THE SIGNIFICANCE TO OPTICAL INTERCONNECT: PROPERLY CLEANING A FIBER OPTIC CONNECTION

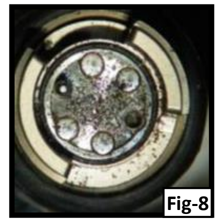
Fig-8

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Abstract:

Fiber Optic transmission rates and capacity continue to expand open-endedly. The need to clean is well-intentioned. Less is understood about end results from improper cleaning and the wide range of debris often present at the installation site. There are three cleaning commercially promoted cleaning techniques: 1.) a "dry" method, 2.) a "wet-to-dry" method, and, 3.) a "combination" or "hybrid" technique.

There is a fourth all too common procedure: "blind cleaning", wherein the fiber optic surface is cleaned in a 'leap of faith' without benefit of visual inspection of any kind. This brief paper discusses the interaction of existing standards and how these are considered "best practice" when in reality they are only minimum requirements that do not assure the connection is cleaned in a scientific manner. The tenets are applicable to all industry segments.

Background and Definitions of the Study:

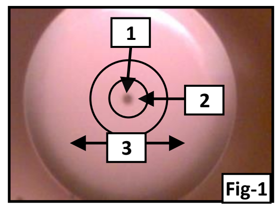


Fig-1

Regard for 'sciences of precision cleaning' is essential to all fiber optic inter-connects. All existing standards are based on IEC 61300-3-35 which characterizes the end face in a limited two-dimensional field of view as well as characterizes debris and contamination in two-dimensional diameter on this plane. **(Fig-1)** These areas are often termed in "zones" where "Zone-1" is the core or fiber, "Zone-2" is the cladding, and "Zone-3" is the area approximately a 250-300 micron radius of the core which roughly corresponds to a 400x field of view of commonly used video inspection. This "3-Zone Measurement" standard (which can also have an added area called the adhesive zone between the cladding and ferrule) characterizes contaminant measurements and relative position to the core. For this discussion, dry contamination **(Fig-2)** is defined as "debris", a fluidic (transferring) type a "contamination" **(Fig-3)** and "mixtures" (of both) or 'unknowns'. **(Fig-4).**

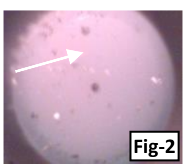


Fig-2

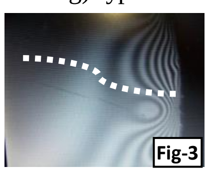


Fig-3

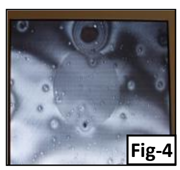
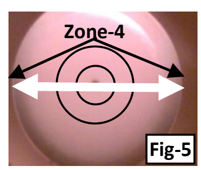


Fig-4



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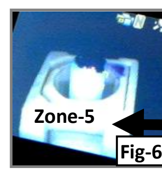


Fig-6

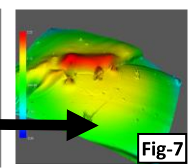


Fig-7

In reality, the fiber optic interconnect is not a two-dimensional structure, but rather with three dimensions as shown in Figure-5/6. When categorizing a fiber optic end face there is also a "field of view" (noted with the white line in Figure-5) extending beyond existing standards. Thus, an end face is more accurately described in three-dimensions with Five Zones. Per standards, debris and contamination is standard measured only in diameter. In reality interferometer readings as noted **(Fig-7)** define "soils" also in real-world three dimensions. Debris and contamination may not be present on lenses on expanded beam **(Fig-8)** or end face connector surfaces but reside in other areas and *cross-contaminate in times of post cleaning and post inspection*. Clear definitions and awareness is critical as capacity and speed increase. *It is no longer acceptable to imagine one industry segment as separate from the other as skills and technology transfer freely.* This trend is likely to continue as installations are performed by OEM crews as well as independent contractors or in-house personnel. In July-2014 The Technical University of Denmark set a new world record of 43 Tbps over a single fiber. Speed and capacity, reflectance and refraction, insertion loss calculations are all influenced by improperly cleaned and contaminated fiber optic connections of all types.

Considering the fiber optic connection as a three dimensional structure provides clarity to the network designer and field worker with the responsibility for deployment and long term maintenance. A suggestion to revise the existing "Three Zone Standard" comes at a time when deployment speeds and capacities have increased beyond 'theoretical' when the existing Zone-Cleaning/Inspection scheme was conceived in the late 1990's. These tenets are unchanged and likely will not with upcoming revisions. Existing standards are published in five to ten year cycles. This gives producers time to develop test equipment and other materials based on the standard. However, transmission equipment and consumer demand often mean that a standard is obsolete at the time it is published. For these reasons a standard should be: 1.) considered a minimum requirement, and, 2.) be updated annually, or, 3.) supplemented and superseded by internal standards. Internet access means that updates can be originated and enacted in nearly virtual ways and means unlike the cumbersome sessions of the past often based on commercial interest.

Standards tend to remain "stable" when they should "flex" with equipment and transmission speeds and capacity. The 4megabit service of 2013 is now being expanded to 1 gigabit as Verizon's envision with FiOS is realized by GoogleFiber®, AT&T® and as others become competitive to consumer demand in business, residence, municipality as well as trans-national and trans-oceanic long-haul.

The Sciences of Precision Cleaning: there are many possible sources of contamination that affect fiber optic transmissions.

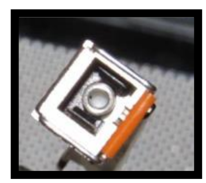
Existing standards are based on the use of test dust, saline particulate, vegetable oils, and dried solvents. These are all relatively easy to remove types of debris and contamination. A 2006 "Cisco-Series" of debris notes ten contaminants ranging from metal shards to graphite to simethicone and dryer lint! Contaminant removal is best considered and standardized considering "worst case" leading to "best practice". Surely, contaminant removal should be "laboratory standardized". However, also encouraged can be "localized debris" ultimately fed into a "living standard" database: sandy soils, mineral oils, silicone soils as well as these soils in combinations are possible. Blog entries mention removal of a "milk shake"; another speaks of "tar". As fiber optic deployments reach into a wider range of global environment, our scientific acknowledgement of any type contamination is crucial. For the most part, cleaning a fiber optic connection is an understated notion: technicians come from a wide background including category cable and Datacom where cleaning a copper connection (rightfully) was not required, considered or taught. There is transfer of craft and skill that urges higher and forward-looking standardization.

In fact, cleaning a fiber optic connection is more often based on "convenience" of a specific tool: *"does it fit in my pocket"* takes precedence over the question *"does it actually clean"*. Since the majority of connections in the "field or outside plant" are not inspected, the technician can easily believe that a clicking sound of the device is sufficient assurance that the device actually works at all! Cleaning products should be "process based" and applications specific in nature. Training and ongoing updated re-training to eliminate and mitigate many years of misdirection is essential. The fiber optic medium is an amazing science within itself. The art and skill is not limited to one industry segment or the other…nor should it be.

To assure ultimate success that the connection surface must be clean may give way to the time when the connection itself is "self-cleaning". While that may well be in some future time, the reality is that for the foreseeable there are many, many types of fiber optic connections that are deployed in many environs. Some such as the "expanded beam" claim to be impervious to signal loss, while others are proven to be highly sensitive. The issue is there is so little definition as one type is cleaned successfully and the other not at all. This is suffered by a lack of clarity, training and awareness of ability of one cleaning process or product to meet or exceed expectations. In short, one process or product is often thought to clean any and all potential debris and contamination when this (simply) is not logical! These is an intense need for applications specific ways and means to not only precision clean fiber optic connections, but also more







clearly understand inspection procedures as they may interact with the cleaning activity that can range from Class 10,000 clean environments, to a spliced connection (and end face) in a jet engine bay in a tactical environment, to a network passing through a sewer system. "Inspect and Connect" is meaningless without clearly defined precision cleaning procedures. Thus, contamination type, cleaning ability, and inspection are the three aspects of any fiber optic installation.

This is the time in the evolution of fiber optic transmissions to define and "future proof". Not doing, in my opinion, can slow or otherwise negatively deter fiber optic deployment by non-fiber optic competitive interests or simplistic and benign ignorance. Commercial interests produce products based on standards: long production runs of repetitive products are commercially important but not always scientifically best practice. It is possible and practical to match the two. Ignoring the reality of matters such as the three dimensional natures of a connection or debris and contamination is not the best science. In the end, it is the science of fiber optics that satisfies consumer demand at all levels. Fiber optic transmission is not "them" or "us": we are all in this together to the ultimate success of the medium. *An improperly cleaned fiber optic end face of any type is the weakest link in a deployment of any type.* This is a time for clarity from those of us committed to the science of fiber optics just as there are those who are committed to the success of other transmission types. It is survival of the fittest and there is always the potential that fiber optics becomes too expensive or too unreliable to endure.

A major tenet of soil removal is that soils are attracted to and remain with moisture. Soil removal of virtually any contaminant using a "dry process" is problematic. Static field contamination also is a phenomenon that can be created by a "dry" procedure. Likewise, soil removal with an ultra-fast evaporating solvent can redeposit and surface bond contamination before the cleaning process is complete. Slow drying cleaners can create residues or re-deposit soils or create and attract residues. The use of 99.9% IPA is also problematic for two significant reasons: 1.) the chemical is not suitable to remove other than an ionic contaminant, and, 2.) the chemical is hygroscopic which means in the instant it is subjected to the atmosphere it begins to attract moisture which further diminishes its cleaning ability. Since fiber optic connections are made in many ambient environs by crafts persons who may have wide technical acumen, there is need to simplify to one Industry-Standard process. This begins with an accurate description of the advantages and disadvantages of precision cleaning chemicals and associated wiping materials. These include: 1.) relative cleaning ability through a wide range of possible debris and contamination, 2.) health, safety and environmental impact in all regions of the world, 3.) cost, transport and other associated factors.

Common misimpressions such as excessive use of any solvent/cleaner can easily flood the end face. **(Fig-4)** The act of "drying" a connection may not be as easy a task as simply saying "dry it"! Convenience is important but cannot compromise and "short-cut" proper cleaning. A dirty connection is said to be 70-80% of connectivity problems. Video inspection with extended field-of-view provides best results with the future increases of speed and bandwidth. Some cleaning techniques re-deposit removable soils, while other procedures are scientifically unable to remove soils which are inappropriately characterized as "un-removable artifacts". Contaminants are not only "dry" but also "fluidic" as well as "mixtures". It is likely that a cleaning technique can move a contaminant from the "vertical" (Zone-5) to the "horizontal" segment of the connection and an often-used cleaning process can result in Zone-5 fluidic contamination. Existing standards suggest up to five different cleaning operations when first time cleaning is attainable.

Fluidic debris from either outside Zone-3, Zone-4 or Zone-5 can transfer after a "snap shot video inspection view" of a specific end face. **(fig-3)** Surely, a video record is important but what happens "after" the image is placed in record is not being considered. Typical video inspection only sees slightly beyond Zone-3 to a 250-300 micron radius of the fiber core. While it may be debatable if a dry soil outside "Zone-3" has impact on transmission, there can be little doubt that fluidic contamination creeping from the recesses of a connector housing can easily transfer throughout connector geometry.

Additionally, a hardened soil of "height" can create a 'standoff' or damage at time of the physical connection. This paper details some of the results of an ongoing ten year study to further the concepts of "best practice".

Understanding the limitations of (any) process is essential to assure success of any installation. In my opinion we have an ethical responsibility to our technicians to establish these baselines for their future success and as ongoing mentorship of others…and surely as well the Industry itself.

Inclusion of: a.) Two additional zones and b.) Standards that expand soils to a wider range

Cleaning a fiber should be a simple and scientifically considered task that is a cost-effective and intuitive 1st step prior to test, "turn up" or any action. In my opinion the most important contribution of IEC 61300-3-35 and IEC TR-62627 is the recommendation that every connection be cleaned and inspected each time it is opened. This includes, each new jumper or printed circuit board with a fiber optic connection and each type in between!

All existing standards begin to break-down in the following ways: 1.) the time between update can extend between 5 and 10 years, 2.) the methods and materials used to test any given cleaning procedure are relatively simple-to-remove types of debris or contamination, 3.) there is reliance on multiple cleaning efforts to achieve success. We must ask the question of each product and procedure: "What if the product or procedure is not capable of removing a specific debris?" As such, if the debris is not removable, is it really "benign"? Moreover, *"If the contamination is outside the field of view of a specific inspection device, does it mean it does not exist?"*

Precision cleaning performance should be based on "worst case". Precision cleaning should include the possibility of not only removal residual contamination, but also ways and means to assure what remains truly is a scratch, defect or other defined artifact. Recent tests have shown that one product or process does work better than the other on the same debris and over a wider range of debris than considered "industry standard". Therefore, logical consideration of every connector *(as it is)* as a three-dimensional structure, every connection *(as it is)* with real-time dimensions that extend beyond a limited "horizontal plane", as well as dry debris, fluidic contamination and combinations of the two also *(as it is)* in three dimensions is a logical and scientific approach to the end results of a "best practice" procedure.

Precision Cleaning Materials Selection

Use of a precision cleaning solvent that cleans the widest range of soils is highly desirable. The CFC ban of the 1990's largely eliminated chemicals that contribute to stratospheric ozone degradation. In recent times, some chemicals have been assigned Global Warming values (GWP) and others are VOCs. A new generation of "aqueous fiber optic cleaners" may be considered. Some chemicals may be used in some parts of the world and not in others: transportation of certain chemicals may have hefty fines present in one nation and not in another.

Transportation of chemical packages is strictly regulated by US-DOT, IATA (International Air Transport Association) and should not be a performance consideration. *Selection of: 1.) the highest performing cleaner, 2.) of the widest range of contaminants, 3.) in least possible use per application, 4.) for the most reasonable cost , 5.) that will have the lowest environmental and user impact, are realistic and essential contemporary considerations for future standards.* This criteria is not in place at this time.

Terms such as “lint-free” should be quantified: cotton and 100% cellulosic (paper) products are not acceptable. Foam based materials can be the most clean as they are used in clean room-tolerance environs. Other possible selections include certain polyesters, microfibers, and non-woven materials. Compressed Gas Dusters are not effective except to dry an end face in storm or water damaged instances prior to a precision cleaning procedure. Personally, I am not an advocate of “canned air” (actually a compressed gas which may be flammable or not, plastic safe or not, and not effective in most always every case to actually clean a fiber optic connection. However, certain compressed gas duster containers may be useful to “dry” water damaged components prior to precision cleaning. These matters should be presented in an accurate light and not as a blanket statement one way or the other!

The call for a higher standard of inspection and cleaning: anticipate all soils over the complete end face.

There are four cleaning techniques: 1.) “Blind Cleaning” without benefit of inspection, 2.) the “Dry Method”, 3.) Wet/Wet-to-Dry Methods”, and 4.) A “combination” technique that limits solvent use and automatically dries the end face is integral to the cleaning procedure. Of these, the “Blind Cleaning” technique remains most prevalent in Outside Plant operations. While this “leap of faith” is not advisable for any fiber optic connection, there may be a potential to advance the science of cleaning and inspection by requiring a standard of first time cleaning rather than five times as otherwise documented. Therefore a standard could be created based on the top line of “first time” and subsequent levels ending up with failure at some level. “Blind cleaning” should be recognized: this common place.

When actually cleaning, most technicians begin with a “dry technique” and follow with a 2nd or 3rd procedure that may include use of a solvent. Too often at this point insertion loss is measured and the result is acceptable. A light source and power meter is not an acceptable means to determine if the connection is actually clean. In reality, the first cleaning process should always utilize a solvent: a.) static dissipation, b.) solvency interaction with appropriate wiping material returns better measured results, and c.) the test of success must be with visual/video inspection are some reasons to promote this fundamental process change.

Test soils should widely be varied. A 2005-06 “Cisco Series” of soils is an interesting benchmark of diversity. Telcordia GR-2923-CORE (02-2010) evaluates removal of a wide range of soils. This higher standard places demands on the actual cleaning procedure and cleaning the widest range of soils over the complete end face is not simply highly desirable, it is the best practice as speeds and capacity move into theoretical ranges. Leaving analysis of soils, which may remain as “artifacts”, to the discretion of a user becomes an opening to flaws. Software analysis should be honed to a higher standard that is variable and programmable to specific soils.

Desert dust in Afghanistan is different from the Arizona Road Dust standard soil or beach sand in Virginia Beach compared to that in Huntington Beach! Every person’s body oil is different. Different also are characteristics of mineral oils compared to silicone oils or lithium grease. Testing on “dry debris”, “fluidic contamination” and “mixtures” of these leads to clear differentiation of various cleaning processes and associated products. Any standard should be based on varied types and updated annually. This can be easily implemented by generating an “internal standard mechanism” which, in itself, defines how to standardize. A suggestion would be to clean ten times and digitally photo document each instance. A Class-1 result is “first time cleaning” followed by subsequent levels established by agreement. Most of these considerations are common sense; not currently in standard practice.

The actual cleaning motion should be clearly defined as a “straight line action that moves the debris or contamination away from the initial point of contact” and not the ‘polishing action’ of a ‘figure-8’ that may re-contaminate the end face.

Conclusion:

2008-09 standards for end face cleaning and inspection are already be outdated as will those to be published in the next few years! Reference to a relatively small area of the ferrule does not address a commonly used and scientifically deficient processes. Inspection of the end face is limited to a small area with no regard to transfer potential of soils. Belief that one technique works as well as the other, misapplication of test and measurement equipment creates a false sense of security that a connection is clean in times that video inspection is not available.

This paper argues expansion of soil sampling and removal of all contaminants without regard to size and position over the complete end face. Residual soils cannot become artifacts and this may be the case with an ineffective cleaning procedure. A *“zero soil standard over the entire end face”* is practical, easy to comprehend, and, realistic to implement. A standard begins with a clear understanding of precision cleaning and the efficacy of an applications specific process. A cleaning procedure that may not be adequate leads to misinterpretation of test results. Test equipment that is not capable of discerning a wide range of contamination leaves open the potential for mis-test and misinterpretation of data. Chemical and cleaning material selections should be based on performance and environmental characteristics. Standards documents should be fluid and easily updated to mesh with network, system and equipment advances as well as customer expectations. Identical and interactive standards should be relative to all telecommunications industry segments.