the part of the connector that connects the cable either to another cable, a transmitter or a receiver. Made of either glass, plastic, metal or ceramic, the ferrule is composed of three principal zones (see Figure 2 a): (1) Zone A, which is defined as the core of the fiber where the light travels; (2) Zone B, called the "cladding", is the outer optical material surrounding the core that reflects the light into the core and (3) the buffer coating protects the fiber from damage and moisture as it surrounds the cladding and is normally made of plastic.

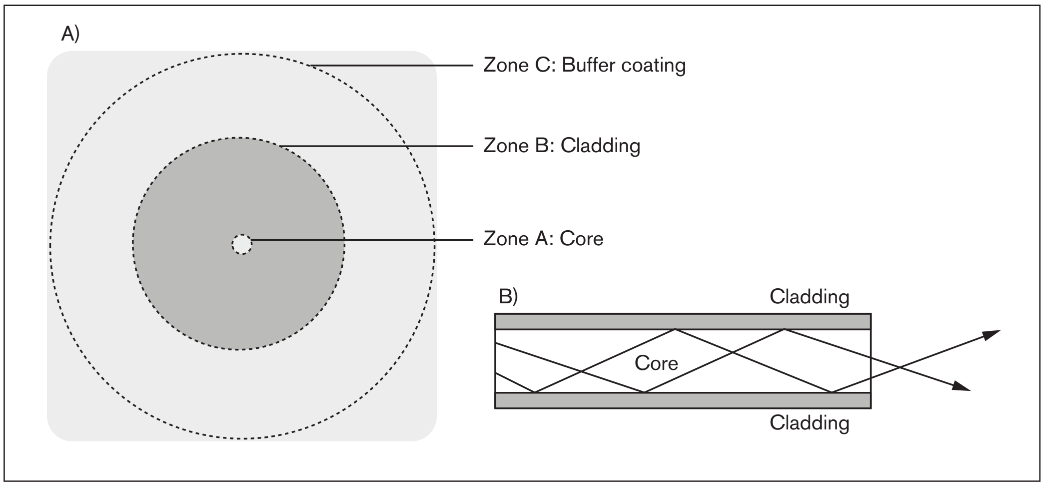


Figure 2. A) Zones defining the ferrule

B) How light is guided through an optical multimode fiber

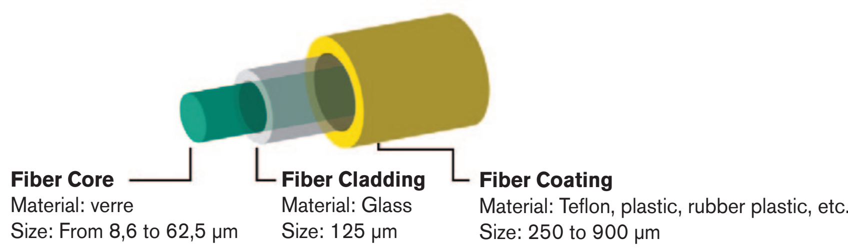


Figure 3. Layered view of a fiber cable

Inspecting Connectors

Since the core and cladding are the two main sections of the ferrule, it is critical that they be maintained in good condition–to minimize the loss that occurs when two ferrules are mated together. In order to properly carry out connector maintenance, the connector end-face must first be visually inspected. As shown in Table 1, the core diameter of a single-mode fiber is less than 10 microns, which means that without the proper inspection tool, it is impossible to tell if the ferrule is clean, making it essential to have the right tools.

Fiber Type	Core Diameter (µm/inches)	Cladding Diameter (µm/inches)
Singlemode	9/0.000000394	125/0.000354
Multimode	50/0.001969 or 62.5/0.002461	125/0.000354

Table 1. Singlemode and multimode core and cladding diameters

To properly inspect the connector end-face, it is recommended to use a microscope that is specially designed for the fiber-optic connector end-face. There are many types of inspection tools on the market, but they all fall into two main categories: fiber inspection probes (also called "video fiberscopes") and optical microscopes. When considering the purchase of an inspection tool, there are a number of points that need to be considered to ensure that the tool purchased suits the applications and connector types that will be inspected. Table 2 below lists the main characteristics of fiber inspection probes and optical microscopes:

Inspection Tool	Main Characteristics
Video fiber inspection probes	– Image display on an external video screen, PC or a test instrument (see Figure 3) – Eye protection from direct contact with a live signal – Image-capture capability for report documentation – Ease of use in crowded patch panels – Ideal to inspect patchcord, patch panel, multifiber connector (e.g., MTP) – Different degrees of magnification available (100X/200X/400X) – Adapter tips for all connector types available
Optical microscope	– Laser safety filter* to protect eyes from direct contact with a live fiber – Two different types of microscopes needed–depending on the types of connector to inspect –one to inspect patchcords and a different one to inspect connectors in bulkhead-patch panels

* It is highly recommended to never use a direct magnifying device (optical microscope) to inspect live fiber.

Table 2. Inspection tools

Figure 4. Video inspection probe

Inspecting Ferrules

When inspecting a connector ferrule, two types of problems can be encountered: a damaged end-face or a dirty end-face.

Damaged End-Faces

Physical damage to the connector end-face are, in general, permanent and will, in most cases, require a connector replacement—unless the damage is not detrimental to the end-face. In order to determine whether the damage is detrimental or not, a good rule of thumb is to discard or replace any connector that has scratches near or across the fiber core (see Figure 5 a), since these scratches can generate high loss and affect the connector performance. For physical damage, including chipped cladding (see Figure 5 b), worn connectors and/or excessive epoxy residue on the cladding, the connector must be replaced .

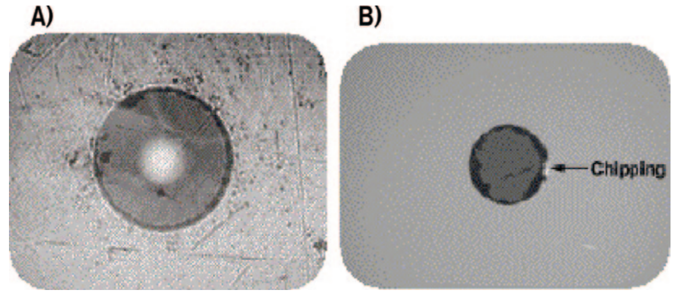


*Figure 5. A) Scratch in the core region
B) Chipping on the cladding*

Dirty End-Faces

In an ideal world, free of contaminants, connector end-faces would always be clean and would not require in-depth maintenance; however, this is not the present reality, and many fiber-optic connector contaminants exist. For example, a 1 µm dust particle on a single-mode core can block up to 1% (0.05 dB loss) of the light—imagine what a 9 µm dust particle can do. Another important reason for keeping end-faces free of contaminants is the effect of high-power components on the connector end-face—some of today's telecommunication components can produce signals with a power level up to +30 dBm (1 W), which can have catastrophic results when used with a dirty or damaged connector end-face (e.g., fiber fuse).

Dust, isopropyl alcohol, oil from hands, mineral oils, index matching gel, epoxy resin, oil-based black ink and gypsum are among the contaminants that can affect a connector end-face. Some of these contaminants are single soil or they may come in complex soil combinations. Note that each contaminant appears differently, but regardless of its appearance, the most critical areas to inspect are the core and cladding regions—as contamination in these regions can greatly affect the quality of the signal. Figure 7 illustrates the end-face of different connectors that has been inspected with a video inspection probe.

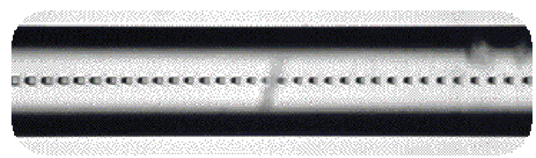


Figure 6. Effect of a fiber fuse on a fiber core

Good practice for avoiding connector end-face damage or contamination is to always keep a protective cap on the unused connector—thereby stressing the importance of storing unused protective caps in a sealed container to prevent contamination. When inserting the protective cap on a ferrule, do not insert it all the way since small dirt particles can accumulate at the bottom of the cap and if the bottom of a contaminated cap comes into contact with the connector end-face, it can contaminate the connector end-face. Note that outgassing from the manufacturing process of the dust cap can leave a residue of the mold release agent or materials in the cap. Therefore, the presence of a dust cap does not guarantee cleanliness; it is a protective device to prevent damage. Another interesting fact about test jumper and connectors, which you take right out of the sealed bag from the supplier, is that they are not always clean before sealing of the bag and therefore will be dirty. Fortunately, using the proper cleaning tools and cleaning procedures can effectively clean a soiled connector.

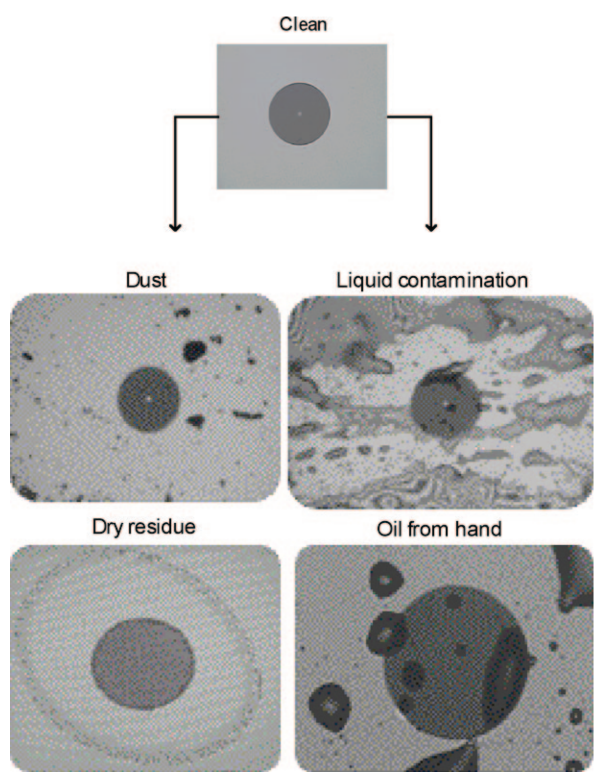


Figure7:Cleanconnectorend-facevs.end-facescontaminatedwithdifferent materials

The Cleaning Phase

A reliable network begins with connector care and cleaning. Through the years, many devices and procedures have been used. In the past, the way a connector was cleaned did not affect performance, but nowadays with fiber-optic network demands increasing to meet consumer expectations of services, the way the connector is cleaned is vital. Therefore, before connecting a connector, it is essential to make sure that the connector is clean and exempt of defects. To ensure connector cleanliness, the connector must first be inspected with either a fiber-optic microscope or a video inspection probe and cleaned if necessary.

Note: Always inspect a connector before cleaning–inspection may reveal that the connector does not need to be cleaned.

There exist various approaches for cleaning connectors, but for the purpose of this document, the three cleaning procedures that are the most commonly used in the industry will be discussed: dry cleaning, wet cleaning and hybrid or combination cleaning.

The Dry Cleaning Method

Dry cleaning is an efficient technique for removing contaminants, such as light dust particles and oil from hands and is often considered the technique of choice in a controlled manufacturing environment–where speed and ease of use are important factors. This cleaning method is also widely used in outside-plant applications, yet is sometimes not sufficient enough to completely remove all the types of contaminants that can be found in this difficult environment. One of the drawbacks to the dry cleaning method is that the dust particles found on the connector end-face can scratch the surface of the connector, causing signal loss and permanently damaging the connector as the dust is removed. Some dry cleaners can also create electrostatic charges on the end-face, which continues to attract particles floating in the air.

Another common contaminant found in the outside-plant environment is a water-blocking gel from the cables–dry cleaners are rarely effective for removing this product. It is also important to understand that a commonly used dry-cleaning process also uses compressed gas dusters, commonly and incorrectly called “canned air”. These chemicals are not compressed oxygen, but are rather compressed gasses. Note that these are not effective to clean fiber-optic end-faces with precision (e.g., not effective on particles embedded in the micro-polished end-face). Tests have shown that these compressed gas dusters are effective in efforts to restore water-damaged connectors prior to a proper precision-cleaning process.

Advantages	Disadvantages
– Convenience of readily available tools – Fast and easy	– Can possibly create electrostatic charges – Not effective in removing all contaminant types – Possible cost consideration

Table 3. Advantages and disadvantages of using the dry cleaning method

There exist different types of dry cleaning tools on the market that are made of various materials and that come in a variety of shapes, depending on the type of connector to clean. Table 4 below lists the most popular and affordable tools used in the dry cleaning method:

Dry Cleaning	Application	Image
Lint-free swabs	Bulkhead, receptacles and patchcord end-faces	
Lint-free wipes	Pigtails and patchcord end-faces	
Compressed gas dusters	Pigtails and patchcord end-faces	
Specialized lint-free wipes	Pigtails and patchcord end-faces	
Cartridge (ReelCleaner/CLETOP)	Pigtails and patchcord end-faces	
Specialized cleaner	Bulkhead, receptacles and patchcord end-faces	

Table 4. Dry cleaning tools

The Wet Cleaning Method

One of the main active elements of the wet cleaning method is the solvent used and selecting the right one, along with an effective and reliable drying is essential for effective wet cleaning. The main purpose of using the wet cleaning method is to raise dust and contaminants from the connector's end-face, which avoids scratching the connector. The most widely-known solvent in the industry is the 99.9% isopropyl alcohol (IPA), which is effective for removing a large majority of the contaminants; yet some of them—such as matching gel and most lubricants—are quite resistant and can leave soil residue.

IPA is by nature a hygroscopic solvent, which means that IPA absorbs moisture from the air to which it is exposed as it strives to get to its natural equilibrium of 65% IPA to 35% moisture, making it a less effective cleaner as it gets more exposure. Another issue with IPA is the application method used by the technician. Over-saturating the swab or over-using IPA (or any solvent) to clean an end face can cause the IPA to absorb additional moisture as it slowly evaporates on the connector, leaving a halo effect or residue (as seen in Figure 7) that can adhere to the end-face. New specialized solvents have been developed that offer better results then IPA; their dissolving power is greater; their evaporation rate is faster and their actions on contaminants are better. Note however that these new products are more effective when used in combination with a dry cleaning process. Overuse of a solvent can result in the excess solvent becoming trapped in the vacuum of the side of the ferrule. In this instance, the solvent may appear to be dry when viewed through a videoscope, but in reality the excess solvent feeds from the vacuum of the side of the ferrule to the end face even after connection—the result is a solvent/contaminant residue that impedes signals and is more difficult to remove than the original contamination.

Advantages	Disadvantages
– Can dissolve complex soils and contaminants – Eliminates the accumulation of electrostatic charge on the ferrule	– Can leave residue on the ferrule when too much solvent is used and not properly dried – Solvent choice can be confusing with issues of performance and EH&S

Table 5. Advantages and disadvantages of using the wet cleaning method

Table 6 below shows the various tools available for the wet cleaning method:

Dry Cleaning	Application	Image
Pen style container	Connector end-face cleaning	
Pre-saturated wipes IPA wipers	Connector end-face cleaning	
Precision solvents	Connector end-face cleaning in combination with an integrated drying procedure	

Table 6: Wet cleaning tools

The Hybrid Cleaning Method

Hybrid cleaning (also called "combination cleaning") is a mix of wet and dry cleaning methods. The first step in hybrid cleaning is to clean the connector end-face by using a solvent and then to dry any remaining residue with either a wipe or a swab, depending on the type of connector being cleaned.

As explored earlier, dry cleaning is especially effective when the contaminants are light particles of dust or oil from the hand, while other types of contaminants (i.e., index matching gel, liquid contamination, gypsum or lint or phosphor powder, oil or dry residue) may require solvents in order to completely remove/dissolve the contaminant from the connector end-face. Those contaminants are most likely to be found in field and service applications where the connector end-faces are subjected to harsh environments, requiring a cleaning technique that is more specialized. It is good practice to identify a single cleaning procedure and implement it system-wide; in this way, there is no guess-work on the soil type but rather one procedure that is highly effective in virtually all applications.

An interesting fact about hybrid cleaning is that not only does it clean the connector end-face, but it also prevents and eliminates the accumulation of electrostatic charge on the ferrule—hybrid cleaning was developed to overcome the drawbacks of dry cleaning or wet cleaning alone. This process offers a cleaning technique that is more effective, which enables complete removal of contaminants, while reducing the chance of damaging the connector end-face. The combination of the wet and dry applications lifts contaminants off the end-face to be collected as the connector is dried. If IPA is used, extra attention should be paid to the amount of solvent used and a quick use of a dry wipe is required to avoid evaporation issues described in the previous section.

Advantages	Disadvantages
- Cleans all soil types - Reduces potential of static field soil accumulation - Automatically dries moisture and solvent used in the cleaning process - Captures soil in wiping material as an integrated aspect of cleaning procedure - Not expensive	- Requires multiple products and re-training of existing procedures

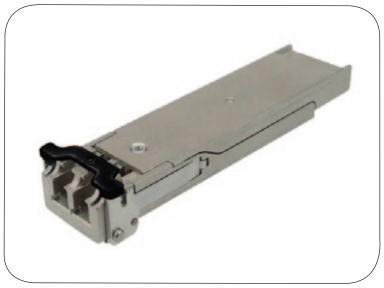
Table 7. Advantages and disadvantages of using the hybrid cleaning method

Cleaning the connector end-face using the hybrid technique:

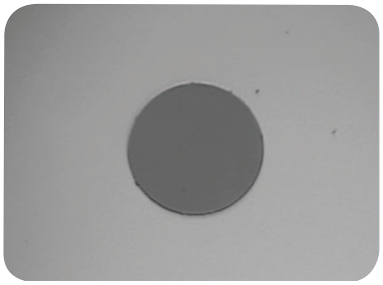
1. Pull a wipe from the specialized wipe container (SWC).
2. Spray a small amount of specialized solvent on the wipe.
3. Place the end-face in the wet portion of the wipe. For a standard polished end-face (UPC), hold the end-face at 90° perpendicular to the SWC platen. Tilt the container or end-face to find the angle on the angled polish connector (APC).
4. In a smooth linear motion, trace the end-face lightly over the platen from the wet section to the dry area without picking up the connector. Do not press too hard and do not perform the cleaning procedure over the same area. It is recommended to repeat this step three times.
5. Using a video inspection probe or other inspection device, inspect the connector end-face to make sure there is no solvent residue or remaining contamination.

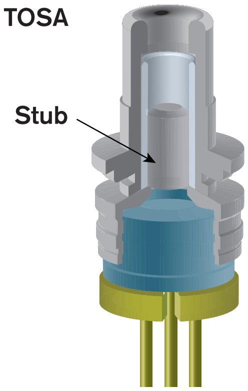
Figure 8. Cleaning procedure

Challenges of Cleaning SFP (SFFP), XFP, CFP, MSA Transmitters

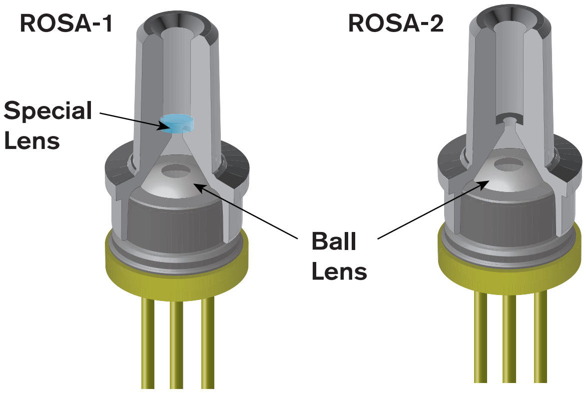


Most small form factor pluggable (SFFP) module transmitters have an LC or SC connector with a stub. These types are relatively easy to clean following the standard connector cleaning procedures outlined in this document.

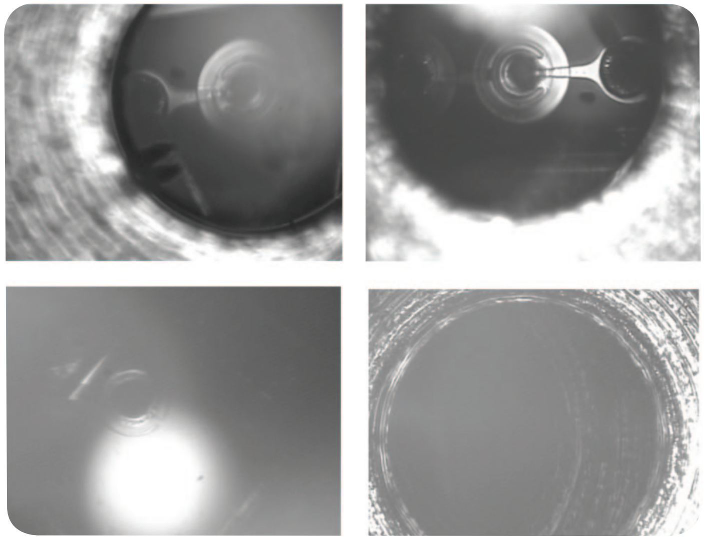




However, the (SFFP) receiver can have an internal lens or an air gap chamber, which makes cleaning and inspecting them much more difficult.



When inspecting these types of transmitters with a fiber inspection probe (FIP), the image is not clear because of the internal design.



Here is the proper cleaning procedure for cleaning these types of transmitters:

1. Open the dust cover or remove the dust plug from the module.
2. Use a non-abrasive cleaner (canned air) to remove any dirt or debris.
3. Insert a lint-free cleaning stick of the appropriate size (2.5 mm or 1.25 mm) and turn clockwise. Dry cleaning is recommended. Do not use alcohol-based cleaning sticks.
4. Repeat steps 2 and 3 as necessary.
5. Remove the cleaning stick, close the dust cover or reinsert the module's dust plug.

   Always keep the dust cover or dust plug inserted in the module when not in use.
6. Always make sure that the connector that will be plugged into the module is also clean before connecting it to the module—to prevent cross contamination.
7. This procedure should be followed when connecting or disconnecting fiber to or from the module.

Conclusion

There are a number of reasons to be excited about by what is going on technologically in the optical telecommunication world. With the advent of 40 Gbit/s transmission and even faster in the near future, numerous challenges will be faced. However, it should never be overlooked that what may seem as a trivial task–ensuring that connectors are clean before connecting–may represent one of the most difficult challenges in the field. In light of this, it is important that connectors receive proper maintenance and that the cleaning procedures are respected to avoid network failure.

Appendix

Cleaning Procedure

Figure 9 below, illustrates the step-by-step inspection/cleaning procedure that should be rigorously followed before a fiber is connected to another optical component–using this simple procedure can avoid costly network downtime.

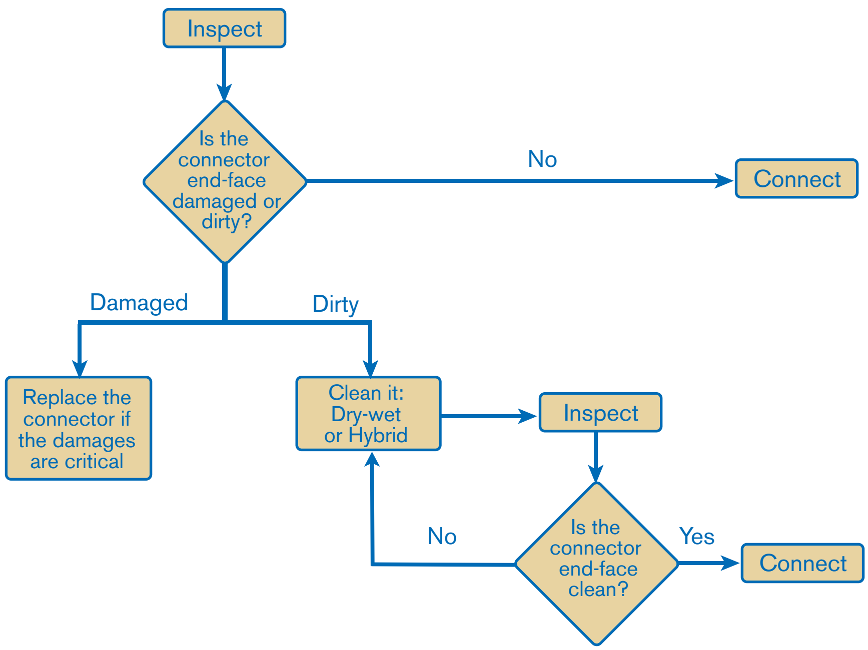


Figure 9. Connector inspection and cleaning procedure

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