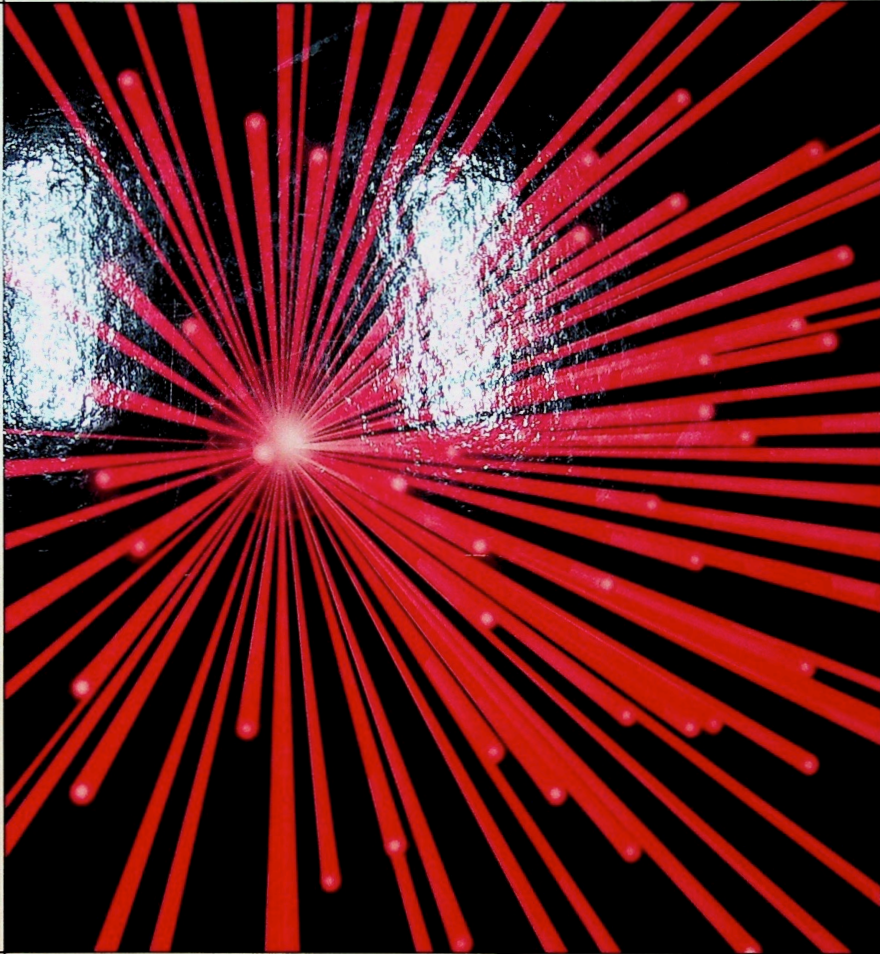


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Technician's Guide to Fiber Optics

4th Edition



Sterling

TECHNICIAN'S GUIDE TO FIBER OPTICS

FOURTH EDITION

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FOURTH EDITION

DONALD J. STERLING, JR.

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Donald J. Sterling, Jr.

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chapter fourteen

FIBER-OPTIC CABLE INSTALLATION AND HARDWARE

This chapter looks at some of the factors involved in installing a fiber-optic cable system. These factors are of interest because they not only demonstrate the practical importance of the mechanical properties of a cable, but they also demonstrate the practical aspects of dealing with fiber optics. We will also describe some types of common fiber-optic hardware, such as closure/organizers, rack boxes, and distribution panels. This hardware is an important part of more complex fiber-optic systems.

BEND RADIUS AND TENSILE RATING

Because of their light weight and extreme flexibility, fiber-optic cables are often more easily installed than their copper counterparts. They can be more easily handled and pulled over greater distances.

Minimum bend radius and *maximum tensile rating* are the critical specifications for any fiber-optic cable installation, both during the installing process and during the installed life of the cable. Careful planning of the installation layout will ensure that the specifications are not exceeded. In addition, the installation process itself must be carefully planned. This chapter discusses the factors involved in the planning.

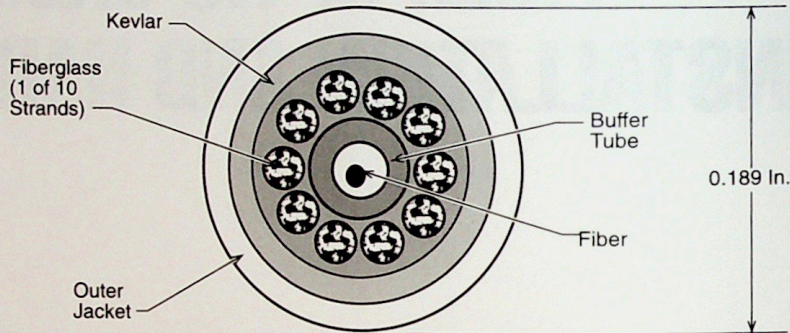
The minimum bend radius and maximum tensile loading allowed on a cable differ during and after installation. An increasing tensile load causes a reversible attenuation increase, an irreversible attenuation increase, and, finally, cracking of the fiber. The tensile loading allowed during installation is higher than that allowed after installation. Care must be taken in either case not to exceed the specified limits.

The minimum bend radius allowed during installation is larger than the bend radius allowed after installation. One reason is that the allowed bend radius increases with tensile

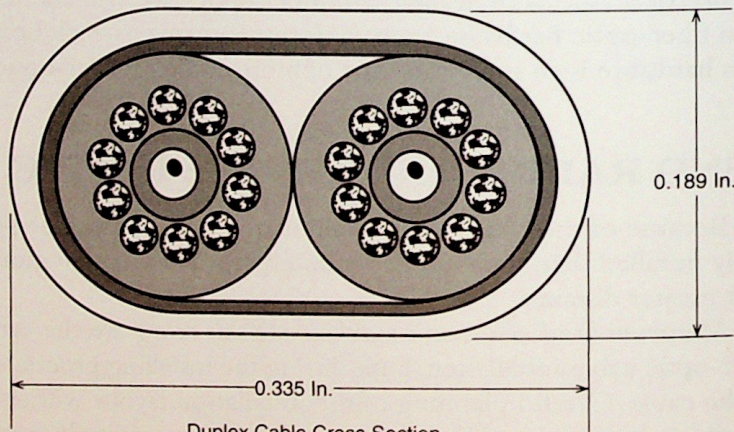
loading. Since the fiber is under load during installation, the minimum bend radius must be larger. The allowed bend radius after installation depends on the tensile load.

Figure 14-1 shows the cross section of a simplex fiber and a duplex fiber, which we will use as examples in this chapter, and gives the specifications for their minimum bend radius and maximum tensile rating.

FIGURE 14-1
Bend radius and
tensile strength
loading for cable
examples
(Courtesy of
Canoga Data
Systems)



Simplex Cable Cross Section



Duplex Cable Cross Section

Tensile Loading (Max)	Cable
During	90 lb (400 N)
After	11.25 lb (50 N)
Bend Radius (Min)	Cable
During	5.9 in (150 mm)
After (No Load)	1.2 in (30 mm)
After (Full Load)	4.0 in (130 mm)

As discussed in Chapter 7, outdoor cables are commonly multifiber cables with constructions more complex than indoor cables. Indoor cables are typically simplex or duplex.

DIRECT BURIAL INSTALLATION

Cables can be buried directly in the ground by either plowing or trenching methods. The plowing method uses a cable-laying plow, which opens the ground, lays the cable, and covers the cable in a single operation. In the trench method, a trench is dug with a machine such as a backhoe, the cable is laid, and the trench is filled. The trench method is more suited to short-distance installations.

Buried cables must be protected against frost, water seepage, attack by burrowing and gnawing animals, and mechanical stresses that could result from earth movements. Armored cables specially designed for burial are available. Cables should be buried at least 30 in. deep so they are below the frost line. Other buried cables should be enclosed in sturdy polyurethane or PVC pipes. The pipes should have an inside diameter several times the outside diameter of the cable to protect against earth movements. An excess length of cable in the pipe prevents tensile loads being placed on the cable.

AERIAL INSTALLATION

Aerial installation includes stringing cables between telephone poles or along power lines. Unlike copper cables, fiber-optic cables run along power lines with no danger of inductive interference.

Aerial cables must be able to withstand the forces of high winds, storms, ice loading, and so forth. Self-supporting aerial cables can be strung directly from pole to pole. Other cables must be lashed to a high-strength steel wire, which provides the necessary support. The use of a separate support structure is the usual preferred method.

INDOOR INSTALLATION

Most indoor cables must be placed in conduits or trays. Since standard fiber-optic cables are electrically nonconductive, they may be placed in the same ducts as high-voltage cables without the special insulation required by copper wire. Many cables cannot, however, be placed inside air conditioning or ventilation ducts for the same reason that PVC-insulated wire should not be placed in these areas: A fire inside these ducts could cause the outer jacket to burn and produce toxic gases.

Plenum cables, however, can be placed in any plenum area within a building without special restrictions. The material used in these cables does not produce toxic fumes.

TRAY AND DUCT INSTALLATIONS

The first mechanical property of the cable that must be considered in planning an installation is the outside diameter of the cable itself and the connectors. Here we discuss the cables from Figure 14-1 terminated with SMA connectors. The connector's outside diameter is 0.38 in. (9.7 mm). The outside diameter of the simplex cable is 0.189 in (4.8 mm). The duplex cable has an oval cross section, 0.193×0.335 in. (4.9×8.5 mm). If the cable must be pulled through a conduit or duct, the minimum cross-sectional area required is 0.79×0.43 in. ($20 \text{ mm} \times 11 \text{ mm}$) for duplex cable. For simplex cable, the minimum cross-sectional area is determined by the pulling grip used.

The primary consideration in selecting a route for fiber-optic cable through trays and ducts is to avoid potential cutting edges and sharp bends. Areas where particular caution must be taken are corners and exit slots in sides of trays (Figure 14-2).

If a fiber-optic cable is in the same tray or duct with very large, heavy electrical cables, care must be taken to avoid placing excessive crushing forces on the fiber-optic cable, particularly where the heavy cables cross over the fiber-optic cable (Figure 14-3). In general, cables in trays and ducts are not subjected to tensile forces; however, it must be kept in mind that in long vertical runs, the weight of the cable itself will create a tensile load of approximately 0.16 lb/ft (0.25 N/m) for simplex cable and 0.27 lb/ft (0.44 N/m) for

FIGURE 14-2
Corners and exit slots (Courtesy of
Canoga Data
Systems)

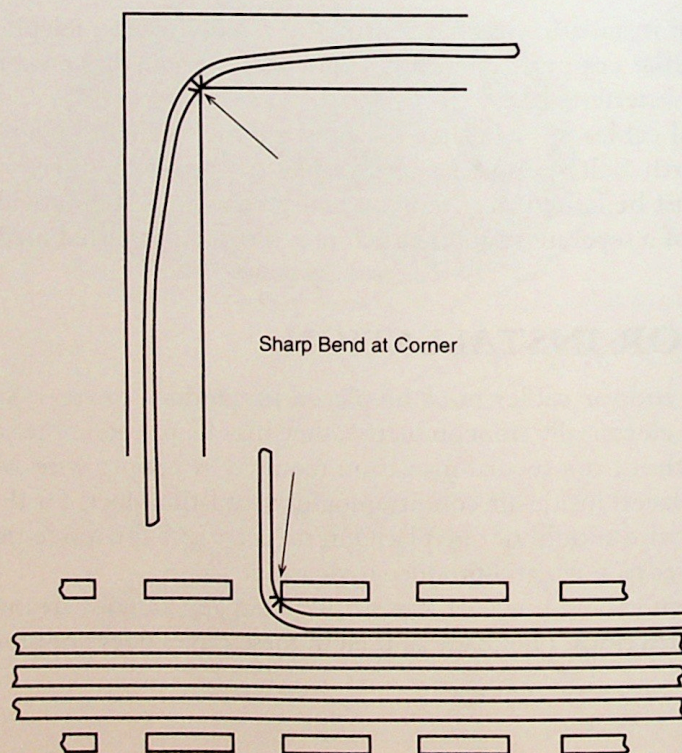
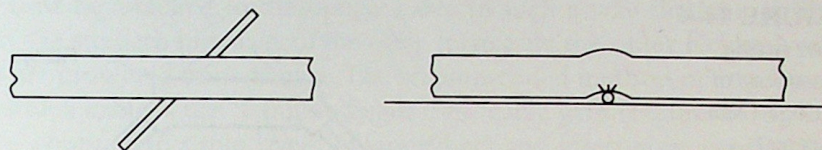


FIGURE 14-3

Crossovers
(Courtesy of
Canoga Data
Systems)



duplex cable. This tensile load must be considered when determining the minimum bend radius at the top of the vertical run. Long vertical runs should be clamped at intermediate points (preferably every 1 to 2 m) to prevent excessive tensile loading on the cable. The absolute maximum distance between clamping points is 330 ft (100 m) for duplex cable and 690 ft (210 m) for simplex cable. Clamping force should be no more than is necessary to prevent the possibility of slippage, and it is best determined experimentally since it is highly dependent on the type of clamping material used and the presence of surface contaminants, both on the clamp and on the jacket of the optical cable. Even so, the clamping force must not exceed 57 lb/in. (100 N/cm) and must be applied uniformly across the full-width of the cable. The clamping force should be applied over as long a length of the cable as practical, and the clamping surfaces should be made of a soft material, such as rubber or plastic.

Tensile load during vertical installation is reduced by beginning at the top and running the cable down.

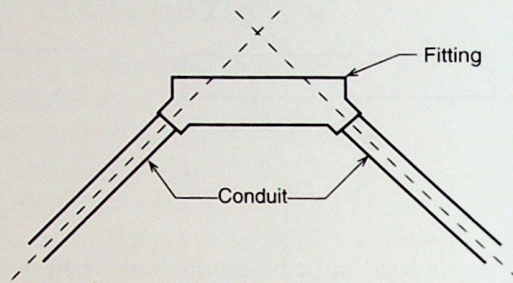
CONDUIT INSTALLATIONS

Fibers are pulled through conduits by a wire or synthetic rope attached to the cable. Any pulling forces must be applied to the cable strength members and not to the fiber. For cables without connectors, pull wire can be tied to Kevlar strength members, or a pulling grip can be taped to the cable jacket or sheath. More care, as discussed later in this chapter, must be exercised with cables with connectors.

The first factor that must be considered in determining the suitability of a conduit for a fiber-optic cable is the clearance between the walls of the conduit and other cables that may be present. Sufficient clearance must be available to allow the fiber-optic cable to be pulled through without excessive friction or binding, since the maximum pulling force that can be used is 90 lb (400 N). Since minimum bend radius increases with increasing pulling force, bends in the conduit itself and any fittings through which the cable must be pulled should not require the cable to make a bend with a radius of less than 5.9 in. (150 mm). Fittings, in particular, should be checked carefully to ensure that they will not cause the cable to make sharp bends or be pressed against corners. If the conduit must make a 90° turn, a fitting, such as shown in Figure 14-4, must be used to allow the cable to be pulled in a straight line and to avoid sharp bends in the cable.

FIGURE 14-4

Turn fitting
(Courtesy of
Canoga Data
Systems)



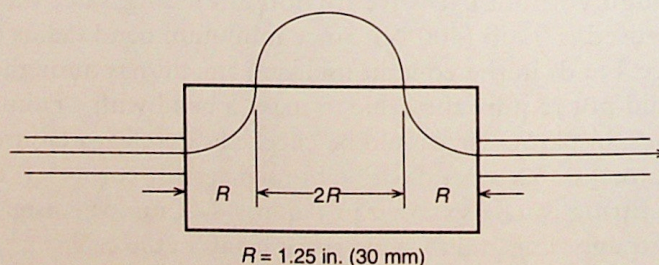
A pullbox is an access point in a conduit. Pullboxes should be used on straight runs at intervals of 250 to 300 ft to reduce the length of cable that must be pulled at any one time, thus reducing the pulling force. Also, pullboxes should be located in any area where the conduit makes several bends that total more than 180° . To guarantee that the cable will not be bent too tightly while pulling the slack into the pullbox, we must use a pullbox with an opening of a length equal to at least four times the minimum bend radius (4.75 in. or 120 mm). See Figure 14-5, which shows the shape of the cable as the last of the slack is pulled into the box. The tensile loading effect of vertical runs discussed in the section on tray and duct installations is also applicable to conduit installations. Since it is more difficult to properly clamp fiber-optic cables in a conduit than in a duct or tray, long vertical runs should be avoided, if possible. If a clamp is required, the best type is a fitting that grips the cable in a rubber ring. Also, the tensile load caused by the weight of the cable must be considered along with the pulling force to determine the maximum total tensile load being applied to the cable.

PULLING FIBER-OPTIC CABLES

Fiber-optic cables are pulled by using many of the same tools and techniques that are used in pulling wire cables. Departures from standard methods are due to several facts: The connectors are usually preinstalled on the cable, smaller pulling forces are allowed, and there are minimum bend radius requirements.

FIGURE 14-5

Pullbox dimensions
(Courtesy of
Canoga Data
Systems)



The pull tape must be attached to the optical cable in such a way that the pulling forces are applied to the strength members of the cable (primarily the outer Kevlar layer), and the connectors are protected from damage. The recommended method of attaching a pulling tape to a simplex cable is the "Chinese finger trap" cable grip (Figure 14-6). The connector should be wrapped in a thin layer of foam rubber and inserted in a stiff plastic sleeve for protection. Since the smallest pulling grip available (Kellems 0333-02-044) is designed for 0.25-in. (6.4-mm)-diameter cable and the outside of the simplex cable is only 0.188 in. (4.8 mm), the cable grip should be stretched tightly and then wrapped tightly with electrical tape to provide a firm grip on the cable.

The duplex cable is supplied with Kevlar strength members extending beyond the outer jacket to provide a means of attaching the pulling tape (Figure 14-7). The Kevlar layer is epoxied to the outer jacket and inner layers to prevent inducing twisting forces while the cable is being pulled, since the Kevlar is wrapped around the inner jackets in a helical pattern. The free ends of the Kevlar fibers are inserted into a loop at the end of the pulling tape and then epoxied back to themselves. The connectors are protected by foam rubber and heat-shrink sleeving. The heat-shrink sleeving is clamped in front of the steel ring in the pulling tape to prevent pushing the connectors back toward the rest of the cable.

During pulling of the cable, pulling force should be constantly monitored by a mechanical gauge. If any increase in pulling force is noticed, pulling should immediately cease, and the cause of the increase should be determined. If the pulling wire is subject to friction, the tensile force on the pulling wire will be more than the force applied to the fiber-optic cable, resulting in false readings.

Pull tension can be monitored by a running line tensiometer or a dynamometer and pulley arrangement. If a power winch is used to assist the pulling, a power capstan with adjustable slip clutch is recommended. The clutch, set for the maximum loading, will disengage if the set load is reached. Relying on the experience of those pulling the cable is another alternative.

If necessary during pulling-in, the cable should be continuously lubricated. The lubricant can be poured or brushed on the cable as it enters the duct or conduit. Alternatively, a slit lubrication bag can be pulled ahead of the cable so that the lubricant spills out during the pull. Lubrication should be used only for difficult pulls.

FIGURE 14-6
Simplex pulling grip (Courtesy of Canoga Data Systems)

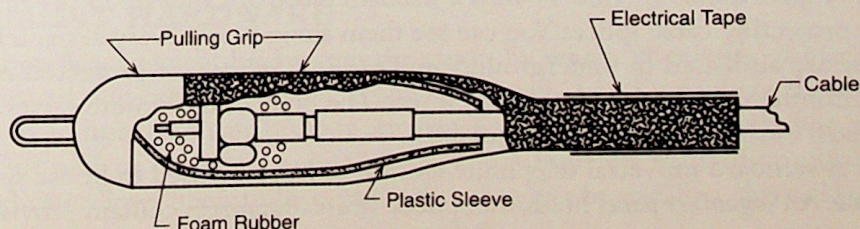
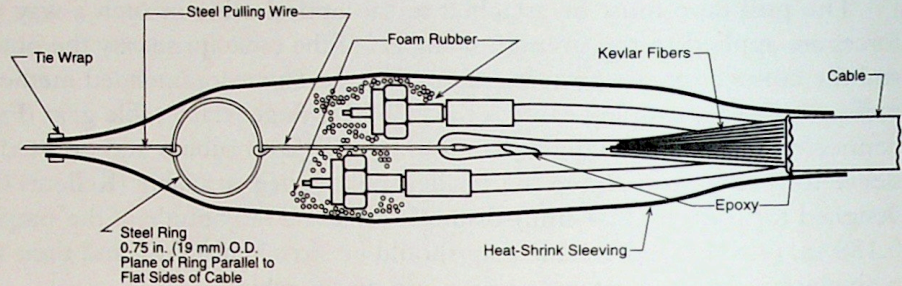


FIGURE 14-7
Duplex pulling
grip (Courtesy
of Canoga Data
Systems)



At points such as pullboxes and manholes, where the cable enters the conduit at an angle, a pulley or wheel should be used to ensure that the cable does not scrape against the end of the conduit or make sharp bends. If the portion of the cable passing over the wheel is under tension, the wheel should be at least 12 in. (300 mm) in diameter. If the cable is not under tension, the wheel should be at least 4 in. (100 mm) in diameter.

As the cable emerges from intermediate-point pullboxes, it should be coiled in a figure-8 pattern with loops at least 1 ft in diameter for simplex and duplex cable and proportionally larger diameters for larger cables. The figure-8 prevents tangling or kinking of the cable. When all the cable is coiled and the next pull is to be started, the figure-8 coil can be turned over and the cable paid out from the top. This will eliminate twisting of the cable. The amount of cable that has to be pulled at a pullbox can be reduced by starting the pull at a pullbox as close as possible to the center of the run. Cable can then be pulled from one spool at one end of the run; then the remainder of the cable can be unspooled and coiled in a figure-8 pattern and pulled to the other end of the run.

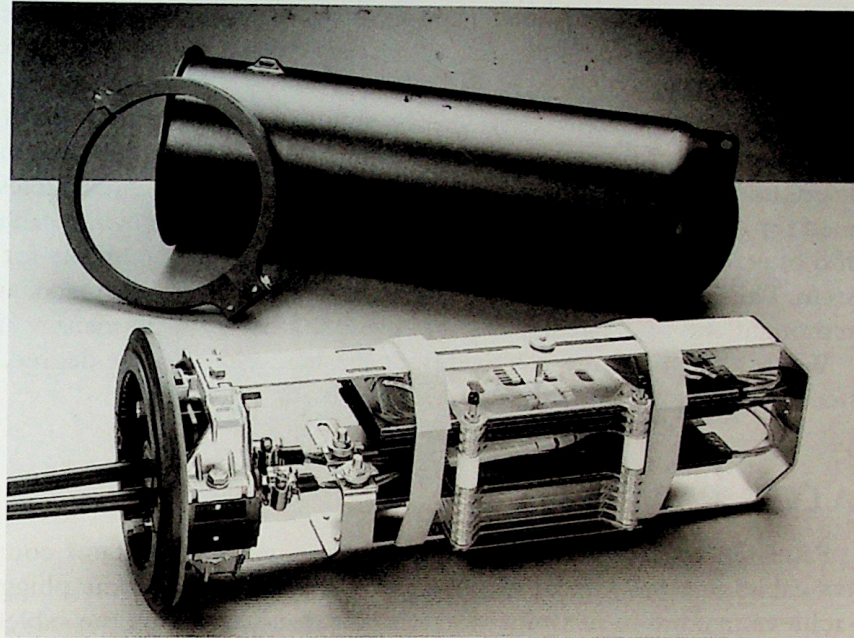
Bends in the pull should be near the beginning of the pull. Pull forces are lower if the conduit bend is near the beginning. Bends tend to multiply, rather than add, tension. For example, if a cable goes in at 20 lb, it may come out of the bend at 30 lb. If it goes in at 200 lb, it may come out at 300 lb. In the first instance, the bend added 10 lb; in the second it added 100 lb.

SPLICE CLOSURES/ORGANIZERS

A *splice closure* (Figure 14-8) is a standard piece of hardware in the telephone industry for protecting cable splices. You can see them along nearly every aerial telephone run, and they are also used in underground applications. Splices are protected mechanically and environmentally within the sealed closure. The body of the closure serves to join the outer sheaths of the two cables being joined.

A standard universal telephone closure can also be used to house spliced fiber-optic cable. An *organizer panel* holds the splices. Most organizers contain provisions for securing

FIGURE 14-8
Splice closure
(Photo courtesy
of Corning
Cable Systems)



cable strength members and for routing and securing fibers. Metal strength members may be grounded through the closure.

Organizers are specific to the splice they are designed to hold. In a typical application, the cable is removed to expose the fibers at the point they enter the closure. The length of fiber exposed is sufficient to loop it one or more times around the organizer. Such routing provides extra fiber for resplicing or rearrangement of splices.

Closures can hold one or more organizers to accommodate 12 to 144 splices.

Closures have two main applications. The first is a straight splicing of two cables when an installation span is longer than can be accommodated by a single cable. The second is to switch between types of cables for various reasons. For example, a 48-fiber cable can be brought into one end of the closure. Three 12-fiber cables, all going to different locations, can be spliced to the first cable and brought out the other end of the closure.

MANAGEMENT HARDWARE

Neatness counts. Management hardware is the means by which fiber-optic cables are routed, interconnected, and organized in a neat and manageable way. Once there are more than a few cables in an installation, unless they are managed neatly and efficiently you will end up with a rat's nest of cabling, a tangled mess, and a hopeless mass of confusion. Management hardware allows fibers to be organized so they can be installed correctly and

maintained efficiently. It is quite common for cables to be re-arranged as needs change. If you cannot identify the cables and where they are routed, you cannot properly maintain an installation.

Figure 14-9 shows examples of a fiber-optic installation in both an unmanaged and managed state. In the unmanaged state, cables are run directly between the input and output points, with no thought given to keeping things neat and tidy. Cables cannot be easily traced for identification, changing a cable might involve untangling cables, and the likelihood of error is high. In short, pity the poor technician responsible for maintaining the system. The managed version is obviously more coherent, organized, and installed with forethought and care. The payoff is an installation that is easy to manage and maintain.

While all installations have management hardware to some degree, in the successful system the hardware is properly installed and used.

PATCH PANELS

Patch panels are rather straightforward—panels that contains coupling adapters to allow cables to be plugged or unplugged. Most patch panels permit plugging on both sides to achieve maximum flexibility in arranging and rearranging the cables. Others provide cable management to keep the routing and placement of cable orderly. In practice, one side of the patch panel is “fixed” cable that is not intended to be rearranged. An example

FIGURE 14-9
(PART 1)

Neatness counts:
Management
hardware can be
the difference
between a
mess . . .

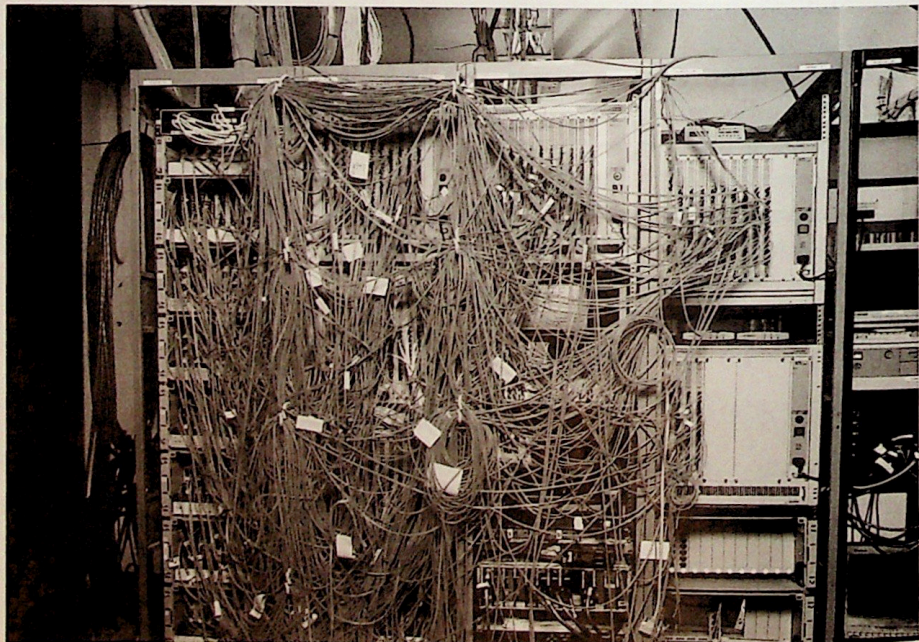
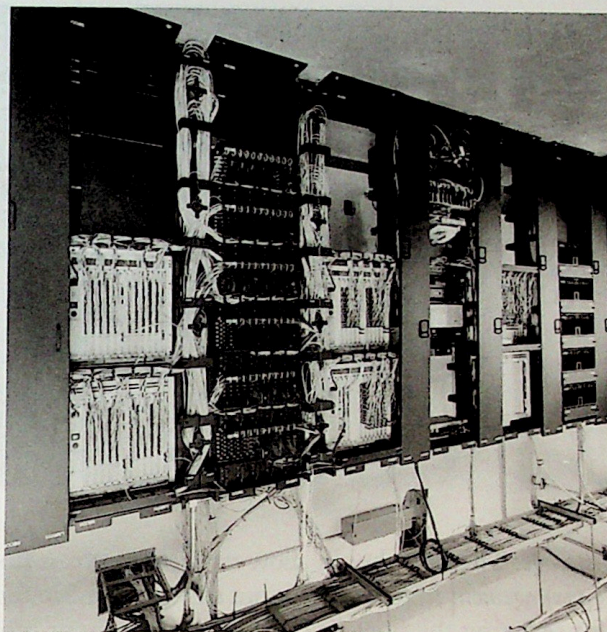


FIGURE 14-9
(PART 2)

... and a tidy,
manageable
installation
(Photos courtesy
of Corning
Cable Systems)



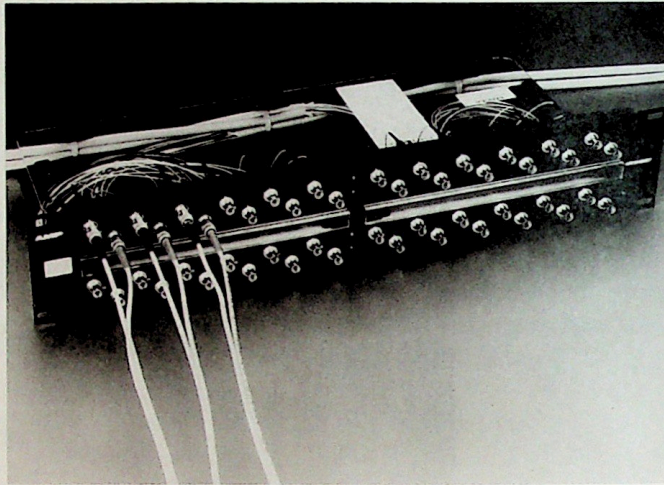
would be the behind-the-wall cables in a building network. These would run to the rear of the patch panel. Patch cable would then run between the patch panel and the equipment. By rearranging the patch cables, you can connect ports on the equipment to different cables in the building. Another use for a patch panel is to form a transition point between multifiber cables and duplex cables. A 72-fiber cable can connect to 72 separate adapters in the patch panel. Individual or duplex cables then connect to the front of the patch panel. Figure 14-10 shows a patch panel.

DISTRIBUTION/MANAGEMENT HARDWARE

Distribution units and enclosures are similar to patch panels, except they provide additional space to organize fiber. It's always a good idea to leave some extra fiber—this slack is then available if it becomes necessary to reterminate a connection. The distribution units provide an area to store the extra fiber in a large loop.

Distribution hardware comes in both rack-mount and wall-mount configurations, and in a variety of sizes to fit different applications needs. Large units will accommodate hundreds or thousand of fibers in large buildings or telecommunications centers, while smaller units meet more modest needs. Among features found in organizers are the following (the exact mix of features can vary with the specific hardware):

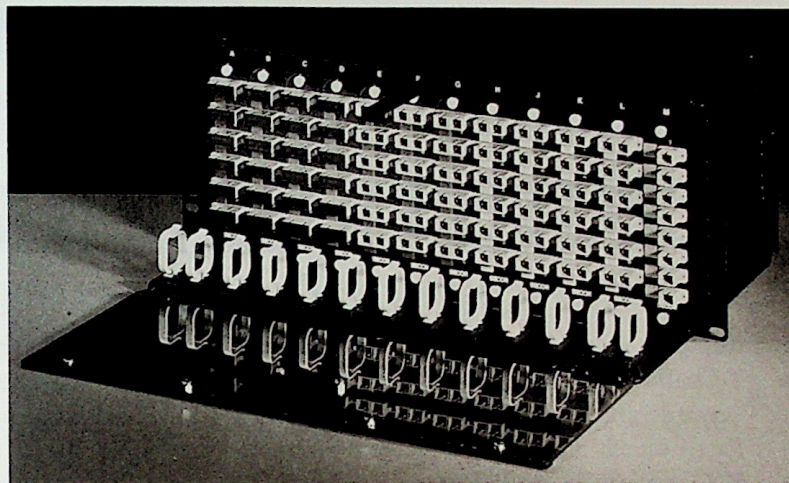
FIGURE 14-10
Patch panel
(Photo courtesy
of Tyco
Electronics)



- *Fiber storage:* The unit should allow storage for excess fiber.
- *Cable management features:* Provisions should be made for keeping loops neat and for securing the fiber or cable with tie wraps or other fasteners. Many enclosures have studs or other positioning features that the cable can be wrapped around neatly.
- *Fiber access:* The enclosure should allow multiple points of entry for fiber so that routing from outside to inside is convenient and flexible. The access points should guard against abrasion to the fiber jacket.
- *Protection:* Many units are fully enclosed to protect the fiber.
- *Human access:* How easy is it to gain access to the inside of the box for maintenance or other needs? Front and rear access is handy. Some hardware feature swing-out or pull-out access to patch panels or splices.
- *Security:* Is there a need to lock the box to prevent unauthorized access?
- *External cable routing and management:* Does the hardware support rings or other brackets to help route the cable? Again, such devices are important to keeping the installation neat and maintainable.
- *Labels:* The enclosure should allow all ports to be easily and clearly labeled. All cables and ports must be clearly identified so that the network can be documented. If nobody knows what connects to what, how is the system to be maintained?
- *Multimedia support:* Many installations must support both copper and fiber. Management hardware is available that allows both to be used.

Most management hardware mounts in a 19- or 23-inch-wide rack—standard widths in the telecommunications and electronics industry. Figure 14-11 shows a typical enclosure.

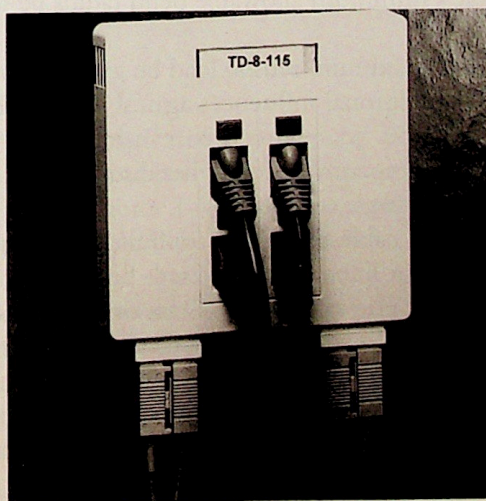
FIGURE 14-11
Management
distribution
hardware (Photo
Courtesy
of Corning
Cable Systems)



OUTLETS

You're familiar with the telephone jack in a home or office, used to plug in your telephone (or computer modem). Outlets are similarly available for fiber. Some, such as the one shown in Figure 14-12, provide a connection for both copper and fiber. In an office, there is often a need for many connections: telephone(s), fax, computer network, and so forth. The wall outlet provides the transition between the building cable and the office

FIGURE 14-12
Outlets allow
users to plug into
fiber (or copper)
systems (Photo
courtesy of Tyco
Electronics)



cabling. Interfaces are available in almost every conceivable style. Almost every variation of outlet devised for copper telephone/network cabling has also been adapted to accept fiber connections as well.

SUMMARY

- The two most important concerns in installing a fiber-optic cable are minimum bend radius and maximum tensile load.
- Cables can be buried, strung aerially, or placed in trays and conduits.
- Closure/organizers are used to organize and protect spliced cable.
- Distribution boxes provide protection and organization for fibers and allow versatile and flexible distribution of fibers as application demands.
- Patch panels allow pluggable, rearrangeable interconnection of fibers.
- Wall outlets are similar to electrical outlets in that they allow equipment to be plugged into building wiring.



Review Questions

1. What are the two most important factors to be considered when installing a cable?
2. Will a cable's minimum allowable bend radius be less during the installation or after?
3. Will a cable's maximum tensile load be greater during the installation or after?
4. Name three additional influences against which a buried cable must be protected.
5. In an intrabuilding application, what distinguishes an ordinary duplex cable from a plenum duplex cable?
6. When pulling a cable through a conduit, to what part must the pulling forces be applied?
7. Why is a fiber-optic rack either 19 in. or 23 in. wide?
8. What type of hardware allows connection between intrabuilding cable and drop cables from equipment?
9. What distinguishes a patch panel from a distribution box for splices?
10. If the total length of an application is twice the distance that can be achieved in a single pull, where is the best place to begin?

chapter fifteen

FIBER-OPTIC SYSTEMS: NETWORK AND PREMISES APPLICATIONS

As we turn to applications of fiber optics and optical communications, our main focus is the network and telecom markets. While fiber optics find use in other applications ranging from automobiles and aircraft to home entertainment systems and factories, networks and communications are by far the largest market segments.

We are going to spend a fair amount of time discussing Ethernet, a widely popular network. While our discussion of Ethernet will take us away from optical communications a bit, the detour is worthwhile to help demonstrate some issues involved with networking. By seeing how frames and packets are made, how networks are structured, and how Ethernet's components fit into the larger scheme of things, you will have a better sense of the role of fiber optics in network communications.

LANs AND WANs

A local area network (LAN) is a sophisticated arrangement of hardware and software that allows stations to be interconnected and pass information among them. Most business computers are connected to a LAN, and home LANs are becoming popular as many families have more than one computer. LANs allow users to access information, send and receive e-mail, pass files back and forth, and share resources such as printers, fax machines, servers, storage, and Internet access. In general, a LAN is a network of computers in a limited geographical area, such an office, building, or group of buildings. Individuals can also be connected over a wide area network (WAN). A large company with offices spread all over the country (or even the world) can connect a number of LANs through WAN links. Most WAN connections, however, are through the public telecommunications system or private service providers.

Technician's Guide to Fiber Optics

4th Edition

Sterling

An excellent primer, this current edition provides a practical, real-world perspective on the fundamentals of fiber optic technology and optical communications. It examines the reasons that optical fibers are the preferred communications medium, surpassing copper wire in many performance measures. A thorough explanation of how fibers work is provided, as well as useful coverage of other related optical components and how those components fit into system-level applications. Premises (LAN), metro, 10G Ethernet, and long-haul applications are all surveyed.

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- Real-world examples bridge the gap between the theory of fiber and its applications in communications.

"I am impressed by the breadth of this textbook and by the ability of the author to explain complicated concepts in terms that can be easily understood by the average beginner."

-Hikmat Chedid, Associate Professor of Electronics and Computer Systems, Lorain County Community College

About the Author:

Donald J. Sterling, Jr., has over 25 years of experience as a technical and ad copywriter in the areas of electronics and high technology. He has worked with AMP, Lucent Technologies, Agere Systems, ExceLight Communications, and other leaders in optical communications.

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