White Paper

Trends in Fiber Optic Connector Cleaning

New approaches for rugged fiber optic connectors

Summary

Fiber optics infrastructures have become quite common in a number of markets and applications. In conjunction with this fiber infrastructure are a variety of fiber interconnect solutions. Clean, reliable optical connectors are paramount in providing a reliable, high performance fiber infrastructure. This paper addresses the importance of cleaning and maintaining these optical connectors for optimal performance & reliability. The paper also addresses new approaches to rugged fiber optic connectors to simplify the field-cleaning and inspection process.

By Earl Kneesi, Sales Engineering Manager, Fischer Connectors, Inc.

In addition to his focus on fiber optics, Earl Kneessi is responsible for working with customers to design and develop cable assembly solutions for their devices and applications

By David Magni, Product Manager, Fischer Connectors SA.

David Magni focuses on innovation and creating products that make a difference in the lives of users. He has been working closely with Fischer Connectors' customers to deliver new connector technology to the marketplace

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Introduction

Fiber optics infrastructures have become quite common in a number of markets and applications. These include simple point-to-point security systems, Ethernet mesh networks and high-performance, high bandwidth video transport and switching systems for the A/V and broadcast markets. In conjunction with this fiber infrastructure are a variety of fiber interconnect solutions. These may be as simple as fiber connectors for direct connectivity to patch panels or transmission equipment or as complex as multi-fiber connectors used in rugged, hostile outdoor environments. Clean, reliable optical connectors are paramount in providing a reliable, high performance fiber infrastructure. The result is the ability to reliably use these connectors in new, environmentally hostile applications for years.

About Fischer Connectors

Fischer Connectors has been designing, manufacturing and distributing high performance connectors and cable assembly solutions for almost 60 years. Known for their reliability, precision and resistance to demanding and harsh environments, Fischer Connectors' products are commonly used in fields requiring faultless quality, such as medical equipment, industrial instrumentation, measuring and testing devices, broadcast, telecommunication and military forces worldwide. Primary design and manufacturing facilities are located in Saint-Prex, Switzerland, with subsidiaries and distributors located worldwide.

Headquarters
Fischer Connectors SA
Ch. du Glapin 20
1162 Saint-Prex
Switzerland
Phone +41 21 800 95 95
mail@fischerconnectors.ch
www.fischerconnectors.com

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1. Growth of fiber optics

As more governments, companies, organizations and industries demand increased bandwidth, more data and better quality audio/video, the use of fiber optics around the globe has grown rapidly. That need for more and better data means more fiber optic cable and more high density, reliable optical connectors.

In applications that are considered rugged such as government, military, broadcast, etc., Bishop & Associates reports that rugged fiber optic connector sales grew at a rate of over 25% in 2011[1]. These rugged markets are making the transition from the lower bandwidth, larger core multimode fibers to the more efficient single-mode fiber with its much smaller core or mode field diameter (light carrying portion of the fiber) and extremely high bandwidth. High bandwidth HD video, and now the more recent Ultra HD or 4K video, require the use of single-mode fiber for any long distance applications.

The following table provides some insight into the data rate of some of these high performance video signals – all of which require the use of single-mode fiber. Some of these indoor A/V & broadcast applications include board rooms, studios & control rooms, pre & post production, airports, and concert & entertainment venues, among others. The more rugged outdoor applications include military & security communications, sporting events, video transport, studio to OB van interconnects, rental & staging applications, etc. All of these applications require high reliability fiber optic cable and connectors. It's important to ensure that the proper connectors for the environment and application are chosen to minimize their cleaning/testing/maintenance to ensure the highest reliability and the minimum amount of system downtime.

Signal Type	Data Rate
HDSDI (1080i)	1.5 gbps
HDSDI (1080p)	3.0 gbps
HDMI	6+ gbps
Ultra HD (4K video)	12 gbps

As video resolution continues to increase and the number of signals on one fiber continues to grow, it becomes imperative to incorporate single-mode fiber in new system designs. This usage of single-mode fiber poses new concerns for the fiber connector end surface condition and cleanliness.

When working and properly maintained, there is no argument that fiber has significantly greater bandwidth and is more reliable than copper. There are many ways to compare the benefits of fiber optic cable over copper, including cost comparisons, immunity to EMI & RFI, a technology-proof infrastructure that are beyond the scope of this paper. Companies moving to fiber optics benefit by being able to send high-definition video over long distances without loss of quality, as well as sending data at speeds higher than through traditional copper wiring. Unlike a traditional copper infrastructure, a single fiber can transmit any signal from simple contact closures, to audio, data, NTSC video and now HD & Ultra HD video without the need to change the fiber. In fact, all of these signals can be transmitted over the same fiber simultaneously without any loss of performance. This has significant implications for communications, remote monitoring, and other data-intense applications. Simply stated, fiber optics carries significantly more data over greater distances than copper.

One of the keys to ensuring a quality, high reliability fiber infrastructure is to use high performance, rugged optical connectors that can be easily cleaned and maintained. There are two major approaches for addressing cleaning issues for multi-fiber rugged connectors that are made up of common indoor-use style components:

- Expanded beam uses bigger connectors to reduce the need for cleaning, but the trade off is that you get reduced optical performance when you integrate them into your solution.
- Encapsulated and easily cleanable rugged fiber optic connectors that are easy to clean and still maintain the required high optical performance.

If maintaining optical performance is essential to your application, you will want to examine fiber optic connectors that are encapsulated and designed to be cleaned.

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2. The importance of cleaning

Fiber optic consultant and industry expert John Lee, has worked with leaders in fiber optic cables and connectors for over 15 years. He says that cleaning consideration is the number one issue in fiber optic cable technology today. Costs of cleaning include limiting the life of the fiber optic cable when the ferrule is damaged or broken when connecting. "With 4 ferules in a connector, what's the probability that you lose one ferule…then you lose the whole connector?" That means selecting a connector that is easy to clean can be worth the "total cost of the cable," according to Lee.

Fiber optic connectors require more attention than traditional electrical connectors because they can more easily be damaged. Companies looking to invest in fiber optics should understand the role that cleaning plays in the application at hand, and learn the best methods of cleaning their particular connector. This can play a large role in decisions when fiber optics will be mated/unmated in rugged conditions.

Figure 1 shows the composition of a single-mode fiber (core, cladding, buffer). The light carrying portion of the fiber (core) is generally specified by its mode field diameter (MFD) and has a diameter of approximately 9µm. These fibers have a cladding diameter of 125µm, while the protective buffer has a diameter of 250µm.

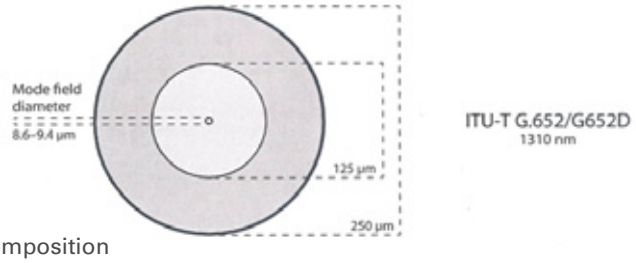

Figure 1
Fiber Composition

As illustrated, when compared to the entire surface of the fiber, the core or MFD is quite small. It's crucial that this surface of the fiber be clean and free of dirt, defects, scratches, etc.
Figures 2 and 3 show actual photographs of the end surface of a typical single-mode fiber connector. Figure 2 shows the face of a clean fiber while the photos in Figure 3 are of the same fiber end surface but contaminated with skin oil. These photos clearly show that contamination has covered some of the fiber's core or MFD. Depending on the type and amount of oil or contaminant, this could lead to significant connector attenuation.

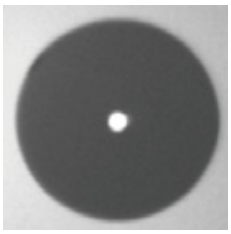

Figure 2
Clean Single-mode Fiber End Face

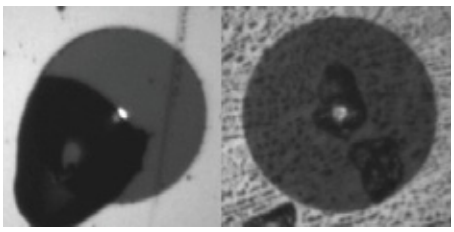

Figure 3
Fiber End Face Contaminated with Skin Oil

Since the fiber contacts, or ferrules, in the connector make physical contact with one another within the connector's alignment sleeve, any contamination or dirt on one of the ferrules can easily be transferred to the mating ferrule, further complicating the cleaning process. This also runs the risk of physical damage to the fiber's end face.

Because the data is transmitted through the small 9µm core of the single-mode optical fiber, a very small amount of dirt or residue may significantly increase the connector's attenuation and weaken the signal. John Lee, consultant and fiber optic industry expert, says contaminants as small as 1µm can have a noticeable effect on the connector's attenuation (in excess of 0.5dB). "In installations with multiple connectors, these dirty or high attenuation connectors can have a significant impact on the system's overall optical link budget, and can reduce its performance and maximum distance", says Lee. System installers, integrators and others just starting to work with fiber will soon realize that a single-mode fiber optic connector is much more sensitive to dust, dirt and other contaminants than standard electrical connectors or even multimode optical connectors (due to their much larger core diameter). And of course, the place where dirt, dust and contaminants enter the system is at the connector interfaces. An assumption is generally made that the dust caps on the connector's optical contacts ensure that the connector's end face is clean and ready to use. Quite the opposite. As Lee states, "Most people think they can remove the dust cap and plug it in. In fact, the inside of the dust cap can actually have significant dirt or other contaminates that are easily transferred to the contact's end face. Without cleaning the contact prior to inserting in the connector, additional loss may be incurred at this connector interface."

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According to Larry Johnson, Director and Founder of the Light Brigade[2], "The importance of proper inspection and cleaning of fiber end faces is critical to the performance and life of any fiber optic system. The lack of applying proper cleaning procedures each time a connector is mated can directly impact the quality of the system's performance." Each time a fiber optic connector is mated, both the plug and receptacle must be cleaned, and, when possible, inspected to ensure that nothing – not even a speck of dust – remains. Bulkhead connectors on transmission equipment and patch panels, for example, can easily be contaminated by dirt from the mating cable or patch cord connector. These recessed connectors, however, can be more challenging to clean and evaluate since it may be necessary to clean the ferrule by accessing it through the alignment sleeve.

A search on the internet will yield numerous sites explaining cleaning techniques, with a variety of companies wanting to sell special tools for cleaning. These optical connector cleaning tools have become more sophisticated and specialized, making the cleaning process easier and more efficient. Like the progress that cleaning tool manufacturers have made over the past few years, the connector manufacturers also have been researching and introducing new ways to protect the optical contact and minimize the cleaning time and difficulty.

The replacement cost in terms of time & money for one of these multi-contact connectors can be quite substantial and may result in expensive system down-time. Since these multi-contact connectors are difficult if not impossible to be repaired in the field, it would be necessary to replace the cable. Again, according to John Lee, "Without a backup cable, it may take up to 4-6 weeks and thousands of dollars to obtain a new one. This could result in significant cost and loss of revenue if the cable were to take down a production line."

3. Safety

Although this paper is not intended to be a cleaning tutorial, any discussion of optical connector cleaning usually comes with safety information. The photos in Figure 4 show the JDSU OLP-82P Video Microscope and Power Meter with the remote probe[3] connected to a Fischer bulkhead connector. Using this probe, a completely safe visual inspection of the connector end surface is displayed on the LCD screen. In addition, this unit also has a power meter function so that power from the connector's ferrule can be measured. The photos in Figures 2 & 3 were taken from this video microscope.

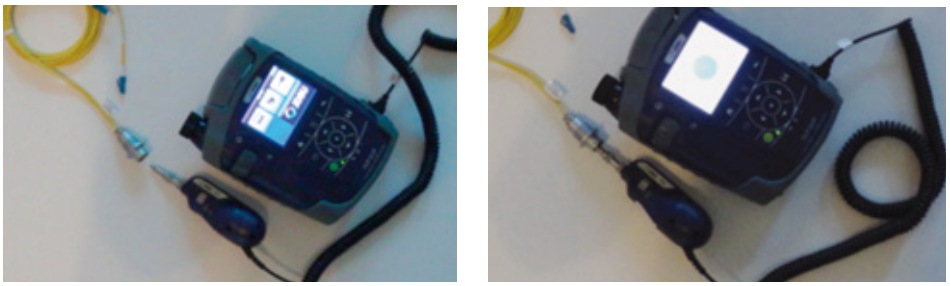

Figure 4
JDSU Digital Video Scope with Probe

Lasers commonly used in these A/V & broadcast systems are low power eye or retina safe, Class I lasers and are, therefore, not hazardous to eyes or skin. However, it is always a good practice to follow the following safety recommendations when working with and inspecting fibers:

- When a power meter is available, it is recommended that the output power from each fiber be checked to ensure that there is no light present.
- Whenever possible, use a video scope for eye protection and improved visual monitoring to inspect fiber connector end faces
- If you are using an handheld optical magnifier to inspect fiber connectors ensure that it has an inter nal filter and a magnification of at least 200x for proper viewing of the fiber end surface
- In addition, wear safety glasses and make sure that the cable is disconnected at both ends, or that the card or pluggable receiver is removed from the chassis.

These cautions are important to take to the field, no matter whose connectors you are using. Since many fibers carry bi-directional signals, it's imperative to ensure that both ends of the fiber are disconnected from the transmission equipment.

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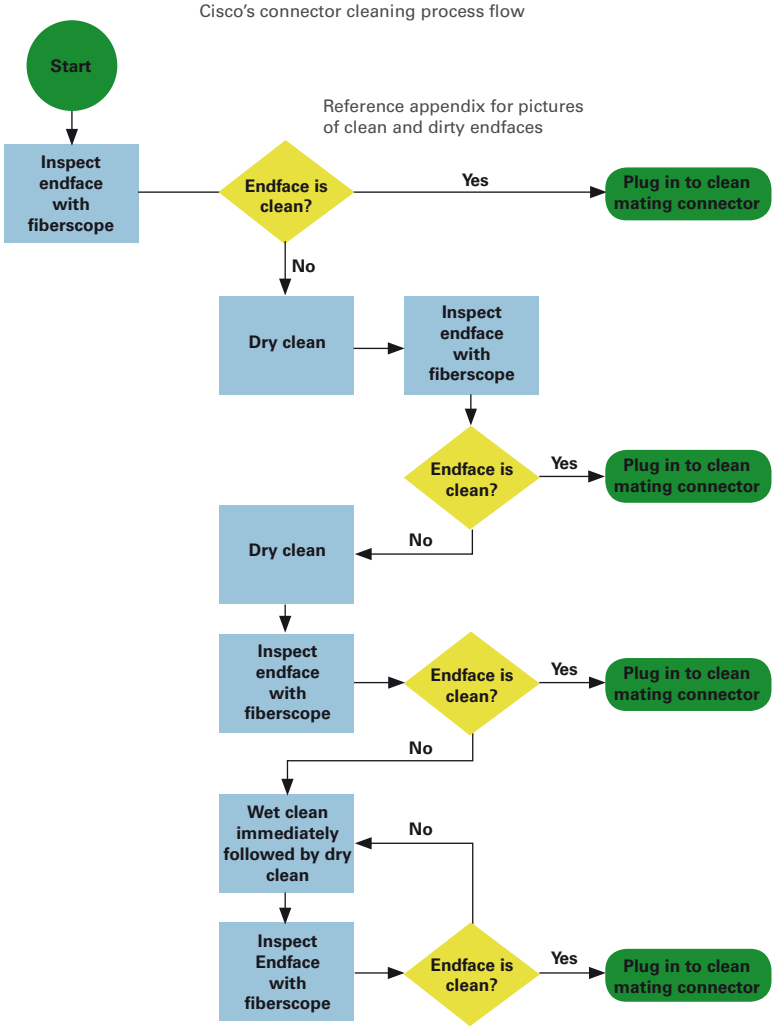
3. The cleaning process

Most companies that install fiber optics on a regular basis have their own set of installation and cleaning instructions. They all have one thing in common: multiple steps that require the installer to clean, inspect and test both the plug and receptacle, with instructions to go from one cleaning method to another if (when) the first and second approaches don't work. Generally, connector manufacturers will publish guidelines for cleaning their connectors and may recommend specific cleaning and ferrule inspection tools to ensure that they are cleaned properly with minimal chance for damage.

Cisco has outlined their connector cleaning approach with the following flow diagram: [4]

Cisco's connector cleaning process flow



Another way to look at the process, with ultrasonic cleaning added as an option:

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4. Cleaning requirements

There are two places that cleaning requirements come into play: in the field (mobile/remote) and in-house (fixed). The troubleshooting lists are different based on the likelihood of contamination and the cleaning materials available. These cleaning techniques are simplified with the use of rugged, sealed connectors.

5. Field Cleaning and Troubleshooting

It is this usually lengthy and detailed cleaning process that may contribute to slower-than-expected fiber optic growth in rugged field conditions. However, attention paid to new connector designs will reduce the time required and difficulty in cleaning. If you have a rugged, sealed connector like the new Fischer FiberOptic connector, field cleaning is simplified by rinsing with any clean, available water source, and drying the ferrules with clean canned air. This approach only applies to connectors sealed to IP67/68 standards where water intrusion is eliminated. The water wash can be done in the field to remove dirt around the outside and inside of connectors without fear of introducing additional contaminants. The following 'water wash' procedure is applicable to the Fischer FiberOptic connector:

- Place the connector under running tap water until everything is cleaned as shown in the photos in Figure 5 below.
- Remove the sleeve holder with the tweezers or small pliers
- Repeat the tap water operation if needed over the exposed contacts
- Dry the contacts & connector by spraying canned air on it.
- Dry the sleeve holder by spraying canned air on it
- Insert the IBC™ Brand Cleaner on all contacts and perform one click / cleaning per contact
- Reassemble the sleeve holder in any of the four positions being careful to align the contacts with the alignment sleeves in the holder.

Always clean both sides of the connector as dirt on one contact may transfer to the clean one which would then contaminate both sides.

Figure 5
Water Wash for the Fischer FiberOptic Connector

The Fischer FiberOptic Connector solution allows for easy field cleaning because of a unique sealing solution and removable parts.

This approach minimizes the time it takes to field clean and inspect a fiber optic connector, making it more efficient and effective.

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6. Maintenance Cleaning

For fixed locations, you can take advantage of ultrasonic cleaning to maintain your connectors (see Figure 6 below).

- Put your connector under running tap water until everything is entirely cleaned
- Remove the sleeve holder with tweezers or small pliers
- Put the connector & the sleeve holder in the ultrasonic bath for ~1 minute, which has been filled with isopropyl alcohol.
- When done, dry the contacts & connector by spraying canned air on it.
- Dry the sleeve holder by spraying canned air on it
- Reassemble the sleeve holder
- Slightly grease the plug sealing plan to recover full sealing capabilities* (see Figure 6, below)

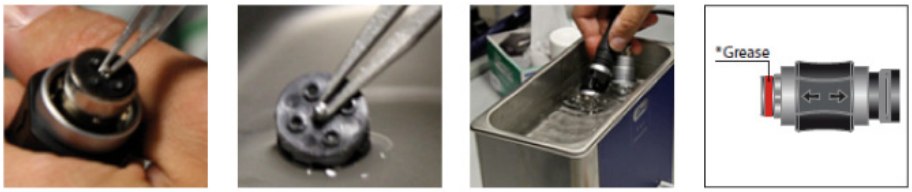

Figure 6
Maintenance Cleaning for Fischer Fiber-Optic Connector

The more difficult and complicated the preparation and cleaning procedures, the longer it takes and the more expensive it becomes. In addition, connectors that are difficult to clean generally require more expensive cleaning tools and may require more experience personnel. In terms of system integration, going 'live', and maintenance, the simpler the cleaning procedure and required tools, the faster the connectors can be prepped and integrated. This, obviously, saves both time & money.

7. Consideration of cleaning capabilities in Fiber Optic selection

Methods for cleaning fiber optic connectors continue to evolve with the innovation of new connectors for rugged environments. This new approach allows companies to consider moving fiber to environments that would not be considered only a few years ago.

As companies continue to innovate connectors and cleaning materials, it is important that designers and project managers select their connectors properly. Considerations that are part and parcel to the connector selection include such factors as costs associated with fiber optic cable/connector deployment, field and maintenance requirements and overall system reliability. With proper selection and care, these fiber optic connectors will perform flawlessly for years in your fiber cable infrastructure.

1 Bishop & Associates Reports, Rugged Connectors Meet Emerging Applications Challenges, 2012
2 The Light Brigade (http://www.lightbrigade.com)
3 http://www.jdsu.com/en-us/Test-and-Measurement/Products/a-z-product-list/Pages/smartclass-fiber.aspx
4 http://www.cisco.com/en/US/tech/tk482/tk876/technologies_white_paper09186a0080254eba.shtml