NEW INSPECTION CRITERIA FOR ALL FIBER OPTIC CONNECTIONS

Edward J. Forrest, Jr.

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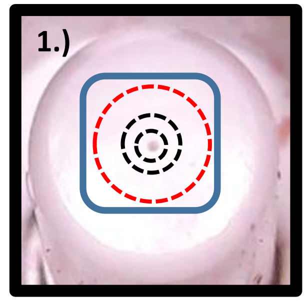
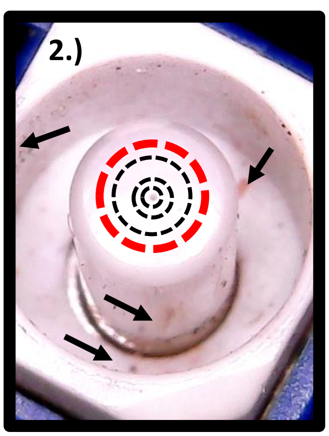
About 300 BCE Euclid formulated a mathematical thesis for the first time: we know this now as Euclidian Geometry. It is, among other things, a two-dimensional study of intersecting lines. Euclidian Geometry is mathematical science. Around 200AD, Ptolemy postulated the thesis of a solar system. In 1492, Christopher Columbus proved the thesis that the world is not a flatland. In the mid 1600's Galileo, considered The Father of Astronomical Physics, set the stage for Rene Descartes' study of three dimensions in the 17th Century that lead to Albert Einstein's thesis of time and space. In the early 1900's, Max Planck, a contemporary of Einstein, expanded Physics with his study, Quantum Theory, of atomic structures. Planck's work brought Mathematics and Physics together. All of this proves what we know: we exist in three dimensions!

For nearly thirty years, a definition of the fiber optic surface and subsequent precision cleaning standards have been established by producers and researchers. Heretofore, video inspection has dictated cleaning products and techniques. Recently, a new video inspection instrument has been invented that employs sciences of contamination as the foundation for video inspection. The two approaches are not the same.

Traditional inspection and microscopy traces back to 1590 AD when a Dutchman, Zarhcarias Jannsen, is said to have invented the first microscope. Since that time, devices by Nikon, Olympus, Leica and Zeiss (only to name a few) set the stage for the current range of fiber optic video inspection instruments. Each, starting with Westover (Vivaldi), EXFO, Fluke, Noyes (AFL) ODM advanced not only magnification levels, but also, image resolution and convenience. Both laboratory microscopy and fiber optic video inspection are based on Euclidian Geometry. Until now: a new instrument has been invented.



For a time, fiber optic surfaces were observed with 'direct view' designs. These devices are not suitable for observation of an active laser. This set the stage for the current state-of-art: hand-held, automatic detection of contamination, and ultra-convenient wireless designs. Yet, the fundamental flaw in both 'direct view' and 'standard video inspection' is the limitation on 'field of view'. Some video inspection instruments used 'scrollers' to examine a complete surface while others diminished the magnification and significantly increased resolution to compensate and discern 'removable contamination' from an 'un-removable artifact'. Image (1.) represents a typical view of the 'horizontal end face' as seen by a contemporary video inspection microscope. The innermost circle identified the fiber, or 'core', the second concentric circle is the limit of the cladding/epoxy ring, and the third concentric circle is a radius area of about 250-300 microns (from the core). Nothing is seen 'outside-the-box': in general terms, is the visible surface limit of a 400x inspection instrument.



As well, existing inspection is not able to view aspect ratios outside the 'horizontal ferrule' surface of the end face. The portrait in image (2.) shows a complete jumper ferrule: arrows point to clear indications of contamination on surfaces *other than* the horizontal end face. Until now, no practically-available video scope could see the alignment sleeve, areas of an adapter, much less within the recesses of alignment pins and other such surfaces. Such imagery may be obtained with a jeweler's loupe or laboratory microscope. However, 'direct-view' of any active fiber optic surface can cause permanent eye damage such practice should be strictly avoided and discontinued.

The new instrument can easily see a far greater field-of-view than ever before…in addition to the traditional images. In image-2, the customary 'Zone 1-2-3' designation is replaced with a 5-Zone three-dimensional definition. The 'black dotted lines' represent the typical 'field of view' of a 400x video scope and the 'red dotted line' represents the surface area of a 130x high resolution 'field-of-view' instrument. Looking outside the 'horizontal end face', arrows point to contamination on surfaces of the ferrule. The unseen contamination can be the cause of frustrating attempts to clean one side, and then the other, as contamination transfers between these 'soil points'. The new inspection system provides a '3-D snap shot' of the complete surface area. From there an appropriate method and procedure is established to restore the connector to service without the problematic efforts of multiple cleaning.

WHY IS THIS IMPORTANT?

To better understand the need for an instrument such as this, a brief lesson on contamination is helpful and essential. Existing world-wide standards for inspection and cleaning are based on a 'mother standard': IEC 61300-3-35. From this, TIA 455-240, Telcordia GR-2023-Core, as well as Aerospace and Defense standards written by SAE-Aerospace, ARINC, and IEEE-Aerospace are further defined. While IEC 61300-3-35 uses relatively easy to remove contaminants, the more problematic concern for field service is the establishment of a limited surface area, the 'two-dimensional baseline of a horizontal end face', as these interact with various types of contamination. IEC 61300-3-35 is a superior work for production line applications where the environment is controlled, the actual cleaning process performed by trained workers who become further skilled through repetitive action.

However, the 'mother-standard' concept breaks down for field service and installation. As of July-2016 the only 'field service' standard is IEC TR-62627. None provide a clear definition of the interaction of types and location of contaminants, nor provide a defined cleaning procedure other than speak to a "dry" or "wet-to-dry" cleaning process. The unintended consequence is the reality that field service is not a controlled environment. There are simply too many potential contamination types for even computer-enhanced 'automatic detection systems' to adequately or accurately portray or predict.

WHAT IS THE QUESTION?

The only way to know if a connection is actually contaminated is to actually 'see' it. The problem is compounded beyond video inspection that only considers a two-dimensional (2-D) 'flatland' surface. Debris itself is three-dimensional and complex by nature. Let's define three types: 1.) 'dry', 2.) 'fluidic', 3.) 'combinations of the two'. There are, of course, many possibilities: Cisco® has a list of about ten, ARINC another dozen including aviation fuel and salt water and in December-2014 I tested the current class of cleaning devices against 4 dry types, 4 fluidic types and 4 combination types. The published results show that *with a minor process change*, all existing cleaning products can work closer to first time efficacy. Most do not when used per manufacturer's instructions!

Dry debris ranges from 'Arizona Road Dust', or ARD (used in IEC 61300-3-35 standardization) to, dust which may be in the back-corner of a data center, or, fine 'desert dust' from the Middle East, or, 'beach sand' which varies widely. Removal of one contaminant type does not prove cleaning ability!

Fluidic Contamination may range from perspiration (represented in IEC 61300-3-35 by vegetable oil as a means of standardization of a polar soil) to mineral oil which is a non-polar soil. The fluid may also be hand lotion, which itself may be natural as Aloe Vera, or processed/synthetic as lanolin. On the production line it is not uncommon that hand lotions are banned. In field service, it is impossible and impractical to control use of hand lotions, much less anticipate the type or extent of any specific ‘fluidic contamination’.

The third type of contamination is a ‘combination’ of the first two. This type contamination may be most common. Personal experiences range from ‘dust and perspiration along a right of way in Kansas at a live-stock feed lot’ to ‘tar along a railroad right of way’ … in the same general geographic area. *Combination contamination is ubiquitous and infinitely universal*. Always follow this rule-of-thumb: “Worst Case Leads to Best Practice”.

The point is clear: there is a need for a new type of inspection that clearly depicts far more types of contamination and their physical location on the connector: to a greater extent than existing instruments as defined by the ‘mother standard’. The instrument should be a cost-effective, ‘go-no/go’ means, that is easily interpretable by technicians of all skill levels.

WHAT IS THE ANSWER?

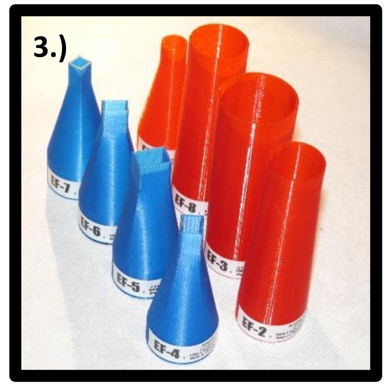
The most important aspect of fiber optic precision cleaning is to inspect. The two matters are inextricably intertwined.

Power meters and light sources, fiber identifiers, and even measurement of insertion loss with an OTDR can’t indicate actual cleanliness. Over the last twenty years, there have been numerous video inspection scopes: each limited to a ‘flatland’ two-dimensional horizontal view. This is the essence of general laboratory microscopy that was applied to fiber optics. While many of these instruments have recording functions as ‘proof of cleaning’, what’s lacking is the understanding the reality a fiber optic connection and contamination both are 3-D structures. Viewing a fiber optic surface is not the same as viewing a 2-D measurement of a laboratory specimen such as bacteria.

There are four actual cleaning techniques while IEC 61300-3-35 only classifies two. My ‘first of the four’ may be contentious to some, however in field service there is a reality: cleaning without inspection. I term this Blind Cleaning®. An ongoing survey of approximately 2,500 technicians over three years indicates ‘blind cleaning’ may be prevalent in as many as 60% of all field operation connection deployments.

The ‘mother standard’, manufacturer’s designations, and professional training programs speak of the second and third cleaning process: ‘dry cleaning’ and ‘wet-to-dry cleaning’. The general recommendation is that if ‘dry cleaning does not work, then use the wet-to-day technique’. If 60% of connections (or any percentage) are cleaned ‘blind’, then a threat is posed to the future of successful fiber optic deployments. Furthermore, there is no clear understanding of ‘wet-to-dry’ really means! In a demonstration I have conducted for nearly fifteen years, perhaps more than 10,000 times, ‘wet-to-dry’ cleaning has proven to ‘flood’ the end face from areas not seen by typical video inspection. (YouTube® https://youtu.be/qZTCutx2hsg)

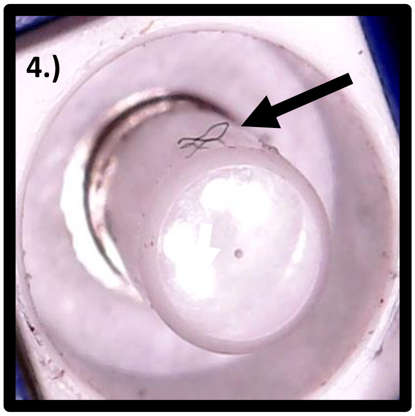
As of July-2016, the most recent “telco’ standard speaking to a cleaning process is Telcordia GR 2923-Core. This work defines a fourth process: ‘combination or hybrid cleaning’. This standard clearly defines a process that approaches ‘first time cleaning’, unlike ‘mother-standards’ that permit ‘up to five times’. This process is not the same as ‘wet-to-dry’ cleaning.



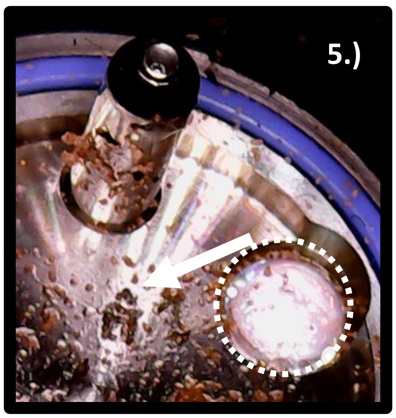
THE ROTATING ADAPTER©

In early 2016 'patent pending' was issued on a new type inspection device. The instrument utilizes a new connection style between the microscope and connector. It is termed a Rotating Adapter© (3). The unique nature of a 'Rotating Adapter© differentiates the instrument from all others. The 'rotating adapter' creates a field-of-view that is typically only found in laboratory magnification with a 90x magnification compared to 130x-200x-and 400x. The technical concern at 90x magnification is loss of resolution to identify some defects such as scratches. The rotating adapter enables the technician to see both the customary end face, but also the vertical surfaces as well as other components such as an alignment sleeve. This is accomplished by rotating the adapter in an eccentric fashion at both planes of the connection. The rotating adapter moves about the camera and connector to provide heretofore never seen imagery…and records for proof of performance.

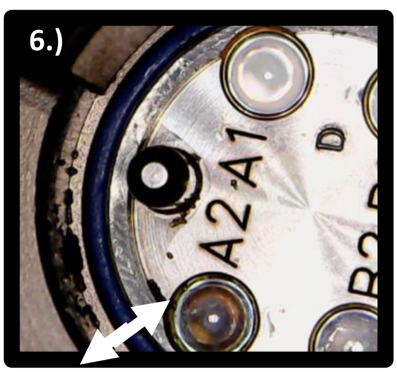
Imagery through the Rotating Adapter is different: the lighting is 'direct' and not 'oblique' as used by existing fiber optic video microscopy. The images are different and, while not difficult to understand, training is important. The reality is many thousands (or more) have been under-trained to address the future of ultra-speed and ultra-capacity fiber optic transmissions. Using a Rotating Adapter is far easier than describing it in words!



For ‘large can’ expanded beam, TFOCA, or other such style connectors with 2-4-8-12 or more fibers, the rotating adapter clearly sees each lens, but also ‘inter-surfaces’ and debris at various points that can be ‘contamination points’. For both commonly used SC, LC, MT-Type, and even old-style “biconic connectors, the technician views and isolates contaminated surfaces that can create a fouled “Zone-1” fiber core. Image 4 shows a thread on the ‘vertical ferrule’.



In the expanded beam images (5/6.) most typically the expanded beam manufacturer would be concerned with the lens (white circle, image bottom left). However, clearly there is also contamination on the alignment pin and inter-surfaces. These can migrate.

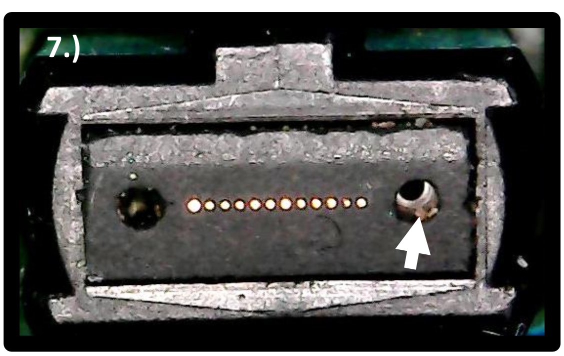


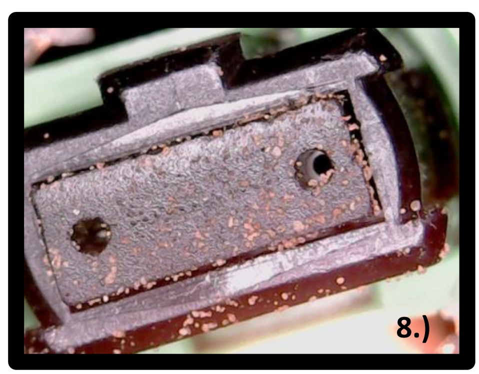
Contamination on the adapter housing of a SC connector (7.) can transfer either with a touch-insertion ‘jumper to backplane’, or also in the time of post cleaning and post inspection. Knowing the physical location of these ‘soil points’ is important to successful high speed and high capacity installations. Utilizing a rotating adapter device can eliminate multiple cleaning, return of soiled components as ‘defective-warranty’, and enable the technician to concentrate on far more technical matters than improper cleaning and limited inspection techniques. However, over the last twenty years many technicians have been under-trained.

WHAT IS THE DIFFERENCE?

Existing inspection is based on microscopy with 100x direct view microscopes that were, essentially, enhanced jeweler's loupes! This is the same science of inspection as used in microscopy of all kinds including binoculars and star gazing since the late 1500's! Existing 'state of the art' video inspection is designed to discern scratches, pits and defects, and also contamination. These instruments gave birth to the current range of standards. Defects such as pits or excess epoxy are important for production line applications. Contamination type and location is more critical for field service.

The Rotating Adapter concept considers: 1.) the type of contamination and 2.) the location of contamination. It's not necessary to identify a miniscule defect as this has already been accomplished on the production line. What is critical and essential for field service is to identify the location of contamination and then take the decision which cleaning process will eliminate it…most effectively. Both concepts arrive at the same result: The Rotating Adapter© concept for field service and traditional video microscopy for production line applications. The rotating adapter enables a technician to adjust the parallax and angles of the interconnection of the digital camera to the connector. Image 7 shows dust in an





alignment pin. Image 8.) shows a full image of a contaminated "MT-Type" connector *in situ*. Until now, these 'portraits' are unlikely seen even from the best scrolling or wide field-of-view devices". Images as this are essential information for proper field work, quality control and customer satisfaction.

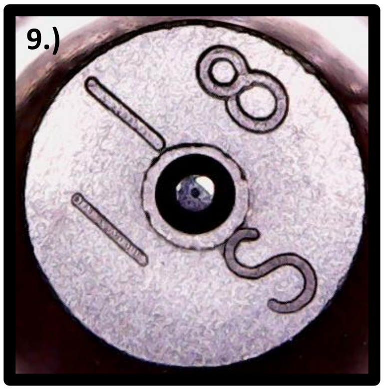
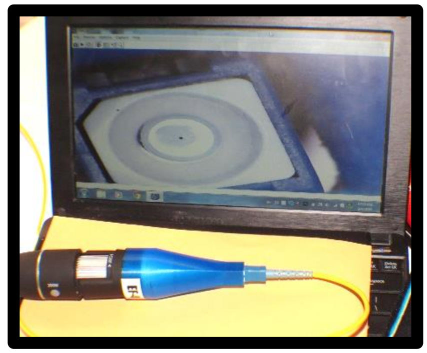


Image 9 depicts the biconic connector and how difficult it is to actually clean … much less be seen!

Surely, a clean fiber is important. As well, awareness of other soil points becomes the new "Best Practice". For all of these criteria, best practice is to assure the complete surface is clean … and not only the limited area of the fiber core or horizontal. It may be that not all contamination 'must be removed'. However, this determination is not possible without actually seeing where is the contamination in the first place!

Such cleaning is highly likely utilizing the third procedure as defined in Telcordia GR-2923-Core. This process is not the same as "wet-to-dry cleaning". The instruction to "dry clean first" should be modified to: *"dry clean when the contaminant can be identified as a fluidic type".* Dry Cleaning is a 'mopping action'. For procedural simplicity 'dry cleaning' should be eliminated: there are phenomenon such as 'static field attraction' that obsoletes this instruction and some contaminant cannot be removed by 'dry cleaning'. Precision Cleaning should be a first time event and not as described in the 'mother standard' which speaks to 'begin with dry' and 'utilize wet-to-dry' if that does not work up to five times. In the sciences of cleaning, use of some type of moisture enhances cleaning in all ways. (Please refer to White Paper, "Precision Cleaning a Fiber Optic Connection". www.fiberopticprecisioncleaning.com.) Always use a small amount of fiber optic cleaner with all cleaning devices: this is Best Practice.

CONCLUSION: Existing video inspection has reached a plateau that does not enable adequate determination if connector surfaces are actually clean. Since debris does transfer as a part of the connection process, and residual (fluidic) contamination can transfer, or, be present from various recesses of the connector, a new inspection device and criteria is essential as fiber optic speeds and capacities previously considered theoretical.



The new instrument, with patent-pending features, is the first practical update of existing 16th Century microscopy based on Euclidian Geometry to a system based on proven theories that began with Ptolemy's discourse of the universe and continued with Einstein and Planck's definitions of the reality we exist in three-dimensions! The condition of not only the end face, but also, other sectors of the connector by understanding their nature and contamination as three dimensional structures leads the industry to best practice servicing of all connections … from 'existing' to 'super channel'…both expanded beam and direct connect types.

ABOUT THE AUTHOR

Ed Forrest has an ongoing career in the fiber optic industry, including patents, products in production and patents pending. He is an expert on the 3-D nature of connectors, contamination, cleaning and the implications for network design and performance. His new product, the RMS-1 Rotating Adapter© Video Scope will be available in late 2016. Please contact Ed at +770-971-8100 (USA) edforrest@fiberopticprecisioncleaning.com, or the website www.fiberopticprecisioncleaning.com for information regarding other White Papers, additional research studies, training, and other services.