OPTICAL FIBER CONNECTOR TYPES AND TERMINATION TECHNOLOGIES

Making the Right Choice for Your Installation
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INTRODUCTION

Selecting the right connector for your needs can be complicated by the many choices available today. Choosing the best fiber optic connector for any installation will have an impact on how efficient and cost-effective the job is completed. To make matters even more complicated, the right answer may not be a single connector type or technology! This white paper will help alleviate the confusion by reviewing the basic considerations prior to deciding on the best connector for an installation considering the connector type, the standards and termination technology. There are a few other considerations that are also worth noting covered in this document.

CONNECTOR TYPES

In today's local area networks (LANs), there are two primary legacy optical fiber connector types (the ST-style and the SC Duplex) and two primary small form factor (SFF) connectors (MT-RJ and LC). All four of these connector types have been in use for several years and have a proven track record for the performance and reliability desired for local area networks. However, there are some significant differences between these connector types.

The ST-style Connector

This connector type, sometimes referred to as the “BIFOC” connector, is a simplex fiber connector – that means one fiber in one ferrule – with one 2.5mm cylindrical ferrule. To get a duplex ST-style connection, four connectors and two adapters are required. The housing of the ST includes a push-and-twist, spring-loaded latching mechanism that is relatively large by today's standards, particularly when consideration for “finger space” (the space around the connector that is needed to get fingers in to grip, push and twist the connector) is considered. This connector was one of the first high-performance, robust optical fiber connectors and, as such, was widely adopted in the telco market. This popularity spilled over into the LANs that incorporated optical fiber cabling and was widely used. To this day, it is still a very popular optical fiber connector.

The SC Duplex Connector

While the ST-style remains a completely functional connector, some of its properties are not well-suited for the LAN market. Since most all LANs are based on duplex optical fiber runs, a simplex connector is less desirable than a duplex. For this reason, the SC Duplex was introduced. While the base component (the ferrule) is the same as the ST-style, the housing is completely different. The SC connector has a housing that features a push-pull latch mechanism, making it easier to mate and de-mate, and reducing the finger space needed. The SC Duplex connector, sometimes referred to as the TIA568A connector, consists of two SC connectors yoked together, which can both be mated or de-mated with the same push or pull action. These features helped the SC Duplex become the recommended connector in LAN standards – both in North America (in EIA/TIA-568-A) and internationally (in ISO 11801). Even though this recommendation was initiated almost ten years ago, only recently has the number of SC connectors installed in LANs equaled the number of ST-style connectors.

Small Form Factor Connectors

Although the SC Duplex solved some of the LAN-related issues for fiber connectivity, it didn’t solve one of the most important issues: density. Because of the single-fiber ferrules, the large housings and the finger space, the fiber connection density was still twice that of traditional copper terminations (RJ-45). The industry really needed a duplex fiber connector that had the same basic size as the RJ-45 copper connector - a small form factor connector. As the TIA-568-B standard revision was being developed, five different small form factor connector designs were considered. Today, nearly six years later, only two of these designs seem destined to survive, the MT-RJ and the LC.
The MT-RJ Connector
Recognizing that fiber spacing was the limiting factors in fiber connection density, the MT-RJ connector was developed with a single, two-fiber ferrule. The ferrule itself (called an MT ferrule) has a rectangular cross-section with two fibers spaced 700µm apart and two guide pin holes. This makes the MT-RJ the small form factor connector with the highest fiber density. The housing around the MT-RJ has a slightly smaller cross-section than the RJ-45, so an MT-RJ connector can fit in the same port space as an RJ-45. It also features an RJ-style latch, so it’s just as easy to mate and de-mate as an RJ-45 plug. When combined with the no-epoxy/no-polish termination technology (discussed later), this connector type offers high density and ease-of-installation advantages. (For more information on MT-RJ technology and products, see the white paper entitled “The MT-RJ Advantage” at www.ampnetconnect.com)

The LC Connector
Recognizing that fiber ferrule size was the limiting factor in fiber connection density, the LC connector was developed using a reduced-diameter, simplex fiber ferrule. Instead of the 2.5mm ferrule, the LC connector uses a 1.25mm cylindrical ferrule. The smaller ferrule allows for a smaller housing and thus a smaller connector. Small enough that two LC connectors yoked together take up about the same port space as an RJ-45. The LC connectors also feature a latching mechanism similar to the RJ-45, and the smaller ferrule also reduces the time required for the polishing step for epoxy/polish connector termination.

Choosing a Small Form Factor Connector
The choice between the MT-RJ and LC connector is a bit more complicated than choosing between ST-style and SC Duplex. Since they are both duplex, RJ-latch style connectors, some other comparisons may help in the selection process. One of the most obvious differences is the form of the connectivity. The AMP NETCONNECT MT-RJ System uses the same concept as copper networks – the plug and jack model. The advantage of this concept is that it’s a two-part connection. The LC is similar to the ST-style and SC Duplex, using a plug-adapter-plug concept for each connection – two plugs and an adapter are required to make a connection.

<table>
<thead>
<tr>
<th>MT-RJ and LC Duplex Connector Comparison Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ferrule Type</strong></td>
</tr>
<tr>
<td><strong>Ferrule</strong></td>
</tr>
<tr>
<td><strong>Duplex Connector?</strong></td>
</tr>
<tr>
<td><strong>Latching Type</strong></td>
</tr>
<tr>
<td><strong>Single Ferrule</strong></td>
</tr>
<tr>
<td><strong>Smallest Size (Duplex)</strong></td>
</tr>
<tr>
<td><strong>Plug and Jack Model?</strong></td>
</tr>
<tr>
<td><strong>GbE Compliant?</strong></td>
</tr>
</tbody>
</table>

The Standards
So, there are four major connector types for the LAN, and each one seems to be a good choice. How do you choose which one of the four to use? Before making a selection, it’s a good idea to check the Standards. In North America, the applicable standard for structured cabling is the ANSI-approved TIA-568B Standard, Commercial Building Telecommunications Cabling Standard. Internationally, the ISO 11801 Standard, Generic Cabling for Customer Premises, applies.

TIA-568-B
After a substantial debate, it was clear there would not be a consensus on choosing any one connector type for the new Standard. While this lack of consensus was widely criticized, it underscored the fact that each connector type has certain advantages that individual customers may appreciate. Without any underlying technical reason to eliminate any one, it only seemed fair to proceed. So, the Standard was written to allow for customer preference and to allow for the installed base. The resultant wording in the standard basically allows any optical fiber connector type instead of requiring everyone to use one type. To prevent the use of a connector that may not have sufficient performance for LANs and thus protect the end-users from selecting a “fly by night” connector type, the TIA-568-B Standard was written carefully to allow only optical fiber connectors that satisfy two requirements.
First, there must be a TIA-approved FOCIS document for the connector type. FOCIS stands for “Fiber Optic Connector Intermateability Standard”. This document outlines the key dimensions and constructions of the connector and transceiver interface so that connectors from different vendors will intermate. Thus, all FOCIS-compliant SC Duplex compliant connectors will mate with all other FOCIS-compliant SC Duplex adapters and transceivers. This requirement protects the end user from adopting a connector type that may be a proprietary (one-source) connector, and ensures the end user will be able to purchase products in a free-market environment with multiple suppliers.

**FOCIS Document Reference Chart**

<table>
<thead>
<tr>
<th>Connector Type</th>
<th>FOCIS Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-Style</td>
<td>TIA/EIA-604-2A (FOCIS 2)</td>
</tr>
<tr>
<td>SC and SC Duplex</td>
<td>TIA/EIA-604-3 (FOCIS 3)</td>
</tr>
<tr>
<td>MT-RJ</td>
<td>TIA/EIA-604-12 (FOCIS 12)</td>
</tr>
<tr>
<td>LC and LC Duplex</td>
<td>TIA/EIA-604-10 (FOCIS 10)</td>
</tr>
</tbody>
</table>

The FOCIS documents address the connector dimensions and tolerances, but not the performance. So, the second condition requires the fiber connector performance to comply with TIA-568-B.3 Annex A, *Optical Fiber Connector Performance Specifications*. This annex lists the insertion loss, return loss, mechanical performance, and environmental performance requirements for compliant optical fiber connectors. Compliant connectors are thus assured to have the performance needed for LAN applications.

All that being said, the ST-style, SC Duplex, MT-RJ and LC connectors are all allowed by TIA-568-B, assuming the vendors’ products comply with Annex A. However, it is important to note that the SC connector remains the recommended connector and that ST is allowed for networks with an existing installed base of ST. In other words, TIA-568-B recommends using the SC duplex or a small form factor connector for new installations and thus allows the consistent use of one connector type throughout the campus if a customer wanted to take advantage of the small form factor connector types.

**ISO 11801**

The international standard took a slightly different approach, allowing all connector types, there is an additional restriction. Although there are similar intermateability and performance requirements included, this standard further requires the SC Duplex at the telecommunications outlet, or TO (equivalent to the work area outlet in 568B). If the installation must comply with ISO 11801, then the work area outlet must have the SC Duplex connector, but connector types used in other locations do not have to be SC Duplex.

**TERMINATION TECHNOLOGY**

Sure, that was a lot of information with no real conclusion, but that's not necessarily bad. The real conclusion shouldn’t be reached until a review of the connector termination technology is completed. Depending on the type of installation, the experience of the installer, the available tools and equipment and the termination technology are all critical factors in the decision process.

The optical fiber industry has come a long way in the past decade. Advances in machine and mold tolerances, factory automation and adhesives have opened up a world of connector technology options that can make termination easier and less expensive. But, with so many termination technologies, products, techniques and procedures to choose from, selecting the right one for each application can be difficult and will definitely impact how quickly and cost-effectively the job gets done.

Applying these technologies appropriately will have a true, positive impact on the installation costs of a fiber network. Understanding the benefits and tradeoffs each one offers is the key to selecting the right termination for each part of the installation. Since there is no “one size fits all” solution, it is entirely possible or even recommended to use more than one technology in the same network installation.

**Installed Costs**

The installed cost of a connector is the best way to compare connector termination technologies, since component costs alone can be misleading. The two main factors in the cost of an installed connector are the labor (hours of
training and experience and hours on the job) and material costs (connectors, tools and consumables). Accordingly, in higher labor rate areas, it may be advantageous to use a technology with the shortest training and installation time.

As a basis for comparison, consider these factors that affect the installed cost when choosing connection technologies. For purposes of this discussion, it is assumed that all technologies require the same standard cable preparation tools, the same time for transit to the site and the same time for cable preparation. Additionally, alcohol and wipes are considered as consumables for all technologies.

- **Setup & Takedown**: This is the preparation time required before installing the first connector at a termination location and includes staging the necessary tools and ovens, setting up a termination area and preparing the consumables. The time to pack away all these items is also included.
- **Installation**: This is the time it takes to install a connector on a single fiber and includes any necessary steps such as stripping the buffer, applying and curing the adhesive, polishing, and crimping to result in a testable termination.
- **Materials**: This includes the cost of the connector kit along with the costs of any additional consumables (adhesives, polishing papers, etc.), of any protecting hardware and of any necessary tools. Additionally, this covers the “extra” connectors to cover any terminations that don’t pass when tested.
- **Skill**: While some level of training is required for all connector products, some technologies will require skilled technicians while others allow installers with limited training to produce good results. Higher skill usually incurs higher labor costs on an hourly basis.

**CONNECTOR TERMINATION TECHNOLOGY CHOICES**

There are four basic classifications of fiber termination: no-epoxy/no-polish, no-epoxy/polish, epoxy/polish and pigtail splicing.

**No-epoxy/no-polish connectors**

No-epoxy/no-polish connectors offer the easiest and quickest termination technology available. Installers only need to strip, cleave, and lock the fiber into the connector body, which also contains a short pre-polished fiber stub in the ferrule. In effect, this is a connector with a built-in mechanical splice and a high-quality, factory-controlled end face that provides excellent return-loss performance for a field-terminated connector.

These connectors are ideal for locations with low-fiber-count terminations, such as small building backbones and work area outlets, or for maintenance, repairs, short moves, small adds, and quick changes. Installers with high labor rates, inexperienced technicians or an inconsistent work force will like the fast training and quick installation and the fact that only a short length of slack fiber is required for successful termination. Recent cost models have shown that this connector technology can be the most cost-effective for field installation.

**No-Epoxy/No-polish Advantages**
- Shortest set-up and takedown time
- Shortest installation time per connector
- Lowest consumables costs
- Minimal training

**No-Epoxy/No-polish Comparison**
- **Setup**: Essentially none: hand-held tools, no curing ovens to warm up, no power and no consumables.
- **Installation**: Less than one minute per fiber, regardless of the number of terminations.
- **Materials**: Highest cost per connector kit since some of the labor (polishing) is done in the factory, but likely to have the lowest labor cost. Some connectors require special tools, but the tools are usually hand-held and comparatively inexpensive.
- **Skill**: Minimal amount of training is required to learn the “strip, cleave and lock” procedure, thus installations can more quickly utilize inexperienced labor without as much sensitivity to the installation process. This type of connector is ideal for installers with a high turnover rate of technicians or that do limited numbers of optical-fiber terminations.
AMP NETCONNECT LightCrimp Plus Connectors
With the AMP NETCONNECT LightCrimp Plus no-epoxy/no-polish connectors, you can terminate optical fibers for premises cabling and FTTD (Fiber-to-the-Desk) applications in less than a minute. LightCrimp Plus connectors use patented Tyco Electronics splice and crimp technology to make fiber optic termination a quick, clean and simple mechanical process. Only a few simple tools with limited training are required. With LightCrimp Plus you can terminate fibers without epoxies, without polishing papers, without ovens, without power, without visual fault locators and without UV lamps. AMP NETCONNECT LightCrimp Plus connectors are available in single-mode (SC and LC) 50-micron multimode (SC, LC and ST), 62.5-micron multimode (SC, LC and ST) and XG.

AMP NETCONNECT MT-RJ Jacks
The AMP NETCONNECT MT-RJ jack is about the size of a standard phone jack, and it’s just as easy to connect and disconnect. Additionally, the no-epoxy, no-polish MT-RJ jacks make fiber termination quick and easy with typical termination time in less than two minutes for two fibers. The MT-RJ jack features a two-fiber, factory polished ferrule enabling each fiber to be terminated in three easy steps - just strip the cable, cleave the fiber and lock on the connector. It’s half the size of the SC connector it was designed to replace, so it offers twice the port density of traditional fiber connectors. It’s designed to fit into conventional RJ-45 faceplates and patch panel cutouts, minimizing the equipment needed for conversion to fiber. With MT-RJ jacks, you can terminate fibers without epoxies, without polishing papers, without ovens, without power, without visual fault locators and without UV lamps. MT-RJ Jacks are available in 50-micron multimode, 62.5-micron multimode, and XG. MT-RJ Pigtail jacks are available in single-mode, 50-micron, 62.5-micron and XG.

No-epoxy/polish connectors
No-epoxy/polish connectors replace the need for epoxy by using a crimp or clamp mechanism to lock the fiber in the ferrule. The excess fiber is then cleaved at the end face and hand-polished to produce a working connector. This is a popular choice for installers because it eliminates two of the industry’s primary complaints about fiber terminations: the need to mix and apply epoxy and the need for a curing fixture (ovens or lamps that require power).

No-epoxy/polish is ideal for locations with moderate fiber-count cables or for companies that perform a mixture of backbone and FTTD projects. It is easily adaptable for high-fiber-count and low-fiber-count locations and ideal for installers with moderate labor costs and a reasonably stable, trained work force because it offers the maximum flexibility with one technology, and a good balance between material and labor costs. Recent cost models have shown that the no-epoxy/polish technology can be very effective when compared to epoxy/polish terminations.

No-epoxy/Polish Advantages
- Moderate material cost
- Moderate capital investment in tool kit
- Moderate installation time

No-epoxy/Polish Comparison
- **Setup**: Takes about nine to 15 minutes at each location to set up the polishing station.
- **Installation**: Takes about five to ten minutes to lock and polish each fiber.
- **Materials**: Moderate cost for the connector kit, but there is no need for an oven or for epoxy or adhesive which can be an expensive consumable. A polishing kit is required as are the appropriate fixtures for the connector type, the polishing papers and fluid consumables. Thus, there is a moderate capital investment and consumables cost.
- **Skill**: Although the locking mechanism is essentially the same for the no-epoxy/no-polish technology, the amount of training and skill is increased because of the polishing procedure which takes a bit of time to develop a “feel” for how it is done.

AMP NETCONNECT LightCrimp Connectors
AMP NETCONNECT LightCrimp optical fiber connectors are no-epoxy/polish connectors that make optical fiber terminations easier by eliminating the need for messy, expensive and perishable epoxies. The LightCrimp features a
ceramic ferrule for fiber termination in four easy steps. Just strip the cable, strip the fiber, crimp on the connector, and polish. Multimode LightCrimp connectors work for 50-micron, 62.5-micron and XG (850nm LO 50-micron) fiber terminations. A single-mode version is available for ST.

**Epoxy/polish connectors**

Today, there are two options for this technology: heat-cured, which requires 20 minutes or more in an oven, and quick-cure, which uses and fast-setting epoxies like cyanoacrylates. Both methods are suitable for terminating high-fiber-count cables in a single location. In these situations, the longer setup time and curing time can be offset by establishing an assembly-line type of process - while some connectors are being polished, others are in the curing process. The process takes some experience to get proficient but can yield some of the lowest loss terminations. So, it’s an excellent option for installers with low labor costs and a stable, trained work force.

Obviously, however, setting up a curing and polishing station at every work area is too cumbersome and time-consuming – particularly in cramped and difficult-to-access locations like under a desk. The faster-curing adhesives considerably reduce the curing time, often to within two minutes without the need for an oven or power source, but are more expensive and must be used quickly once opened and have a short shelf life even if unopened.

**Epoxy/Polish Advantages**

- Lowest connector kit cost
- Can offer the best performance (lowest loss, lowest reflections)

**Epoxy/Polish Comparison**

- **Setup:** Takes approximately ten to 15 minutes per location, because the adhesives must be prepared and the polish station must be prepared before starting.
- **Installation:** Takes as long as 25 minutes for a single connector but can be an average of six minutes each for a large number of connectors in a single location.
- **Cost:** This has the lowest connector kit cost, but does require a separate investment in a curing oven and polishing station. Additional consumables costs for the adhesives, fluids and polishing papers must also be considered. For these reasons, the epoxy-polish connectors are economical if these costs can be spread across a large number of connectors and if waste is kept to a minimum.
- **Skill:** Although the technique is not difficult, it does require the most training and skill, specifically in the application of the adhesive and the polishing of the connector. These skills take time to learn and master and must be taught and acquired to produce consistently good results. Accordingly, this technique is most suited to installation companies with a trained work force, low turnover rates, and low labor costs. Due to the time required, high labor rates can adversely affect the cost-effectiveness of this technology.

**AMP NETCONNECT Epoxy/Polish Connectors**

A complete line of epoxy/polish optical fiber connectors (SC, LC and ST), tool kits and consumables are offered through AMP NETCONNECT for field installation as well as for factory installation in cable assembly houses.

**Pigtail Fusion Splicing**

Some installers opt for another termination altogether. Rather than terminate the fiber in the field, they fusion splice a pigtail (basically, one end of a factory-made patch cord) to the installed fibers. Worries about epoxies, hand tools or curing times are eliminated; however it does require the use of a fusion splicer to join the fiber in the pigtail to the installed fiber.

Pigtail splicing makes the most sense for installers that have already invested in a fusion splicer. The compact fusion splicers available today are smaller and less expensive, but still represent an investment of several thousand dollars. Renting these units is often economical for a few days or less. Installation can proceed quickly and the results can be as good as the epoxy-polish connectors. Since pigtails and patch cords are often mass-produced in the factory, the cost is slightly higher than the epoxy-polish connector kit but doesn’t require the assembly and termination labor and thus can offer the best performance for the individual connector. However, there is an additional loss associated with the fusion splice and additional hardware is needed to house the splices or heat shrink splice protectors. This technology works best for installers working with a large number of fibers, or on high-performance single-mode networks.
Pigtail Splicing Advantages
- Low material cost
- Readily available parts
- Good loss and reflection performance

Pigtail Splicing Comparison
- **Setup**: Takes about five minutes at each location to set up the fusion splicer. A power source (or an extension cord to one) is usually required, although many fusion splicers have some inherent battery power. Some fusion splicers require a warmup period of several minutes.
- **Installation**: Takes about five minutes to prepare and fuse each fiber, then protect the splice.
- **Materials**: The biggest cost is the capital and maintenance costs of the fusion splicer. Once this capital investment is made, however, each subsequent use reduces the net cost per termination. Each splice must be protected, either with a heat shrink or sealant and must be housed in separate trays; both add to the materials and real estate (rack space) costs of this method. Pigtails must be purchased separately, but are often available at low cost from several large-scale vendors. Keep in mind that the quality you pay for is the quality that is installed—so buy from reputable and traceable suppliers. Thus, there is an extensive capital investment but minimal consumables cost with this technology.
- **Skill**: Using a fusion splicer takes training and skill, but modern fusion splicers make it easier to get good results once the fiber is loaded into the machine.

OTHER FACTORS

There are other factors that need to be considered. Obviously customer choice, product availability, product familiarity and performance requirements may force a selection that may not be optimal for the installation, but the following information may help to ensure that the best choice is made.

**Electronics**
One consideration may be the interface of the electronics. In some cases, end users want to use the same interface everywhere in the campus. Depending on the electronics vendor and model number(s) they select, this may dictate which connector type is used. However, it is also prudent to realize that the hybrid patch cords (patch cords with different connectors on each end) are readily available in every combination. Therefore, the choice of the connector type does not need to be dictated by the electronics vendor.

**Selecting Multiple Technologies**
Many installations utilize multiple termination technologies, depending on the application and location. For example, it may make sense to use epoxy-polish connectors in telecommunications room locations and no-epoxy/no-polish connectors at the work area outlet. Similarly, it may make sense to use no-epoxy/no-polish connectors for quickly replacing those connectors that fail to meet the specifications when tested. Replacing individual connectors quickly and easily may allow a quick and efficient completion of the installation.

**Selecting Multiple Types**
Some facilities may decide to use different interfaces to segregate networks and prevent inadvertent interconnection between networks. One way to do this, for example, is to use SC Duplex connectors for network A and MT-RJ connectors for network B. The different connector types assist in identifying which connection points are used for which network. Another solution to this problem is to adopt a connector type specifically designed for this type of installation, such as the AMP NETCONNECT MT-RJ SECURE connection system. *(For more information on MT-RJ SECURE technology and products, see the white paper entitled “MT-RJ Cabling For Secure Networks” at www.ampnetconnect.com)*

**SUMMARY**

Familiarity with the time and skill-level requirements, costs and labor rates for each technology will enable an installer to select the optimum technology for any installation. In every case, the cost of the termination includes material costs and labor costs.
End users may have an installed base of a certain connector type and may want to maintain that interface – that leaves a choice in connector technology. Cost models have shown that, for most installations, no-epoxy/no-polish connectors are the most cost-effective, particularly in areas of high labor rates. The AMP NETCONNECT MT-RJ jacks have a very low cost per installed connector, particularly compared to the LC connectors – either in no-epoxy/no-polish or epoxy/polish technology.

Installers may have experience with a certain vendor product and be fully equipped and trained to install those products. These installers should look to products that enable the installation of the most connector types using the same tools and procedure, such as the AMP NETCONNECT LightCrimp Plus connectors.

End users may have additional requirements as well. For example, the IT Manager of a data center may require epoxy/polish connections. This allows the largest selection of connector types, but may not be the most cost-effective termination. However, there are differences between the costs of the connector kits for each connector type and the polishing procedures and consumables for each. Even if epoxy/polish is selected, there are still options to consider which will have an effect on price.

Keep in mind the most important consideration: insist on optical connectors that meet or exceed the requirements established by ANSI/TIA/EIA-568-B.3.

The following summary table is provided for reference.
## AMP NETCONNECT Optical Fiber Connector Termination Comparison Chart

<table>
<thead>
<tr>
<th>Multimode Connector Types</th>
<th>Single-mode Connector Types</th>
<th>XG (850nm LO 50/125μm) Versions*</th>
<th>Termination Technology Setup &amp; Takedown Time (each location)</th>
<th>Installation Time (two fibers)</th>
<th>Connector Cost (relative)</th>
<th>Installation Labor Cost (relative)</th>
<th>Tool Kit Cost (relative)</th>
<th>Skill Level (relative)</th>
<th>Training (relative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC, SC Duplex, ST</td>
<td>SC, SC Duplex, LC, LC Duplex</td>
<td>SC, SC Duplex, LC, LC Duplex</td>
<td>~10 minutes</td>
<td>~5 minutes</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Short</td>
</tr>
<tr>
<td>SC, SC Duplex, ST</td>
<td>SC, SC Duplex, LC, LC Duplex</td>
<td>SC, SC Duplex, LC, LC Duplex</td>
<td>MT-RJ SECURE Outlet Patch Panel Jacks</td>
<td>~8 minutes</td>
<td>High</td>
<td>Low</td>
<td>Lowest</td>
<td>Low</td>
<td>Short</td>
</tr>
<tr>
<td>LightCrimp Plus No-epoxy/No-polish</td>
<td>MT-RJ Jacks No-epoxy/No-polish</td>
<td>MT-RJ SECURE Outlet Patch Panel Jacks</td>
<td>~20 minutes</td>
<td>~5 minutes</td>
<td>Moderate</td>
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<td>Moderate</td>
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<tr>
<td>LightCrimp No-epoxy/Polish</td>
<td>MT-RJ SECURE Patch Panel</td>
<td>MT-RJ SECURE Patch Panel</td>
<td>~24 minutes</td>
<td>~10 minutes</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Epoxy/Polish</td>
<td></td>
<td>Multimode version works with XG</td>
<td></td>
<td>~9 minutes (quick cure)</td>
<td>Lowest</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

*For more information on the AMP NETCONNECT XG (850nm LO 50-micron) Fiber Solution, refer to the white paper entitled “XG Fiber System” at [www.ampnetconnect.com](http://www.ampnetconnect.com)

NOTE: Entries for time and cost are estimated averages and relative comparisons based on a intermediate experience crew. Actual results will vary depending on experience level and conditions at time of termination.