Future-Proof Fiber Networks Require the Highest Quality Fiber Cables

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New FTTH networks are being built at a record pace. An integral part of any fiber network is the fiber jumper assemblies that help interconnect the systems, its branching devices and fiber drops. Fiber network owners put a lot of emphasis on quality components to ensure a future-proof network with minimal maintenance and power costs that will last at least 15 years, and jumpers are one of those components.

There are cable assemblies, and then there are ***GR-326 approved*** cable assemblies. Additionally, some cable assemblies are referred to as the "designed to meet or exceed" style of cable assembly. However, in this scenario there is no mention if the assembly is Telcordia GR compliant.

Tier 1 and Tier 2 Telcom provider networks are reaching further than ever before – which is key in closing the digital divide. Reaching new and existing markets, it is vital to consider the elements exposed to each network. For example, Alaska may see temperatures below –30 degrees Celsius, and conversely see 65 degrees Celsius with 97% relative humidity in Puerto Rico. This is not unique to these two specific markets. Customers across the globe require high-quality and high-performance cable assemblies to not only survive temperatures, but to maintain their performance through harsh conditions with minimal change in optical performance over a long period of time.

The Rigorous Design of a GR-326 Certified Cable Assembly

Source Quality Components:

- **Connectors**: Many sources exist in the U.S. and dozens more offshore. When sourcing, look for well-known connector vendors that have a good reputation and have accreditation for independent testing of their connectors. Again, be careful of the "tested to GR-326". Ask to see the certified test report. This will reveal who performed the tests, provide the actual insertion loss and return loss (IL/RL) results over temperature and expose the baseline pre-test data vs. the post-test data.

  Regarding the material itself, concentrate on the ferrule specifications. For example, a 125.5µm inner diameter (ID) ferrule is recommended for high-performance single mode (SM) connectors.

  The next specification on the check list is fiber hole concentricity. Use a better than 0.5µm concentricity. These specifications hold true for all SM Connectors with a 2.5mm or 1.25mm ferrule. The second component to examine is the connector strain relief boot. These vary slightly in shape and size, so it is important to test all versions of their strain relief boot- most vendors have at least two or three boot designs.

- **Cable:** Generally speaking, it is commonplace to use a cable composed of top tier single mode glass. For cables with jackets ranging from 1.6mm diameter to 3.0mm diameter, use a jacket material that offers a low shrinkage rate--say less than five percent. All indoor cables will have a certain amount of shrinkage, so to select the best fit a "round robin" can identify the right cable for the job. For 900µm cable, be less concerned about shrink rates. That said, a tight buffered 900µm is best for this size of cable assembly.

- **Epoxy:** This is likely the single most important component of the entire cable assembly. Without a superior adherence between the glass and ferrule, temperature cycling IL results would be very erratic. To start, look for a well-known local vendor. Make sure that the epoxy has an operating temperature that exceeds the GR-326 temperature requirements. Also, make sure the epoxy is rated for a glass transition temperature testing (Tg) of 100 degrees Celsius or better. If a Differential Scanning Calorimetry (DSC) analyzer is not available, many regional labs offer Tg testing.

- **Lapping film/Rubber pads:** Instrumental in determining the desired result of the end-face geometry, is the accuracy and consistency of pad durometer/pad height and pad life. This can usually be recommended by the machine manufacturer along with the lapping film. Diamond lapping film is required for efficient ferrule end-face shaping, and a silica dioxide final film is recommended for controlling the fiber height of the polish. Attributes such as grit size and density need to be checked constantly.

Preparation

- **Ferrules:** They often are machined, which tend to leave some residue in the inside chamfer of the ferrule hole from the machining and the ferrule hole itself. Many vendors do clean their ferrule before shipment, but an additional cleaning step at the factory provides better results. This will help the adherence of the glass to the ferrule. An ultrasonic cleaner with an isopropyl mix or perhaps a detergent mixed into the water is best to use.

- **Cable:** It is important to use the connector manufacturer's template for jacket and fiber strip lengths as well as Kevlar lengths. Be sure not to strip the 900µm coating from the glass until the connector is ready to be terminated. This will prevent the fiber from excess exposure to air, which has been shown to leave fibers brittle. Once the fibers are stripped of their coating, a cleaning of the fiber with a lab wipe and acetone has been shown to have the best performance when observing connector fiber heights over temperature. Once cleaned, the fiber should be immediately terminated to the connector.

- **Epoxy:** Most epoxies used for GR-326 testing are a two-part epoxy (with previously mentioned specifications). Removing air bubbles from the two-part mix is vital for a fully cured epoxy. This can be done using a centrifuge or a bell jar style vacuum. Epoxy with air bubbles in it can cause attenuation of the fiber over temperature, or even worse, cause a catastrophic failure. The other important factor is the mix ratio. If willing to go with a higher priced epoxy, a PMF (Pre-mixed and Frozen) is a great option for having the epoxy measured to the exact ratio for the two parts and to avoid excessive air bubble removal.

- **Polishing Machine:** Select a machine vendor that has very tight tolerances on their machines and polishing fixtures. The machine should have controls for downward pressure as well as platen speed. Use of a high-quality diamond lapping film is required for consistent geometry shaping of the ferrule end-face. Attributes like grit size and density need to be checked constantly.

- **Fiber buffer stripper**: The fiber stripper and epoxy are probably the two main root causes for latent continuity issues. The desired epoxy specs have been mentioned above so let's now focus on the fiber buffer stripper. This tool is what is needed to strip the 900µm tight buffer from the 125µm glass. The tool is an automated heat and strip tool. This is basically a buffer removal tool that uses heat as part of the process to ensure pristine glass, void of nicks or scratches. Lastly, the blades only penetrate a percentage of the buffer which ensures the blade will never touch the glass. Years ago (circa 1988), the use of mechanical strip tools was much cheaper and easy to replace. But these tools needed to be inspected on a weekly basis, or even a shorter duration, such as daily inspection. The test for this is quite easy to perform. All that is needed is a high-power microscope to inspect the whole length of glass fiber to search for nicks and scratches. If any of these defects show up in the microscope, then the fiber should be cut even with the buffer. Knicks and scratches are often overlooked. Mechanical fiber buffer strippers that are calibrated to *around* 120µm often cause these defects, which could lead to a nick or scratch to propagate into the cladding and/or fiber core. This would be classified as a catastrophic failure – one that could be avoided if using the automated heated buffer stripper.

- **Connector curing oven:** Use of a high-capacity oven that allows the heating contact/element to have direct contact with the ferrule is preferred. More "economical" ovens are available on the market that position the ferrules/connectors in loose fitting fixture, but this type of oven will not likely achieve a full cure of the epoxy as recommended by the epoxy vendor. A Tg measurement is recommended for determining if the cure time is too short due to the lack of heat transfer to the ferrule fiber hole.

- **Laser cleaver:** A laser fiber cleaver is recommended for its ability to make consistent cuts to the glass, and also for reducing the epoxy bead removal step in the polishing process. The laser cleaver requires cleaning during the day but has virtually no consumable to replace (Note: Mechanical style cleavers have become more accurate and automated lately, so we should consider this as an alternative to laser cleaving).

- **Interferometer:** This tool is crucial for both the process design, and as part of the manufacturing process for connector polishing. Most of today's interferometers will do the job, but using a well-known brand, as well as one offering regional customer support is ideal.

- **IL/RL test equipment:** It's common knowledge that LPM (laser and power meter) testing is the most accurate way to measure mated pair connector loss/reflectance. The equipment selected to perform IL and RL measurements should have good dynamic range, accuracy and repeatability. Choose a well-known test equipment vendor whose equipment offers a data base and ability to serialize and store IL/RL results. This is very important as the GR-326 requires test results and component traceability.

Process:

This paper has outlined the materials and equipment recommendations but has not yet shared any of the process details/tips. Let's start with connector curing. If the epoxy vendor is specifying a certain cure schedule, pick one and add either five degrees or another five minutes as a buffer for the cure schedule.

- **Polishing:** Just as important as the quality of the lapping film is the quality of the rubber pads that the lapping film is placed on. Determining which rubber pad needed requires a bit of process development, with ferrule pre-dome and ferrule hardness as the main variables in the equation. Empirical testing can dial in the process as needed along with a good quality rubber pad. Care in the maintenance of the rubber pad in manufacturing is of utmost importance. Ultra-violet (UV) light from ambient sun light can cause the rubber to lose its durometer specified by the vendor.

- **Geometry:** The current specification for ferrule radius is from 10µm to 25µm. Because there is a temporary deformation of the ferrule end face when mated, and that certain interferometers may have different tolerances, it is recommended to start off with a geometry limit that is well within the GR-326 limit. For example, use an acceptable range of 12µm to 22µm, as opposed to accepting results that may be a few tenths of a micron inside of the limit. Further, the geometries can be altered to reflect optimal performance, such as using different durometer rubber pads, and sometimes the pad height, depending on the manufacturer of the polish machine. Much like the radius requirements, the fiber height should have an internal control that is well inside of GR-326 limit. Because the post-cycling geometry limits for fiber height is +50nm to -50nm, pre-test fiber heights should be in the +10nm to +40nm range. Apex offset is usually a function of rubber pad quality and/or polish plate quality.

- **Testing:** For per-test IL and RL measurements, consider using an internal limit of better than 0.2dB (objective) and 0.4dB (requirement), to allow for some fluctuation that will certainly happen to some extent due to temp cycle/aging. It is usually the company's choice whether it uses a random mating process for testing or a Master Test Jumper. This will need to be determined before environmental testing.

A good amount of empirical testing is required to fine tune the GR-326 process. Consequently, this is precisely the reason why there are only a few Telcordia GR-326 approved cable assemblies. Always beware of the creative wording by the cable assembly vendors that imply they do Telcordia witnessed or approved testing. In the end, it is an investment. Many Tier-1 providers require Telcordia-approved assemblies, and it follows that this is the reason why GR-326 approved/accredited jumpers fetch a higher price. Quality is worth paying for, and some companies demand it.