A PRACTICAL METHOD FOR INSTALLATION OF OPTICAL FIBER CABLE IN METROPOLITAN AREA GAS DISTRIBUTION AND SERVICE PIPELINES

Scott Beals
Vice President, Technology
Sempra Fiber Links, Inc.
San Diego, California 92101
sbeals@sempra.com

1. INTRODUCTION

The FIG$_{sm}$ technology provides a safe, effective and economic means to use gas utility distribution mains and service lines for deployment of fiber-optic cable in metropolitan areas. This method has been used recently to install approximately two and one half kilometers of fiber optic conduit inside gas lines in North Carolina and one and one half kilometers in both Fort Worth, Texas and Long Beach, California.

A description of the technology, its application and potential use by telecommunication companies and natural gas utilities is discussed below.

1.1 Gas Utility and Telecommunications Market Convergence

The demand for broadband communications grew at an astounding rate in the mid- to late-1990's as technology and new applications rapidly evolved in response to opportunities created by emergence of the internet and the world wide web. At the same time, this increasing communications demand was further stimulated by creation of a competitive telecommunications market via passage of the Federal 1996 Telecommunications Act. The market response to this unprecedented bandwidth demand was installation of optical fiber infrastructure -- the only medium with enough bandwidth to carry the enormous amount of information required.

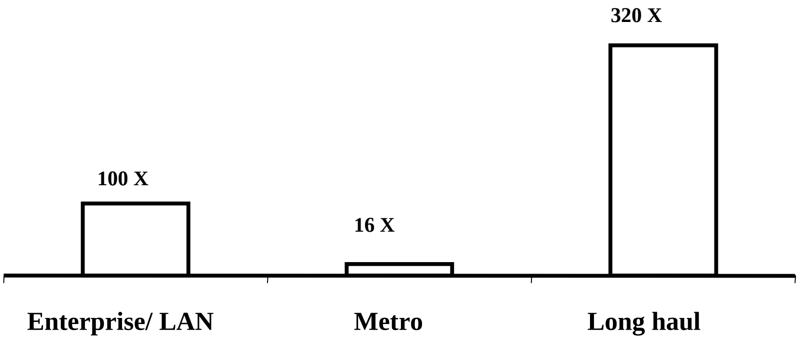

Figure 1: Relative Bandwidth Capacity Increases (1995 - 2000) [1]

The initial expansion of telecommunications focused on deploying long-haul fiber to connect cities and major communications hubs within cities. (See Figure 1, below.) In many cases, electric utilities and regional gas pipeline companies participated in this expanding business opportunity through their existing fiber assets and rights-of-way. For the most part, local gas utilities could not play a part in the fiber boom because their assets were localized within cities and did not connect major hub points between cities. Moreover, a technical means to use their pipeline assets as optical fiber carriers was not readily available.

However, by the year 2000, most of the long-haul fiber routes were filled with enormous amounts of fiber capacity -- most of which was "un-lit" -- and the market turned to the truly difficult and costly task of deploying broadband to end-use customers. This market drive to connect customers in effect was the key to using the enormous excess fiber capacity available connecting cities and became known as the "last mile" challenge. (See Figure 2, below.)

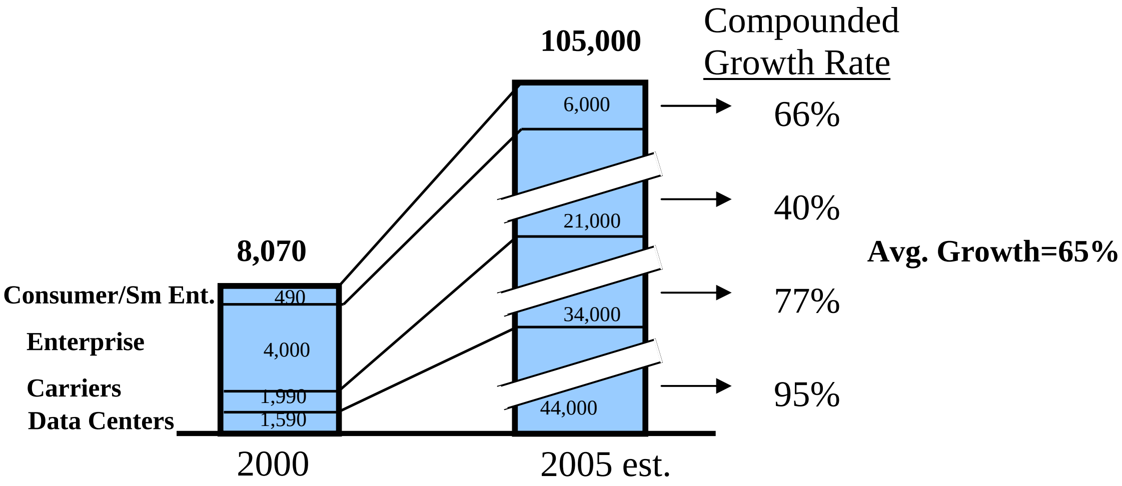

Figure 2: Future Metro Data Traffic Growth [2] (OC-48 Equivalents; one OC-48 = 39,000 voice channels)

Because of the enormous expense of connecting literally millions of buildings and customers, telecommunication companies -- especially new entrants into the newly competitive market -- began aggressively exploring use of existing infrastructure and rights-of-ways. At this point, it became evident that gas utilities, with their gas distribution and service lines providing the potential means for widespread connections within cities, could play an important role in solving the last mile connectivity problem.

1.2. The "Last Mile" Challenge

Because the demand to serve the market for broadband communications is large and growing, technology companies are working aggressively to provide connectivity solutions. Potential solutions range from traditional wireless technology, to power-line carrier options, to infrared and free-space optical solutions. While there is likely a role for all these technologies, each has deployment limitations and none have the potential bandwidth capacity of optical fiber.

Optical fiber, while being the ultimate solution in most cases, is often difficult and costly to install. Because of this, and in spite of tremendous pressure to utilize the existing long-haul bandwidth capacity by connecting the last mile, metro fiber deployment has been remarkably slow. This is illustrated by the fact that, while 35 to 45 percent of commercial buildings are located within three quarters of a mile of a fiber ring, fiber is connected only to about:

- ❑ 2% of the 1.6 million commercial buildings in the U.S. [3];
- ❑ 8% - 10% of major downtown area office buildings [4].

Unacceptable project economics have been the major reason why last mile fiber connections occur in only a small percentage of potential applications. In long-haul installations, fiber can often be installed by plow-in or aerial methods for as low as USD $25 thousand per kilometer [5]. However, in last mile metro applications where concrete or asphalt must be broken, the costs range from USD $120 - $450 thousand per kilometer, and can range up to USD $650,000 per kilometer or more in particularly difficult locations [6]. Furthermore, the cost to connect from the fiber ring to the building adds another USD $30 to $60 thousand per connection depending on difficulty of construction and right-of-way costs [7]. And, except for the largest customers, communications revenues are generally not sufficient to justify the fiber connection costs.

When environmental problems, public nuisance and deterioration of public rights-of-ways caused by tearing up streets are added the high construction costs, it is no wonder that telecommunication companies are hesitant to commit capital to last mile deployment. These problems are exacerbated by the incumbent telecommunication companies' reluctance to strand their existing copper plant investment by upgrading to optical fiber.

The solution to use active gas pipelines as the carrier for optical fibers solves many of the problems described for last mile connectivity. Not only are gas distribution mains and service lines widespread in metro areas where fiber connectivity is needed, but these are also the very areas where alternative construction costs are relatively high.

2. DISCUSSION

2.1 Sempra Fiber Links Fiber-In-Gas (FIGSM) Technology

2.1.1. Overview

Sempra Fiber Links has developed patent-pending technology for installation of optical fiber in gas main and service pipelines operating at 414 kPa gauge pressure or less. The technology can be used in any pipelines that meet these criteria, but the highest economic value is realized in metropolitan area installations where required customer connections are relatively frequent and boring and/or open trenching through concrete, asphalt or other difficult terrain is the alternative. Compared to these conventional installation methods, FIG$_{sm}$ can reduce construction costs by 50 to 70 percent.

Two distinct technologies are employed, depending on whether the application is in gas distribution main lines or gas service lines. Regardless of application, a polyethylene conduit that houses the fiber-optic cable is placed in the pipeline. The conduit size chosen depends on several factors, including the amount of available capacity in the pipeline and the number of fibers required. (See Table 1 below.)

Pipeline Size (mm)	PE Conduit Size, OD/ID (mm)	Max. Cable Fiber Count
20	6.3/3.1	12
25 - 35	6.3/3.2	12
	9.5/6.3	48
50 - 75	9.5/6.3	48
	16/11.3	144
100	16/11.3	144
	28/23	576
> 100	28/23	576

Table 1: Maximum fiber count installation for given pipe and conduit size

For service lines smaller than 20 mm in diameter, fittings that allow a direct cable insertion into the pipe are currently under development.

2.1.2. Installing Fiber Optics in Gas Distribution Main Lines

Figure 3 is a simplified schematic of the FIG_{sm} installation in gas mains. A polyethylene conduit is installed inside the main pipeline through a modified hot-tap access fitting under normal pipeline operating conditions. After the conduit is placed into the pipe and permanent seals applied, the fiber-optic cable is placed inside the conduit from hand hole locations by way of standard cable jetting or pulling techniques. After the cable is placed, a secondary, gas-tight seal is applied to the conduit-to-cable interface inside the hand hole. Although the conduit is not a gas-carrying duct, the secondary seal is applied to keep the gas from migrating into the hand hole in the event the gas pipe and conduit is breached as may happen with third-party damage.

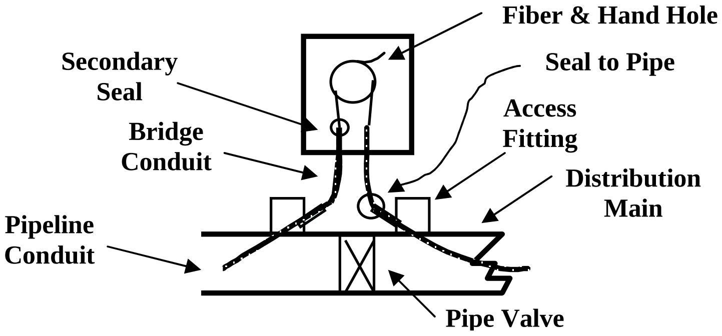

Figure 3: Diagram of FIG_{sm} Distribution Main Technology

2.1.3. FIG_{sm} Fittings and Installation.

FIG_{sm} fittings (See Figure 4) were developed for use on steel, polyethylene and cast iron pipes. The basic conduit placement process for each pipe type is nearly identical, with differences primarily in the fitting material and method of attachment to the pipeline. For steel pipe applications, a standard Mueller or T.D. Williamson hot-tap fitting is shop-modified by welding on an access side-arm port. The fitting is attached via standard welding techniques and then tapped using standard Mueller or T.D. Williamson equipment. After the pipeline is tapped, the conduit is inserted into the pipe through the access side-arm port. Specially designed seals in the side-arm port prevent gas from escaping while the conduit is inserted.

Steel Pipe **Cast Iron Pipe** **Polyethylene Pipe**

Figure 4: Three types of FIG_{sm} Main Access

Once the conduit is placed, a final seal is attached between the conduit and access fitting. The seal employed is a standard service head adapter fitting of the type used for years by the natural gas industry with a long record of documented performance.

On polyethylene pipes, a custom branch-saddle fitting manufactured by Uponor Aldyl Co. for Sempra Fiber Links is used for pipeline access. For cast iron pipes, a Dresser Split Sleeve full-encirclement clamp or equivalent is used with the $\mathrm{FIG}_{\mathrm{sm}}$ steel access fitting attached. In both cases, the same service head adapter mentioned above is used for the final seal to the pipeline.

2.1.4. Conduit Placement Process

The $\mathrm{FIG}_{\mathrm{sm}}$ process employs a standard polyethylene gas distribution pipe as a fiber-optic cable conduit. (In the U.S.A., this type of pipe complies with ASTM D-2513 requirements.) The conduit is inserted into the fully pressurized gas pipe through commercially available “hot-tap” fittings customized for this application and shown in Figure 4 above. Several methods are used to place the conduit depending on pipe diameter and distance between entry and exit points. For shorter distances -- up to 100 meters -- the conduit can be directly inserted into the pipeline using the tractor feature on standard cable jetting machines (see Figure 5). For placement distances up to 450 meters, a standard Power Rod machine is used to insert a metal rod to the conduit entry location at which point the conduit is attached to the rod and retracted through and out the pipe (See Figure 6). Additional methods are currently under development to enable longer placement distances.

Figure 5: Direct conduit insertion using a cable jet tractor

Figure 6: Conduit placement using a standard Power Rod machine

In the direct conduit placement method, a proprietary pressure-lock housing and manipulation device developed by Sempra Fiber Links is used to locate and connect the conduit to an extraction tool at the exit fitting. (See Figure 7.) Once this is achieved, the conduit is pulled out of the pipeline through the access fitting side-arm port. In the Power Rod method, the same tools are used to connect the conduit to the rod, which is then extracted from the pipe.

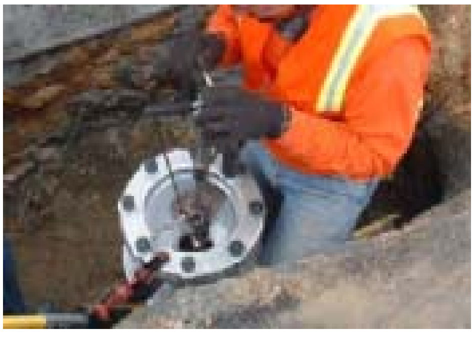

Figure 7: Pressure lock housing and manipulator being used to connect rod to conduit

2.1.5. Installing Fiber Optics in Gas Service Lines

The FIG$_{sm}$ service line technology is used to economically connect individual buildings to a fiber access ring by use of the gas service line. This technology can be used independently or in conjunction with the FIG$_{sm}$ Distribution Main technology. (See Figure 8.)

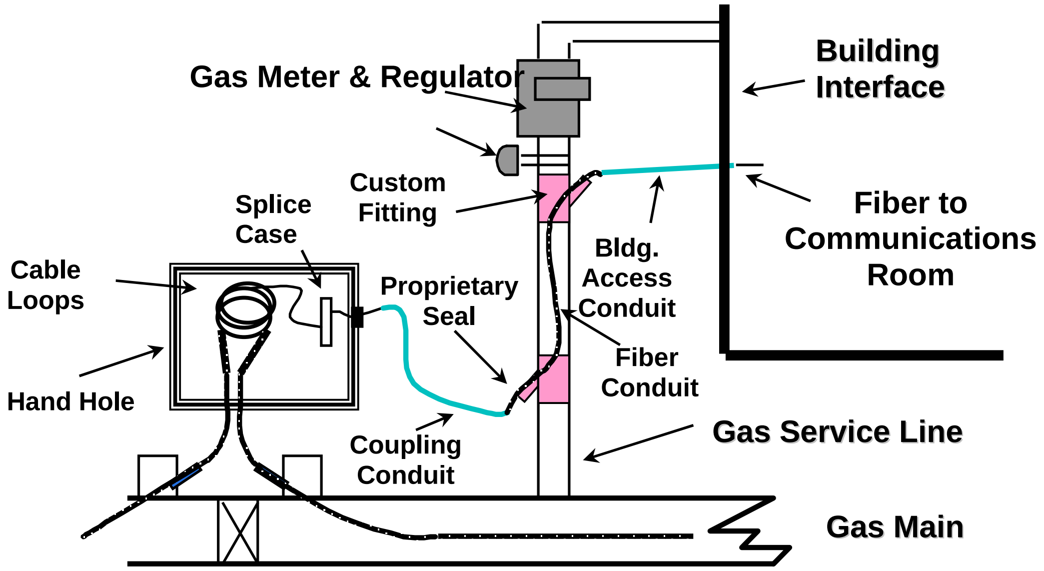

Figure 8: Schematic of the FIG$_{sm}$ service line installation

In larger size service lines (20 – 25 mm or greater), a conduit is installed into the gas pipeline. As with the FIG$_{sm}$ Distribution Main application, the conduit used for service lines is natural gas certified polyethylene pipe. In smaller size service lines, the fiber-optic cable is inserted directly into the pipe in order to minimize effects on capacity. Specially designed fittings manufactured to applicable gas industry standards are used as access points into the service line and to seal the conduit/cable.

In general, the primary economic value gained with the FIG$_{sm}$ service line technology is achieved by connecting the fiber main line to the target-building interface. However, in cases where the meter is located inside a building, regulations usually allow for the installation of conduit/fiber inside the building, as long as the exit point is upstream of the gas meter (see further discussion under Codes and Regulations). Using house piping downstream of the meter as a fiber carrier is generally unacceptable in the United States because of implied disallowance by building plumbing codes. Applicable codes outside the United States are being investigated to determine installation requirements and constraints.

2.2 Pipeline Capacity Reduction from Fiber-Optic Conduit

One important consideration prior to installation of fiber in gas pipelines is to ensure that there is sufficient pipe capacity for the fiber while maintaining the desired gas service reliability. Fortunately, because most local pipeline systems have redundant feed points, and supply of peak demand needs are usually constrained by relatively few “bottleneck” pipes within a pipe system, many pipes have space available for optical fiber placement without effecting natural gas service reliability.

In general, the FIG_{sm} process is designed so that the conduit reduces the pipe cross-sectional area by 10 percent or less. For instance, a 25 mm conduit in a 100 mm steel pipe (4.8 mm wall) reduces the cross-sectional area by 9 percent while the same conduit in a 200 mm steel pipe (6.3 mm wall) reduces the area by about 2 percent. The actual flowing capacity reduction will be somewhat larger than cross-sectional area reduction due to frictional losses caused by the increase in wetted perimeter. Ultimately, if there is any potential impact on service reliability for a particular pipeline or system, the pipeline system with conduit input must be modeled using the utility's numerical analysis flow model (e.g. Stoner Model).

2.3. Safety

The FIG_{sm} technology and processes were designed to maintain or improve safety of the gas pipeline system. Using this criterion, all primary fittings used in the process were derived from existing gas industry fittings. By using this design guideline, the long-term performance in gas pipelines of each fitting is assured and known to be safe. This feature has the additional advantage of keeping production costs low.

Use of gas certified pipe as conduit is a key safety feature of the FIG_{sm} technology. In addition to the fact that this type of pipe has a proven safety performance record in gas environments, the sealing mechanism between the conduit and pipeline is readily available, has a long performance history and is cost-effective. Use of a conduit has the additional advantage in that it allows many different types and makes of fiber cable to be employed or retrofitted, enabling ultimate customer flexibility.

For the utility, a key consideration for any installation of fiber in gas pipelines is the ability to maintain emergency response and gas handling operations. While some utilities use designated valves in pressure control districts to effectuate emergency gas control, others use a variety of other control techniques, including placement of "stopping fittings" and PE pipe pinching. In pipes that have conduit and cable installed, one control option is to incorporate "designated pinch/control points" into the route and into the utility operating plan. These points can be located at each conduit entry/exit location so that control is achieved without hindrance of the conduit/cable inside the pipe. In a typical metro environment, these points will generally be 150 to 300 meters apart and will average about 200 meters apart.

In cases where the utility must be able to achieve control at any point in the system at any time, a variety of specialized tools can be used. These proprietary tools, developed by Sempra Fiber Links, are based on conventional gas control equipment and are available to companies employing the FIG_{sm} technology.

2.4. Codes, Standards and Regulations

In the U.S.A., pipeline safety is regulated by the Department of Transportation as specified in the Code of Federal Regulations (CFR) 49, Section 192. Individual states generally use the CFR as the basis for applicable state regulations, but may choose to impose more stringent standards. All FIG_{sm} fittings and processes comply with requirements of CFR 49, Section 192. Furthermore, FIG_{sm} fittings and processes have been tested to a number of different ASTM standards that exceed CFR requirements.

Recently, a new American Society for Testing and Materials (ASTM International) subcommittee entitled "Deployment of Optical Fiber Cable Systems in Natural Gas Pipelines" was formed to form standards and practices specifically related to installation of optical fiber in natural gas pipelines. The committee is addressing operating and maintenance practices, pipeline selection criteria, installation practices, specifications for materials and components and other considerations.

While gas utilities in the United States generally operate under franchise rights that apply only to gas distribution service, the Federal 1996 Telecommunications Act does address issues related to use of energy utility facilities for telecommunications purposes. However, the implications of the Act on the use of gas pipelines as conduits for fiber-optic cable is beyond the scope of this paper.

3. PRACTICAL APPLICATIONS

The first gas pipeline installation in the United States was achieved using the SFL FIG$_{sm}$ technology in 2001. Prior to that, several installations using technology developed by Alcatel and Gastech have been conducted in Europe and Asia. Alcatel claims a number of installations in Germany and a 140 kilometer installation in Taiwan. The Alcatel process uses a balloon-shuttle device driven by gas pressure to pull ruggedized cable directly into steel pipes. In some installations, including the Taiwan installation, the pipe is depressurized and air pressure used to drive the cable into the pipe [8]. GASTEC NV, located in the Netherlands, employs a technology to introduce polyethylene conduit into lower pressure plastic pipes [9].

As of December 2002, Sempra Fiber Links had deployed the FIG$_{sm}$ technology in three active gas pipelines. The first project was conducted in North Wilksboro, North Carolina in the Frontier Energy pipeline system, a sister company of Sempra Fiber Links. The second project was deployed in Oncor Company's pipeline system in Fort Worth, Texas and a third project installed fiber in the Long Beach Energy pipeline system (metro Los Angeles area).

3.1. Frontier Energy Installation

The FIG$_{sm}$ technology was used to install fiber-optic conduit into a two and one-half kilometer section of 150 mm polyethylene distribution main operating at less than 400 kPa. A first installation was conducted in August 2001, and a second in October of that year. Both installations were conducted as demonstrations for other gas utilities contemplating installations in their own systems.

A variety of installation techniques were tested and perfected during the Frontier installation. Initially, direct conduit insertion methods were used for short runs of approximately 50 meters. Later, fiberglass duct rod was employed to achieve installation lengths of nearly 300 meters. Finally, the power rod method was used to successfully install three 900 to one-thousand-foot sections. Hand holes were placed in several locations in order to effectuate future customer connections. On average, the conduit placement distance was over 270 meters between entry/exit fittings.

Figure 9: Installing fiber optic cable in a Toyota dealership gas service line.

A service line installation was also conducted at a local Toyota dealership. In this case, a 9.5 mm conduit was installed in a 50 meter-long service run through one 90-degree angle, exiting at the meter adjacent to the building. (See Figure 9.)

At the present time, fiber-optic cable has not been placed into the conduit. Future customer connections may involve connection to a Sprint central office and the Lowe's Company corporate headquarters located adjacent to the installation.

3.2. Oncor Gas Company Installation

In May 2002, Oncor Company, an affiliate of TXU Gas Company, requested that Sempra Fiber Links install a section of fiber-optic conduit as part of a Gas Technology Institute's (GTI) international consortium study to evaluate fiber in gas pipeline technology. Market analysis by TXU deemed the installation site to be commercially viable for fiber-optic cable. Oncor's strategy was to conduct a limited

Figure 10: Installation of a 1170-foot conduit section in the Oncor-TXU pipeline.

installation that would later allow the company to assess the potential for widespread deployment. Concurrently, Oncor began working to resolve any outstanding regulatory issues that might impact the ability of a telecommunications company to use that conduit. Once those issues are resolved, Oncor will determine whether to build additional routes and lease the space to telecommunications companies, including their affiliate, TXU Communications.

The trial installation was conducted over the course of two weeks so that the GTI consortium members, other interested gas utilities, telecommunication companies and regulators could view the technology. Four sections between 300 and 360 meters were installed into a 150 mm polyethylene gas pipe using the Power Rod method.

3.3. Long Beach Energy Installation

The city of Long Beach, California (a city of 470,000 residents) owns its own gas distribution internal telecommunications infrastructure. Long Beach Energy, the city department responsible for gas pipelines, contracted SFL to connect two city buildings with fiber using the FIG$_{sm}$ technology. Construction began in late November of 2002 and was completed in early December. Approximately 1.3 kilometers of conduit and fiber were installed in 75, 100 and 150 mm diameter pipelines. Several hand holes were place in the route to facilitate cable placement and serve as future customer connection points. Figure 11 shows the cable being placed into the bridging conduit that is routed from the hand hole to the gas pipeline in the street. Overall, the cost to achieve this fiber connection was significantly less than the considered alternative of utilizing microwave towers and provided substantially greater bandwidth. In addition, the city now has a number of unused fibers it can use for future growth or can externally lease as a revenue source.

Figure 11: Fiber cable placement using standard jetting techniques.

4. CONCLUSIONS

The FIG$_{sm}$ technology introduced by Sempra Fiber Links is an effective method for introducing fiber-optic cable into operating gas pipelines in a safe and cost effective manner. Installations in North Carolina and Fort Worth, Texas prove that the FIG$_{sm}$ technology is a practical and effective method for deploying fiber optic conduit. By economically deploying fiber to the last mile, the FIG$_{sm}$ technology can play an important role in meeting the accelerating demand for broadband communications.

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