Terminated Connector Performance: It's More Than Just IL and RL

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What is the problem?

There are many manufacturers of fiber optic patchcords, which provide for competitive, cost-effective pricing for the end-user of these products. As the product has been more and more commoditized, it is wrongly assumed that all patchcords will perform the same as long as a few given performance metrics are met. Most associate good insertion loss (IL) and return loss (RL) as the only recipe for a good patchcord and, because of this, the barrier to entry is small. There are many "garage shop" environments that can produce a fiber patchcord to meet these metrics but are they really producing a good patchcord that will perform reliably over time? The answer is unknown as they have not made the financial commitment for test equipment that validates whether their process is capable and repeatable. Because their metrics are limited, they can claim first pass yields (FPY) that are on par with a world class manufacturing environment and, yet, offer a price and lead time that appears very attractive to the user.

What should I do?

It is important for you, the customer, to understand what makes a good patchcord by taking the time to research and ask some critical questions of your patchcord vendor candidates. Your inquiry and choice of a vendor should, at the very least, address 3 areas: the connector hardware, termination process, and final inspection methods. Not doing so puts your revenue generating circuits at risk. Patchcord termination quality and performance issues can cause you major headaches as they are often difficult to troubleshoot. A few pennies saved is not very comforting when those few pennies are the reason that your network or critical customer is screaming "Network Down!" at the worst possible time.

Where do I start?

In January 2001, the telecommunications industry began the process to change the testing standards for devices used in uncontrolled environments. The industry established the level 2 certification criteria, SR4226, for fiber optic connectors and jumper assemblies. The criteria was based on Telcordia's generic requirements document, GR-326-CORE, established a year and a half earlier. A revision to enhance the performance metrics is currently under review. The standard addresses the suitability of appropriate use as well as performance metrics and physical geometries of a fiber optic termination. The key metrics of this standard are where you should start when developing your internal standards and what you should use to qualify your vendors against.

However, that's a huge document….and it's expensive! So, what are the key metrics I should look for?

Connector

To begin with, and to remove doubt in this area, a GR certified connector should be used. This is a connector that has been tested at Telcordia or a third party, and meets or exceeds the standard for this network component. You should ask the size of the ferrule being used; a smaller size improves the chance of concentricity (measure of how well the fiber core is centered in the ferrule). Some use a large 127 micron capillary, while a 125.5 improves this metric data as the core/cladding of a terminated fiber measures at 125.

Termination Process

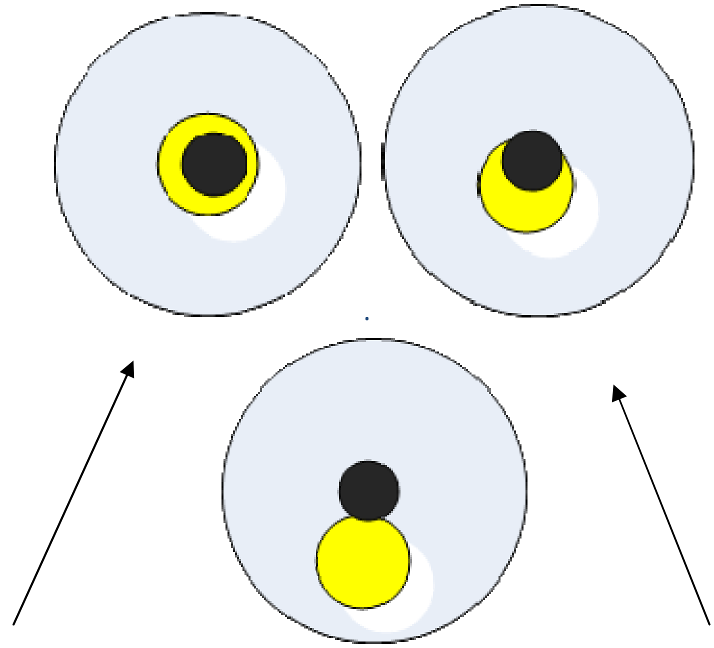
Ask if epoxy is being de-gassed, especially if your patchcord will be used in uncontrolled environments like the OSP. What kind of prepping equipment do they use? The more automated equipment used, the smaller the chance of critical failures long term. A manufacturing process can cheat the system by using manual and cheaper prepping tools. Manual prepping tools can cause nicks in fiber that could only become evident over time.

What kind of cleaving do they perform? Is it manual which requires a high level of skill achieved by years of experience? An automated process like a laser cleaver greatly improves first pass yield data and delivers a more repeatable performance process.

Test and Measurement

Your minimum requirements should include data that meets insertion loss and return loss (reflectance). Insertion loss should meet the 326-Core minimum of .4dB, with reflectance meeting 55dB for UPC connectors and 65dB for APC. Asking the typical performance measures of a manufacturer's process can save you on link loss budgets over a long fiber run through a FTTH network.

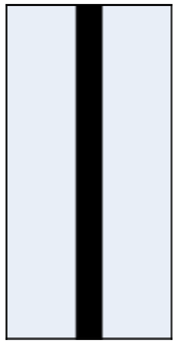
Apex offset, the measurement for how well the center core of the fiber is centered in relationship to the spherical apex of the polished tip, minimizes lateral offset between two fibers and maintains a better physical contact. Apex offset describes a physical condition of the polished fiber, rather than a performance parameter. It is also an acceptance criteria for Telcordia. An excessive apex offset contributes to high insertion loss and high back reflection readings.



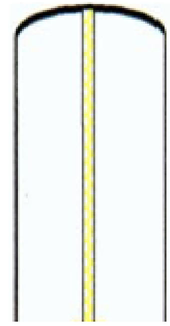
Perfect Offset Unacceptable Offset Acceptable Offset

Fiber undercut or protrusion affects the physical contact zone. This metric measures, in nanometers, the height of the fiber under or below the ceramic end-face. Too much undercut minimizes the chance of a good physical contact, while too much causes excessive fiber deformation when mating occurs resulting in degradation of signal. When two connectors are mated, the ceramic compresses around the fiber core which allows the fibers to squeeze up and make good contact with each other. When they do not touch (because of too much undercut), an air gap is created and loss happens. If the fiber is protruding too far (beyond 50nm), chipping and cracking can occur during the mate.

Radius of curvature is the measurement of the connector end-face spherical condition. The radius generated affects the performance because the radius, when mated with another connector, should be compressing most of the material surrounding the core (ceramic ferrule). A proper radius, 5 to 12mm, allows for the right compression and max performance. Too tight of a radius will put too much compression on the glass and too loose will put too much on the surrounding ferrule with not enough compression. Too much or too little radius can cause light scatter or inadequate physical contact for optimal signal transfer.



Flat – 0mm radius



5-12mm radius

Apex offset, fiber undercut/protrusion, and radius of curvature are the main ingredients that work in concert to deliver good IL and RL performance. Processes that drift out of this geometry range can still yield acceptable IL/RL, but sensitive traffic will be affected (such as video) and long term performance of the connector will be compromised.

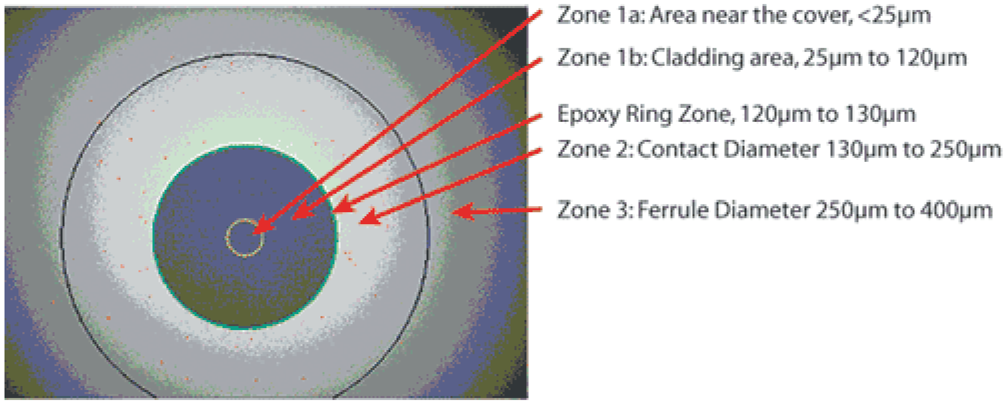
Your vendor should be able to provide these geometry test reports with on-hand interferometer testing. While you may not require this data for each and every connector, you should require that random testing is being performed to ensure the process is capable and not drifting out of spec. “Garage shops” will not be able to deliver this test data on demand.

Your test reports should account for each connector independently and not a total report that summarizes both ends.

End-Face Quality & Cleanliness

Currently, there is not an industry standard for this topic. To be sure, end-face and cleanliness has a direct impact on the performance of the connector.

Several organizations (most notably, NEMI) have studied the impact of end-face defects and cleanliness. The influence of the contamination/scratches becomes more evident if they are located in the core/cladding areas. Particle contamination can cause a significant increase in IL (up to 10 times) and decrease in RL (up to 3 times). Scratches applied to the fiber contact zones 1a and 1b, which is an area from the core out to the cladding (125um), decreased RL by up to 25%. On the other hand, scratches located in the cladding layer showed little effect on IL and RL. Multiple heavy scratches passing through the core caused severe performance degradation in IL/RL and can be catastrophic.



Connectors with particle contamination will pass on contamination to mated connectors. Contaminants can prevent direct physical contact, creating an air gap. Multiply this by the number of re-mates over time and the problem spreads. Pits and scratches, in the critical contact zone 1a, will collect particulates over time and the same contamination-spread occurs. Long term reliability in dynamic circuits is severely reduced as opposed to those that are static. Scratches and polishing marks outside of critical contact areas are acceptable and do not have any impact on signal performance.

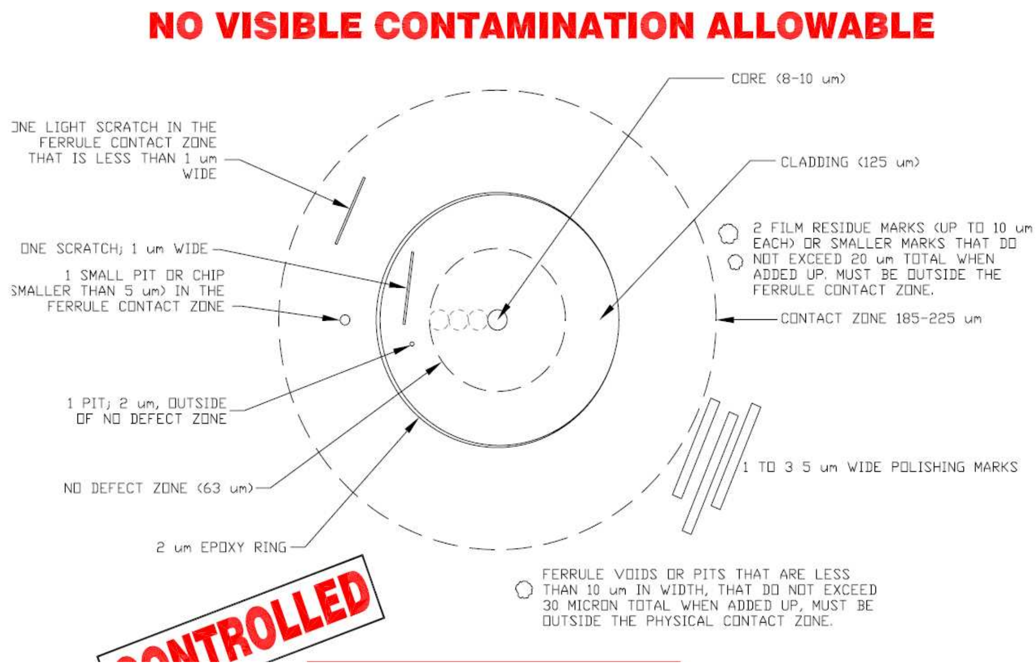
The quality fiber assembly manufacturers and OEMs will have their own inspection criteria. However, these specifications differ from company to company and the differences can cause materials to be "nonconforming" at user/customer sites.

What will your inspection criteria be?

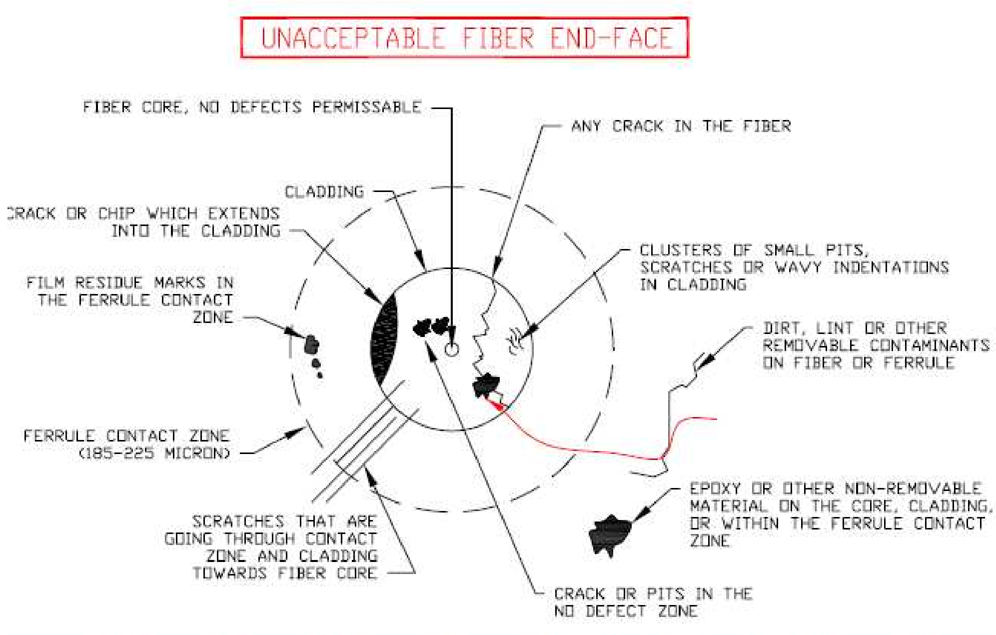
Your vendor should provide visuals at a minimum 400X magnification. While some manufacturers require that there be no visual damage at this magnification in the defect zone (roughly an area 8x the diameter of the core), others require that the entire contact zone be void of defects. Others might allow 1 pit and 1 scratch X microns long or wide. There should never be any scratches or pits through the core.

Other manufacturers will allow some defects in the contact zone 1. And some, the ones you should avoid, do not have a standard in this area. Important point: Zero defects in this area are achievable and you should ask for it.

An end-face defect and cleanliness spec should look something like this:



An example of an unacceptable end-face:



Taking a little time up front to review your vendors' connector choice, termination processes, test and performance methods, and their stated and published end-face criteria will weed out the "garage shop" environments and leave the world-class manufacturers standing. Doing so is important to the investment of reliability of your entire network.