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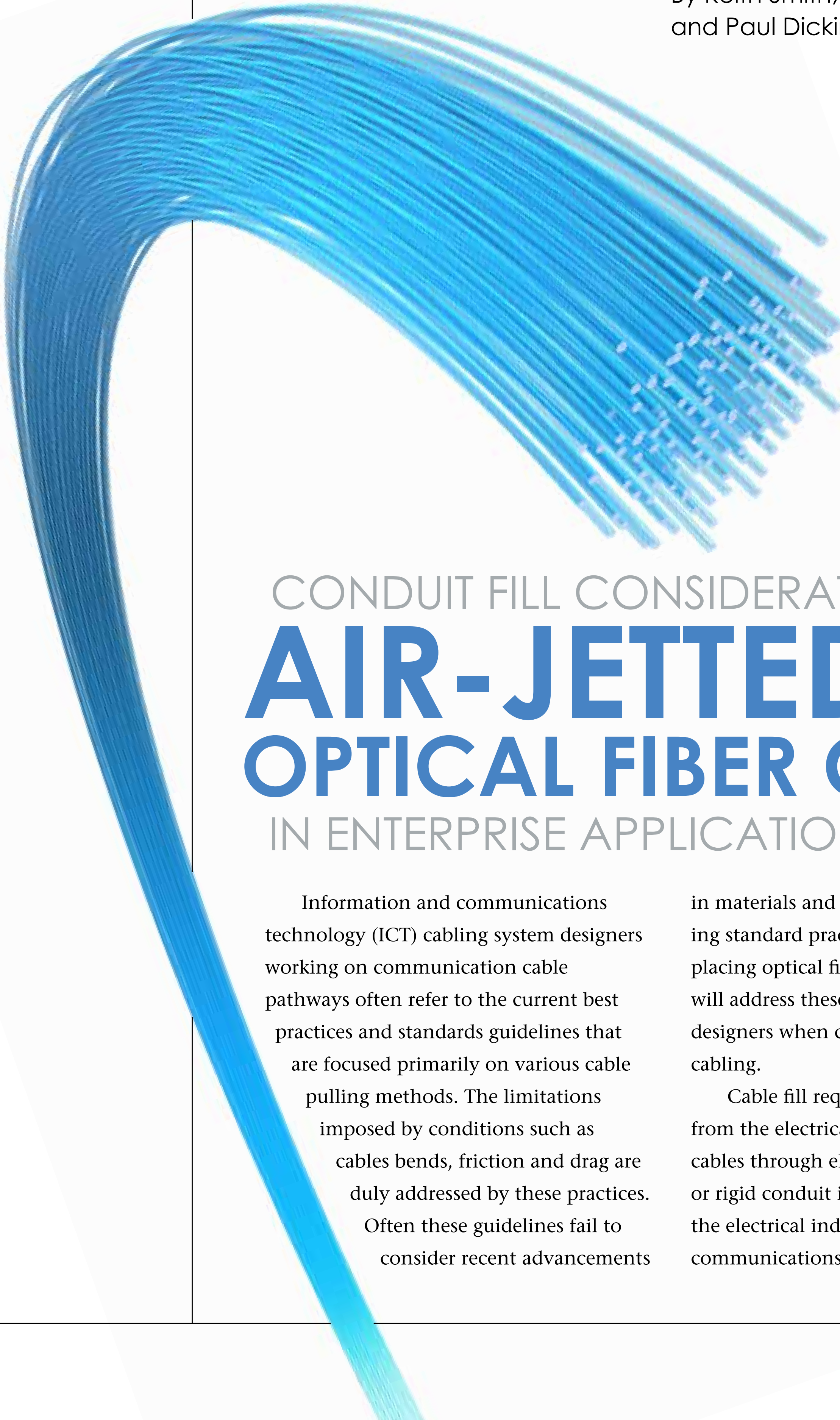


CONDUIT FILL CONSIDERATIONS FOR AIR-JETTED OPTICAL FIBER CABLE IN ENTERPRISE APPLICATIONS

Information and communications technology (ICT) cabling system designers working on communication cable pathways often refer to the current best practices and standards guidelines that are focused primarily on various cable pulling methods. The limitations imposed by conditions such as cables bends, friction and drag are duly addressed by these practices. Often these guidelines fail to consider recent advancements in materials and methods that are becoming standard practice when applied to placing optical fiber cables. This article will address these advancements and aid designers when considering air-jetted cabling.

Cable fill requirements were derived from the electrical industry. Pulling copper cables through electrical metallic tubing or rigid conduit is still the standard in the electrical industry. Today, however, communications cables include optical

THE MICRO CONFIGURATION OF THESE FIBER BUNDLES AND CABLES AND MICRO PATHWAYS REQUIRE MUCH LESS AREA WHILE MAXIMIZING THE FIBER DENSITY CAPABILITIES, SETTING THE STAGE FOR FIBER-ON-DEMAND.

fiber cables that are designed to be blown (jetted) into high-density polyethylene (HDPE), riser or plenum-rated flexible conduits. The current best practices and standards perhaps need to incorporate the increasing use of this type of fiber cable and the corresponding development of these newer products and methods.

This article explains the methods that evolved in the outside plant (OSP) industry when optical fiber cables began to be installed, and the parallels that can be applied to installing optical fiber in buildings today.

FIGURE 1: Jetting microcable into microduct in an OSP environment.

CABLE PULLING TENSIONS

Methods for calculating cable pulling tensions were developed in the mid-1980s by the Electric Power Research Institute (EPRI). Its mission was to develop tools that could be used for calculating cable pulling tensions based on the system layout as it was being designed. Pulling tensions could not exceed cable tensional strength. This was at a time when a growing percentage of cables were being placed underground and new trenchless installation methods, such as horizontal directional drilling (HDD) and chute and pull plowing, were gaining wider usage. Designers needed tools to determine spacing of access points for splicing, switching and terminating the cables.

With the advent of optical fiber cables, the industry quickly recognized that the tools and methods that were being used with copper and aluminum cables might not apply. Although these optical fiber cables were designed with a 600 pound (lb) pull strength and EPRI's tools could be applied if the optical fiber cable was being pulled in, it was discovered that these lighter optical fiber cables could be blown or jetted into the OSP environment (Figure 1). Practices regarding space and tension were no longer relevant.

The concept of blowing fiber cables has been around for some time. British Telecom Research developed the air-blown process in 1984. Using compressed air, three or four bundled optical fibers in a polyethylene jacket were blown into small-diameter microducts to distances exceeding 2 kilometers (6500 feet). Further experimentation with small-diameter, non-cabled optical fiber or fiber bundles proved that the principle of fluid mechanics (i.e., molecules traveling fastest along the walls create a high-pressure area forcing the coated fiber to the center of the tube) allowed the optical fiber to be carried along this blanket of air through the tube with minimal contact with the tube wall, as long as the minimum bend diameter was maintained.

Others utilized this jetting concept to install single and multiple optical fibers into microducts or tube cables (bundled pathways). It was first used commercially in Europe and later in Japan. British Telecom held the master license and leased it to a few companies. Cable jetting is now understood to be the process of blowing a cable through a duct by means of a high-speed air flow (viscous drag method) while simultaneously pushing the cable by means of drive wheels or tractor belts.

Also called the push-jet method, this became the standard method of installing optical fiber cables over long distances in the OSP environment. The advantages of this method include:

- Longer installation distances.
- Less dependence on the duct route geometry (e.g., bends, turns) in determining installation distance.
- Less stress on the fiber/cable.
- Elimination of pull rope/tape.
- Fewer equipment movements (staging).
- The ability to jet fiber cables over existing innerducts.
- Availability of more space.

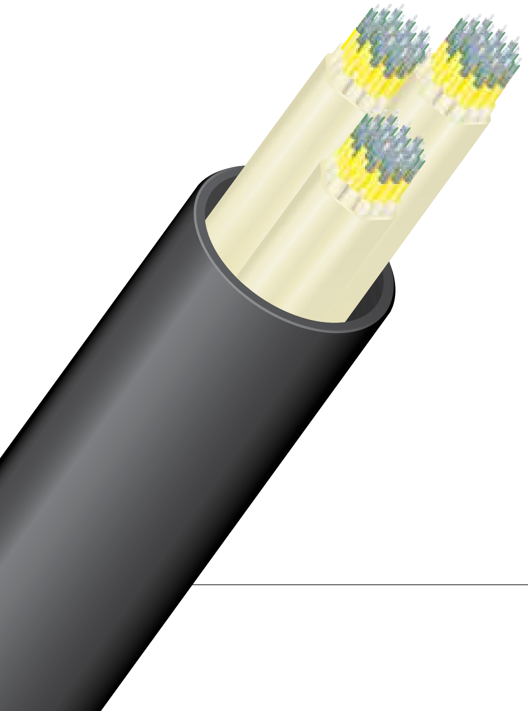
CALCULATING FILL RATIO

The method of calculating fill ratio can vary between standards and manufacturers suggested methods. The methodology in many standards, including the 40 percent fill metric, is calculated using cross-sectional area. This will show lower numbers than the way it is typically calculated in practice.

For instance, consider a 10 millimeter (mm) microduct ID and 7.5 mm cable. A formula that uses diameter divided by pathway ID results in a 75 percent fill ratio. However, the result is different using cross-sectional dimensions, such as 3.14 x 5 mm radius (squared) = 78 mm^2 for area of the conduit and 44 mm^2 for area of the cable. Dividing the area of the cable by the area of the duct results in a 56 percent fill ratio. This use of cross-sectional area to calculate fill results in the appearance of a lower fill, when in reality there is the same amount of space available for airflow using either calculation. Because airflow is an important parameter for jetting cables, this is critical.

But as mentioned, more space is available with the practice of blowing and jetting, maximizing what little free space is available in already dense areas. This newfound space can be used as a cost-effective alternative to installing new conduit and innerduct systems. The micro-configuration of these fiber bundles and cables and micro pathways require much less area while maximizing the fiber density capabilities, setting the stage for fiber-on-demand, allowing a defrayed cost scenario for maximum network implementation and utilization. Even for newer conduit systems, the high-density pathway bundles make it possible to have extremely high fiber density well beyond the current conventional optical fiber cable fill capacities. For example, it is possible to utilize 3 x 19-cell pathway bundles into a 100 mm (4 in) conduit, and subsequently install 57 x 72-strand micro cables (one in each microduct) to provide up to 4,104 optical fibers (Figure 2).

FIGURE 2: 4-in main conduit filled with bundled microducts providing 57 pathways, each filled with a 72-strand microcable.



A method that was invented and intended to be used for very small fiber cables in very small tubes was eventually adopted by the OSP industry. Today, it is becoming more common to place microfiber cables in buildings. The materials and methods originally designed for the inside plant (ISP) environment are finally being adopted. Why so late? It has taken some time for materials to catch up with the placing technologies.

THE NEW MATERIALS

Current best practices and requirements do not fully recognize the benefits of newer materials that have become the standard in the OSP and the variations of these materials that are available for use inside a building.

HDPE conduit is the standard for OSP construction builds where long, continual pathways are desired. Typically shipped on long-length reels, HDPE conduit enables installations that can be open trenched, horizontally directional drilled, and plowed in or pulled into existing conduit. Where necessary, HDPE conduit may be connected using mechanical coupling systems or butt-fused to provide an airtight, watertight pathway. Its design does not require pre-formed bends or joints and gluing up short lengths, as required with polyvinyl chloride (PVC). HDPE in OSP is used in conjunction with both optical fiber and electrical cables. For optical fiber installations in the OSP, HDPE is the standard.

There are also excellent materials available for the ISP environment. Specially compounded polyethylene microduct conduits are available in riser-rated and low smoke, halogen-free versions, and PVC or fluoropolymer material is used for plenum applications. Riser- and plenum-rated duct materials are

THE USE OF MICRODUCTS MORE EFFECTIVELY SUBDIVIDES THE EXISTING SPACE INTO FUNCTIONAL UNITS FOR HIGH-DENSITY DEPLOYMENT.

required in ISP environments where fire rating is nearly always required. These products can be substituted for galvanized steel pipe or conventional PVC. As in the OSP environment, use of continuous length coils or reels of riser, plenum or low smoke zero halogen microduct materials eliminates the time and costs associated with bending, forming, threading and joining the shorter sections of galvanized steel pipe and PVC.

Both riser-rated and plenum-rated microducts must comply with the applicable requirements of UL 2024, *Standard for Safety for Optical Fiber and Communication Cable Raceway*. Riser-rated microducts must comply with UL 1666, *Standard for Test for Flame Propagation Height of Electrical and Optical Fiber Cables Installed Vertically in Shaft*. Plenum-rated microducts must comply with NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces* (Edition 2011). Fire-retardant microducts must be tested to the UL Standard by an approved testing facility and printed with the approval number and fire rating every two feet. Riser-rated microducts must be V-2 rated, and plenum microducts shall be V-0 rated per UL 2024. In addition to individual microducts, bundled riser and plenum versions are available, typically from 2 to 24 individual tubes. When required, low-smoke and halogen-free microducts are available, and these are generally installed in tunnel systems such as trains or roadway tunnels. These must meet the requirements of UL 1685, *Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*. Other standards governing halogen free conduits include IEC 60754-1, *Test on gases evolved during combustion of materials from cables - Part 1: Determination of the halogen acid gas content*.

Specialty riser- and plenum-rated microducts are only part of the latest technology for placing optical fiber inside and between buildings. Microfiber cables, originally used in Europe, are now being deployed in OSP between buildings in the United States (Figure 3). They are smaller than traditional OSP cables, sometimes by half, and are available with fiber counts of 144, 192, 288 and 432. These cables have identical glass strands to the standard full-size cables and therefore can be easily spliced together. All microfiber cables are designed to be jetted or blown in and can be pulled in short distances.

Microfiber cables and microducts are shipped on smaller and lighter reels. Shipping costs, labor requirements and reel-handling equipment and essentials are reduced. Because of the reduced diameter cables involved, bend radii are tighter and storage requirements reduced, such as in the case of handholes or cabinets needed for storage of slack optical fiber cables. The outer sheaths and buffer tube walls of microfiber cables are thinner than those in traditional cables. This means that the prep process is more craft sensitive, and there are some differences with cable prep and fiber access. Applicable

FIGURE 3: 4-in main conduit divided into 60 bidirectional pathways with bundled microducts.

standards governing microfiber cables include Telcordia GR-20-CORE, *Generic Requirements for Optical Fiber and Optical Fiber Cable*, Issue 4, ANSI/ICEA S-87-640, *Standard for Optical Fiber Outside Plant Communications Cable,* and TIA/EIA 455 (IEC60794).

The use of microfiber cables can enable deployment in spaces where placement of larger cables may have been impossible. Empty or partially filled ducts are valuable resources: space is limited and expensive, and alternative pathways such as sewers and gas and water pipes can offer new paths to provide telecom services. Microfiber cables can be used in "build as you grow" networks, enabling the service provider to add capacity in increments and higher numbers of fibers in smaller spaces. This provides a structured cabling system that is often more scalable, flexible and economical than the conventional cabling approach.

There have also been significant advances in the optical fiber bundles used for ISP microduct structured cabling solutions. Prior generations for ISP used in Europe, and to a lesser degree in North America, focused on low fiber counts, fiber bundles (rather than jacketed cables) and fire ratings for the duct/fiber system rather than independent ratings for both duct and fiber.

Newer technologies appear to bridge the gap between earlier blown fiber unit technology and that of conventional cable structured cabling solutions most familiar in the North American market. Features previously only available in conventional cable products, such as fast MTP termination capable ribbon fiber, are also being offered for the ISP environment with fiber counts per cable of as high as 72. Advances such as these will increase adoption of ISP jetted cable technology in key markets including health care, higher education and the federal space where robustness, high capacity and scalability are extremely important.

In addition to microducts and microfiber cables, there is a need for specialty equipment to assist in jetting the cables into the microduct. This equipment also has improved over time and become miniaturized, designed to be handheld when used to install fiber in buildings. Even the jetting engines for the newer generation of ISP microcables, as described above, can be carried in containers as small as a suitcase for installation.

EVOLUTION OF BEST PRACTICES AND REQUIREMENTS

Current best practices and requirements are accurate for pulling in copper communication and conventional fiber optic cables but do not accommodate the development of new materials and methods associated with microducts, microfiber cables, blowing and jetting methods and placing equipment. Additionally, real-world practices demand deviation. It is well recognized that optical fiber enables orders of magnitude higher bandwidth in the same cable space relative to copper. But perhaps not as widely appreciated is that air jetted optical fiber cables provide yet another advantage over both copper and conventionally installed optical cables: scalability and even higher density with existing duct space. The use of microducts more effectively subdivides the existing space into functional units for high-density deployment.

In the majority of installations, if the materials placed within pathways are mostly cables (copper communications and electrical or optical fibers), the guidelines provide a cushion for protection, installation and expansion. That being said, the rules change as soon as the design is completed and initial installation has been accomplished. As the need for expansion begins to occur, the industry requirements and best practices do not offer a solution. Manufacturer-specific solutions using the newest materials and methods have the potential to bring substantial savings in the installation of fiber in buildings.

Multi-cell pathways provide a new technology for both OSP and ISP that can solve the ever-increasing density issue not covered by older standards. Maximum density can be achieved by subdividing standard four-inch conduits into as many as 60 bi-directional pathways (Figure 3).

The combination of bundled microduct pathways with newer air-blown cable technology offers advantages including:

- The ability to defer costs of higher fiber counts (due to unknown future needs) to a time when more fiber is needed.
- Much improved innerduct efficiency, increasing the count of overall cells or innerducts.
- A more efficient way to override existing cables into a congested conduit.
- Elimination of fiber splices as only the pathway transitions between environments (OSP, riser and plenum).
- OSP, riser and plenum versions to conquer fill ratios in both the ISP enterprise and OSP environments.
- 30-50 percent manpower reduction for the initial install.
- Reduction in the combined cost of materials and labor by as much as 50 percent.
- Elimination of disruptive access issues by allowing long pathways to be used without the need to shut down adjacent operations.

SUMMARY

Best practices and requirements for communications cable pathways need to continue to evolve over time to accommodate new technologies, such as multi-cell pathways and jetted fiber optic cable. The benefits of bundled microduct in conjunction with microcable include the ability to place more optical fiber in the space provided and can enable deployment in spaces where placement of larger cables may not be possible. Empty or partially filled ducts are valuable resources - space is at a premium, limited and expensive. Microfiber cables can be used to enable "build as you grow" networks, allowing the enterprise owner or service provider to add capacity in increments if desired and higher numbers of fibers in smaller spaces. If installing copper communication cables and conventional optical fiber cables, the current best practices and standards should still be followed; but for installation efficiency and lower total installed cost of optical fiber, designers should familiarize themselves with blowing or jetting micro-technology and the associated conduit products. ◀

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