The Impact of Primary and Secondary Contamination on all Fiber Optic Connector Surfaces

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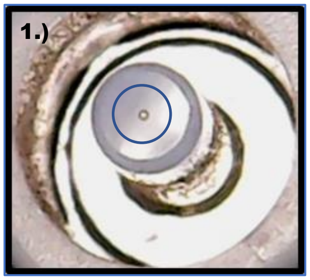
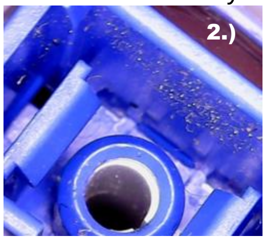
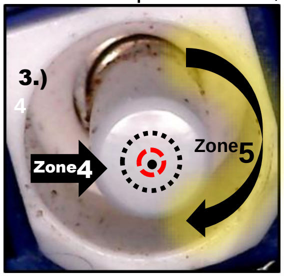


There is an inextricable interaction between type of debris, location and means of removal. This "science of cleaning" began in about 5,000BC with the invention of soap by The Babylonians, and continues to this day as requirements for surface cleaning evolve in all facets of contamination removal: clothing to fiber optics. These sciences are challenged, in a positive way, by concerns for high performance, environmental safety, and, well-being of end users. There have been positive advances in solvent cleaning that includes replacements for chemicals that industrialized our world. These include ultra-fast drying solvents, high performance precision hydrocarbons, and, aqueous cleaners used in a wide range of applications: printed circuit board production, electric motor repair, metal degreasing and fiber optics.

The existing understanding of a fiber optic connector surface is based on IEC 61300-3-35. From this, other standards are created: all consider fiber optic surfaces in a limited area of two-dimensional diameter with no consideration of height. A recent development of a new means to inspect a fiber optic connection reveals important new information for trainers, installers, and network designers. This new instrument defines a "primary surface", which is the basis for IEC 61300-3-35, and the new concept of a "secondary surface". The "primary surface" is defined in the drawing (Figure-1) as *the area within the circle*. The "secondary surface" is all other sectors of the connector ferrule as well as adapters and alignment sleeves. (Figure-2) "Primary" surfaces and "secondary" surfaces have soil points where debris or excess cleaning solvent can 'reside' creating signal loss, misalignment, and damage. A main advantage of cleaning (anything) is the ability to see the before and after. Until this time, this is not always possible with existing fiber optic inspection: either the field-of-view was limited, or, the inspection device could not see an adequate surface area. All fiber optic connections, multi-mode or single-mode must be cleaned each time the connection is "opened". Never assume the connector is "factory clean".



The customary and ever-critical concern is the condition of the fiber "core" as defined by "Zone-1" in standards such as IEC 61300-3-35. Other sectors include the 'cladding' and 'contact' area. These are noted in the drawing. Figure-3. Commonly called the "end face" existing fiber optic connector surfaces are viewed and analyzed often termed "Zones 1-2-3". This limited surface area is noted *within* the circle. 1.) The "black dot" is the fiber transmission core, 2.) the red dotted area is the reflective cladding, and, 3.) the black dotted line defines the approximate contact area and outer limit of most 400x inspection. To properly characterize a fiber optic surface, a three-dimensional field-of-view is essential: adding "Zone-4", which completes the "horizontal end face" and "Zone-5" which is the "vertical ferrule" and all associated components of the connector housing. (Figure-3)



Although contaminated, the end face in Image-3 image "passes" existing standards, including 'auto-detect/pass-fail'. The condition of "primary surface" and "secondary surfaces" are equally critical to proper precision cleaning all fiber optic connectors.

This limited understanding may have been more acceptable in 1998 when transmission rates were mere fractions of practical deployments in these times when 'theoretical transmission rates', regularly become 'practical deployments'. An advanced awareness of precision cleaning and precision inspection assures not only trouble-free deployments, but also the future of fiber optics as a transmission medium. Over the years, a wide range of inspection and cleaning products, methods and procedures were developed and commercialized. Some work well, some are outdated; others poorly conceived. A new instrument has been developed that views all sectors of connectors and connection adapters in virtual 3-D. (Figure-4).

There is need for a new 'future-proof' understanding for all industry segments. While some subdivide fiber optic transmissions into "commercial" or "military", the reality is that the sciences are the same and, increasingly, connector types are shared. There is need to re-train many thousands of misunderstandings and misimpressions. It's anecdotally stated that improper cleaning is 60% of 'network problems'. *A "process standardization" is highly desirable: existing standards are minimum requirements, not best practices.*

Cleaning fiber surfaces and inspection has evolved to 'convenience' rather than 'practical best practice'. For example, use of a 'dry tool' to clean 'dry debris' in a "dry process' can transfer debris, create a static field that attracts more debris, or, is not effective because the technique moves, smears or transfers contamination. In real-world applications, 'dry-cleaning' is used for a surface that is "wet"! Per existing standards, when "dry cleaning does not work" the end user is instructed to use a 'wet-to-dry' technique. In other "real-world applications, "wet-to-dry" cleaning is employed when the surface is "dry". The instructions seem reversed. The vague nature of the term "wet-to-dry cleaning" can result in flooding unseen connector and adapter recesses and surfaces. For these reasons, in 2011, Telcordia® formalized a third procedure termed "combination or hybrid cleaning". This procedure considered a wide range of debris types and sought removal in a first-time procedure. Existing standards suggest cleaning "up to five times" before replacing the jumper, transceiver, or other component. Existing standards are commercialized using easy-to-remove debris. I believe that 'worst case leads to best practices'.

The weakest link in any fiber optic network is the connector surface at the time of transmission. Largely unstudied until the last 12-18 months, there is an inextricable interaction between the three-dimensional nature of connector surfaces, types of debris and location. Need exists to further characterize the horizontal end face beyond existing limitations of a narrow 'field-of-view'. This need is also true with 'hybrid' connectors. Copper connectors, challenged to ever higher capacity, can also benefit from inspection. There is a positive 'argument' to cross-train all technicians: inspect and clean all connectors.

While precision cleaning single-mode fiber on this LEMO® SMPTE® 301 is critical, there are also copper power and data surfaces on this "hybrid" connector that can gall or fret from repeated insertions. (Figure-5) As well, there are military 38999, TFOCA, and MFOCA connectors to be characterized to proper cleaning and inspection methods and procedures. Cleaning and inspection techniques must be updated, re-thought and re-trained to include all connector types. Technicians, network designers, and contractors will continue to 'multi-task' and cross-training becomes a best practice safety net that assures consistency and trouble-free deployments as workers move from one deployment (or employer) to another. Copper technicians who may have 'casual fiber contact' should be schooled on the significance of cleaning fiber optic surfaces.

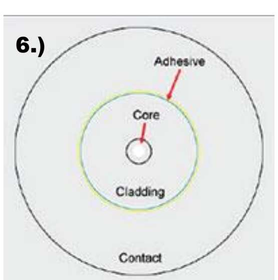
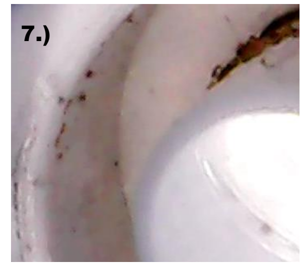


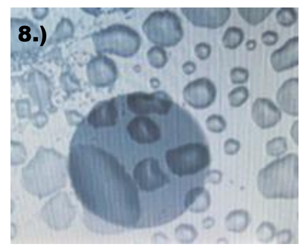
Figure-6 is the customary view of a fiber optic end face. It is a limited two-dimensional perspective of ~250 microns. There are 2500 microns on a 2.5mm surface, thus considerable surface area is not characterized on the 'horizontal' and completely disregarded on 'vertical' and other 'intersurfaces'.

A complete three-dimensional view of, <u>neither</u> fiber optic <u>nor</u>, copper connectors has been practical until development of this new inspection instrument that utilizes digital photography and provides a 'virtual 3-D' portrait of connector surfaces. Using a patent-pending concept of a Rotating Adapter©, the new instrument observes fiber optic, copper, and hybrid connectors in still and motion photography. The RMS-1© device (Figure-4) views debris in digitally enhanced contrast against the connector surfaces in a format different from what the Industry is accustomed to see. The images in this article are some of more than 2,500 that consider all aspects of the connector surface as well as the traditional end face.

What is Primary and Secondary Contamination? Understanding the Science of Debris

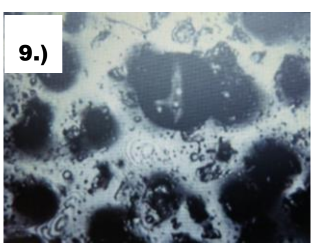


The three-dimensional view of the connector surface is only a part of the overall concern. Contamination itself is a three dimensional 'structure'. IEC 61300-3-35 only defines contamination in terms of two-dimensional "diameter". The standard is based on removal of 'dry' and 'fluidic' debris. In practical reality, contamination can be defined in three general types: 1.) dry, 2.) fluidic, and 3.) combinations of both. *<u>Of course, there are infinite subsets.</u>* "Best practice" is visual inspection. While existing standards define debris in diameter in juxtaposition to the fiber 'core', the reality is that debris can have three-dimensional height greater than the diameter. This debris can 'reside' in unseen sectors of the connector. (Figure-7) I define "Primary Contamination" as understood by existing standards and typically characterized as Zones 1-2-3. (Image-6)



Understanding the 'sciences of soil' is not complicated: "dry debris", as in Figure-7, tends to stay in place either by: 1.) static field attraction, 2.) a monomolecular surface bond, or, 3.) simply lying on a surface or embedded in an imperfection. 'Fluidic Contamination (Figure-8) can result from lack of 'fiber hygiene': finger oils, or, a brief touch-glance of a lotion-covered hand on the fiber end face. Quite obviously, a fluid moves, and this debris may not be seen or characterized by the limited capabilities of even advanced 'auto-detect'. The third type of contamination is the infinite possibility of types that are in "combination". These myriad mixtures of dust types, oil types, and, other substances prove again that visual inspection is the best means to determine cleanliness of fiber optic surfaces.

For example, condensation contamination (Figure-8) is created by temperature differentials of surfaces passed from one ambient to another: service truck in winter weather to an inside data center. While the fluid on this "primary surface" image is obvious, as well is obvious condensation extending outside the 400x field of view. Fluids located outside the field-of-view can leech into active transmission zones in the time of post cleaning and post inspection. "Best Practice" is to consider all surfaces at time-of-service.



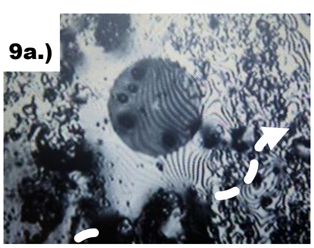


Image 9 is characterized as "Primary Contamination". *However, as the connectors are mated the fluidic "Primary Contamination" becomes "Secondary Contamination" (Figure 9a) as the finger print is compressed between the two mated surfaces.*

Secondary Contamination may be exacerbated by adding debris from an alignment sleeve. (Figure 9b). The realities of cross-contamination underscore the need for inspection of not only both connector surfaces, but also alignment components. Views of a contaminated adapter and alignment sleeve were not possible until this time.

Therefore: a "primary contaminate" is one on the fiber transmission surface Zones 1-2-3, and a "secondary contaminate" may be on other surfaces, Zone 4 and Zone-5.

Understanding the dynamics of connectors and debris may lead you to 'solve the transmission problem' by cleaning other sectors of the connector.

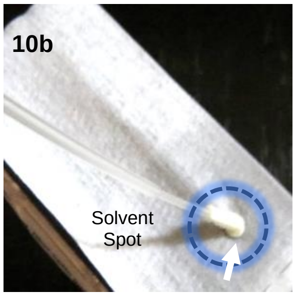
The inextricable Interaction Between Contamination and Location*:*

Until recently, the “Figure-6 diagram” was the Industry Standard understanding of a fiber optic end face surface. Observation of the surface area beyond this dimension has long been possible by reducing magnification which, in most instances, also means the resolution (clarity) of the debris field was also reduced. Examination of the adapter walls, alignment sleeves and other ‘inter-surfaces’ may have been performed by naked eye or jeweler’s loupe. Understanding the potential location(s) of these ‘soil points’ enables the technician to clean more accurately, reduces time to ‘trouble-shoot’ and mitigates warranty claims.

LIKELY YOU WERE TRAINED TO CLEAN FIBER OPTICS USING THE INSTRUCTION: 1.) Clean first ‘dry’, and 2.) if that does not work out for you use the ‘wet-to-dry’ method. However, studies, and field reports indicate that only about 60% of fiberoptic surfaces are inspected. In effect, these surfaces are “blind cleaned” with no indication of the condition of the surface before or after cleaning. Sure, you should use a video scope…but there are practical reasons this is not possible: one of them is the <u>unlikelihood</u> of 100% inspection 100% of the time!

While there is total agreement that every connector should be inspected, what is the ‘safety net’ when this is not possible? In December 2014 I conducted a series of tests that resulted in significant improvement of all popular cleaning tools with a simple ‘process change’. This test is based on a 2005 study termed “The Cisco© Series” which also included complex debris not included any existing standard. Both “The Cisco Series” and other research between 2001 and 2007 lead to a Third Cleaning Technique defined in Telcordia GR-2923-Core. This third technique was also noted in several patents issued between 2006 and 2013.

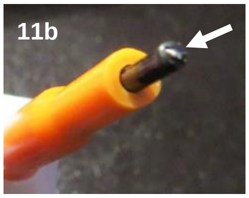
The result of this research, and practical field use by significant carriers. leads to improved cleaning by virtually all tools from five times to ‘first time cleaning” 90% of the time.



Strongly, I encourage that the cleaning process for any fiber optic connector surface *should not begin* with a ‘dry’ method, *nor* the ill-defined and unclear ‘wet-to-dry method’. *What is the ‘best practice technique?* “Combination/hybrid cleaning” was conceived as part of a 2004 patent. This was the first time a defined amount of cleaning solvent was specified: “Hybrid Cleaning” begins by using a minimal amount of fiber optic cleaner. Figure 10a demonstrates the ‘moistening’ technique for a probe tool. The tip is depressed in a ‘solvent spot” for a count: 1-2-3-4-5. Similarly, a swab tool is moistened. (10b) Cleaning “Zone-5” is a procedure only a swab tool can perform. (10c).

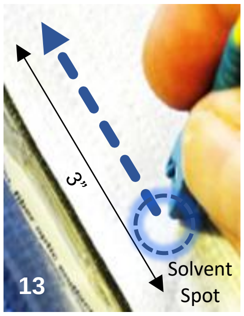
With the advent of “convenience” has also come an over-simplification and an unfortunate sense that “convenience is efficient”. Probe tools (“Clickers”) are an innovation that belies their effectiveness. Some use threads or strings that do not cover (or clean) the end face surface area and are not physically capable of absorbing fluids or dry debris. Both cleaning surfaces (Figure 11a and 11b) are promoted as 2.5mm cleaning tools: which one will clean more of a 2.5mm surface?

Notice the swab tip in Figure 10b is ‘folded’: the design compensates for UPC and APC configuration. Swab tools are used in high-tech wafer fabs and medical applications. Don’t be allured by ‘convenience-for-convenience’s-sake’! Seek tools that perform in applications specific methods and procedures. I urge you: request samples and factory support when you have having a ‘tough dog problem’ that does not seem to resolve by changing brands!



The larger cleaning surfaces of “reel cleaners” (Figure-12) and even-larger “cleaning platforms” (Figure-13) provide greater surface area to clean the end face than probe and swab tools. The advent of “cleaning platforms” about fifteen years ago increased the 1” surface of the reel cleaner to about 3” (Figure-13) . *The*

advantage of a longer cleaning stroke enables debris to be moved away from the initial point of contact rather than swirled with the probe or swab tool. Using a reel cleaner or cleaning platform on the back-plane connector is problematic: few equipment producers have 'swing out' racks providing convenient access. However, there is little doubt the larger the cleaning surface, the more efficient and effective the procedure. The skilled installer has a tool kit that features a selection of tools. *Precision cleaning is approached in applications-specific terms.*



As well, selection of a fiber optic grade cleaning solvent is mandatory. The use of 99.9% "Reagent Grade" was acceptable in 1998 when fiber optic deployments were limited in controlled environments. The expansive development of fiber optic networks into uncontrolled global environments s mandates precision cleaning solvents for fiber optic applications as are commonly used in other critical applications such as electronics, wafer fabs, and, critical metal cleaning. These solvents now have nearly 30 years of practical use and are proven to outperform 99.9% IPA. In conjunction with high performance solvents, use of 100% cellulose (paper) to clean precision fiber optic surfaces is not recommended or acceptable.

Conclusions:

Existing fiber optic standards to inspect and clean any fiber optic connection are "minimum requirements" and not "best practice". The standardization process itself is antiquated in the face of the rapidly evolving technologies of fiber optic transmissions. Updates every 5 to 10 years do not keep pace with the evolution of deployment and transmission. Old style standards can give-way to new, Internet based renditions for the rapidly evolving technologies of fiber optics.

The existing instructions to 'dry clean first', followed by 'wet-to-dry' proposes a conundrum: the 'standard instruction to dry clean first' is accurate if the contamination is a fluid; 'wet-to-dry cleaning' is best when the debris is dry. Understanding the dynamics of a cleaning tool is integral to "best practice". If you are not inspecting…how do you know?

Since surfaces may not be viewed, the updated procedure published in Telcordia GR-2923-Core is a safety net best practice. The wiping materials used on cleaning tools are better choices than paper wipers from a convenience box. The only way to assure a fiber optic surface is clean is to see it: testing for power or light is not acceptable or accurate. Auto-Detect/Pass-Fail technology is an important advance, still in an infancy phase. Algorithms to detect infinite levels of debris have not been written and may never be. At this point, most fiber optic inspection only "sees" a limited surface area as noted in IEC 61300-3-35 and all other standards. There is a need for a formal higher standard and that is the intent of this paper and your decision to implement.

As both copper and fiber optic commercial interests push proprietary sciences to ever higher levels, end users benefit. Manufacturers can help themselves by clearly defining cleaning procedures for their products in applications specific terms. Network designers should clearly specify cleaning procedures, as an applications specific factor, in anticipation of deployment in varied environments. Trainers can provide important services by updating to "best practice". An individual's training session may never (formally) be repeated: a trainer's information continues by word of mouth indefinitely.

No matter where, or what, single-mode or multi-mode, direct contact or expanded beam, the reality is that all fiber optic deployments have one thing in common: a fiber core that must be protected and properly cleaned. One precision cleaning <u>technique</u> for all fiber optic connectors benefits the longevity of the industry. Always select products that are tested and proven: there is a wealth of knowledge from the electronics, medical device, and the solid-state industry. Studies on 'static field contamination' are relatively new for fiber optics: a well-trodden road, with hard-learned lessons, the electronics industry can share with telecommunications.

Challenge your suppliers: request samples and compare performance. Your distributor is an excellent supply point and may, or may not, also provide you with unbiased information or factory contacts: use all resources. "Obsolete" is the instruction to clean dry first and then use wet-to-dry! **March-2018**