**CHAPTER 14**

# Duct and Conduit

## 1 Introduction

This chapter provides detailed information on the applications, features, and benefits, material, material selection, and installation of high density polyethylene (HDPE) conduit and duct for direct buried or innerduct applications. HDPE conduit provides a mechanically protected pathway that promotes an easy installation and replacement of communication and power cables, as well as improves overall system reliability.

This chapter provides sections covering:

- Conduit History
- Industry Terminology
- Standards and Specifications
- Applications
- Product Offerings
- Material Selection
- Design
- Conduit Installation
- Cable Installation within Conduit
- Joining Methods
- Specialty Applications
- Glossary of Common Terms

**Note** that this chapter does not address the safety aspects of handling and installing conduit or cable. See PPI TN-58 *HDPE Conduit & Duct Handling Guide* for safety related information associated with handling coiled conduit and always refer to conduit, cable and equipment manufacturers' safety instructions when installing conduit and cable.

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## 2 HDPE (High Density Polyethylene) Conduit History

The materials and installation methods used to install conduit have evolved considerably over time; beginning with wood, terracotta tile, cast concrete, iron pipe, and galvanized steel, bringing us to today with the material of choice being thermoplastics.

Beginning in the 1960s, the two primary thermoplastic materials used in extrusion, the process used to manufacture conduit, have been HDPE and PVC (polyvinylchloride). The industry experienced a significant increase in demand for HDPE conduit when telephone companies sought to add capacity in major metropolitan areas by removing traditional copper cables and replacing them with small diameter, fiber optic cables.

It was the introduction of trenchless installation methods, such as horizontal directional drilling (HDD) and pull or chute plowing that significantly contributed to the wider adoption of HDPE conduits. When coupled with the HDPE conduit's long reel lengths, trenchless installations are much less intrusive to existing roadways, infrastructure and landscaping, and can reduce installation costs.

Whether it is above or below ground, HDPE conduit continues to be the material of choice as utilities expand their distribution infrastructure in urban and rural areas, and as communication companies increase availability of network bandwidth to meet the needs of the connected population.

HDPE conduit facilitates communication network expansion through a variety of features, benefits, and product offerings such as microducts, color coding, Cable-in-Conduit (CIC), and various packaging methods are explained in the HDPE Product Offering in Section 6.

## 3 HDPE Conduit Standards & Specifications

At the time of its original introduction into the market as a conduit material, HDPE conduit did not have any applicable electrical standards for its use as a pathway for protecting electrical and communication cables; leaving engineers to specify one of the water tubing and pressure pipe approved standards such as ASTM D3035[1], D2239[2], or D2447[3].

In the 1990s, the Plastics Pipe Institute (PPI) created the Conduit Division (later renamed the Power and Communications Division) with the primary focus to develop HDPE conduit standards; the first being ASTM F2160 *Solid-Wall High Density Polyethylene*

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[1] ASTM D3035 - Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
[2] ASTM D2239 - Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
[3] ASTM D2447 - Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter (Withdrawn 2010)

*(HDPE) Conduit Based on Controlled Outside Diameter (OD)* for both power and telecommunications.

The following specifications are now utilized by the industry for the production and specification of HDPE conduit and raceways:

- **Telecommunication Conduits**
  - ASTM F2160 Solid-Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)
- **Power Conduits**
  - ASTM F2160 Solid-Wall High Density Polyethylene (PE) Conduit Based on Controlled Outside Diameter (OD)
  - NEMA TC7 Smooth-Wall Coilable Polyethylene Electric Plastic Conduit
  - NEMA TCB 4 Guidelines for the Selection and Installation of Smooth-Wall Coilable High-Density Polyethylene (HDPE) Conduit
  - UL 651A Schedule 40 and 80 High Density Polyethylene (HDPE) Conduit
  - CSA C22.2 NO 327 HDPE conduit, conductors-in-conduit, and fittings
- **Cable in Conduit**
  - ASTM D3485 Coilable High Density Polyethylene (HDPE) Cable in Conduit (CIC)
  - UL 1990 Nonmetallic Underground Conduit with Conductors
  - CSA C22.2 NO 327 HDPE conduit, conductors-in-conduit, and fittings
- **Premise Raceways**
  - UL 2024 Cable Routing Assemblies and Communications Raceways

PPI Technical Note 50 (TN-50) *Guide to Specifying HDPE Conduit* provides detailed information on each of the above specifications, as well as a flow chart guiding the specifier to the correct industry specification. PPI Model Specification MS-5 provides a suggested format that may be followed when specifying HDPE conduit.

PPI and member companies conduct ongoing development of guidance documents to address the industry’s needs. Visit the Power & Communications Division publications page within www.plasticpipe.org to find the most up-to-date documents.

## 4 Industry Terminology

The conduit industry has terminology specific to the industry and distinct from other industries using HDPE pipe. Firstly, the HDPE tube product that acts as a raceway for the cable is referred to as a **conduit** or **duct**, and these terms are generally used interchangeably within the industry and this chapter. **Innerduct** is conduit used inside another conduit to subdivide the larger duct and provide multiple pathways for installation of current and future cables.

Cables are generally defined as power (electrical) or communication. Power cables can be high (>35KV), medium (15-35kV) or low (600V) voltage. Among other uses, they are commonly used for providing transmission or distribution power, highway lighting, and irrigation system control. Communications cables are often either coaxial (typically used in CATV) or fiber optic designs, used for networks, data centers, telephony, SCADA, etc.

Other terms and acronyms specific to the industry are provided in Table 10 of Section 14.

# 5 Applications

HDPE conduit serves two primary industries: communications (telephone, Cable TV (CATV), data transmission, etc.) and power (transmission, distribution or commercially installed electrical cable). HDPE conduit serves both OSP (Outside Plant) networks and ISP (Inside Plant) premise cabling and enterprise systems. The following subsections provide an overview of each industry followed by a summary of the distinct advantages of HDPE conduit.

## 5.1 Communications

In the communications industry, the advent of fiber optic cable has had a tremendous impact due to its significantly higher data-carrying capacity, necessitated by the explosion of the internet, cloud computing, data centers, 5G wireless and Artificial Intelligence (AI). In telecommunications service (phone, data transmission), fiber optic cable is used, along with traditional copper cable. In cable television service (CATV), the use of fiber optic cable is growing rapidly to supplement, or replace, coaxial cable.

This progression toward fiber optic cable has made the need for cable protection more critical as these materials are sensitive to moisture and mechanical stress. Damage can be very expensive in terms of service interruptions and replacement costs. Also, these cables are installed in very long, continuous runs that require a clear, protected pathway, as well as a leak-free system for air-assisted ("blow-in") installations. In addition to fiber optic cables, coaxial cables have also seen improvements that increase bandwidth making these materials more mechanically sensitive and requiring improved protection.

## 5.2 Power Transmission

In the power transmission industry, a critical requirement is maintaining uninterrupted electrical service as consumers and businesses are even less tolerant of power outages than they are of phone or communication service interruptions. Although many direct-buried power cable systems are designed for 30- or 40-year lifetimes, they are susceptible to external influences, like rock impingement and ground movement, that may require frequent repair.

Severe weather is the number one cause of power outages in the United States, costing the economy between $18 and $33 billion every year in lost output and wages, spoiled inventory, delayed production and damage to grid infrastructure[4]. Also, threats to aerial installations from traffic and wildlife are ubiquitous.

North America's electrical distribution grid is also an aging infrastructure that requires extensive upgrades to effectively meet 21st century energy demands and expectations for grid reliability and resiliency[4].

The use of conduit is finding favor over direct burial cables in these applications due to improved protection, long continuous runs and the ability facilitate quick repairs. HDPE conduit is used to carry both primary (substation to transformer) and secondary (transformer to end-user) cables. Some of these installations also contain fiber optic cables placed alongside the power cables to connect with load-monitoring sensors located throughout the network, known as SCADA (Supervisory Control and Data Acquisition) systems.

Underground installation of power distribution lines using HDPE conduit is a reliable, sustainable and economical solution. When utilities have a choice between burying power lines underground and installing aerial power lines in vulnerable or unsightly locations, the Plastics Pipe Institute encourages them to analyze lifetime costs of underground vs. aerial installations on a case-by-case basis, considering technical, economic and environmental factors. Although initial installation costs of underground power distribution lines may be higher, installation by plowing of HDPE conduit and pulling cable can reduce underground construction costs. Also, by utilizing modern horizontal directional drilling (HDD) technologies, underground power installations can be far less disruptive when replacing or upgrading existing infrastructure partially due to lowering refurbishment costs.

Whether for communications or power applications, HDPE conduit has significant advantages over other conduit materials.

### 5.3 Advantages of HDPE Conduit

HDPE is the most commonly used flexible conduit material due to its physical property advantages such as:

- **Ductility & Toughness**
    - HDPE conduit resists embrittlement over time during its service life
    - Permanent flexibility – HDPE conduit bends and flexes without breakage over a wide range of temperatures, even with ground heaving or shifting.
    - Resistance to rough handling and gouging – HDPE can resistant significant surface damage making it ideal for plowing and HDD installation methods.

[4] Economic Benefits of Increasing Electric Grid Resilience to Weather Outages -Executive Office of the President, August 2013.

- **Temperature Versatility**
  - Low temperature impact resistance – HDPE withstands low-temperature impact. This is illustrated by impact testing on PE conduit conditioned at -4 °F (- 20 °C).
  - HDPE conduit can be installed in ambient temperature ranging between -30 °F to 180 °F (-34 °C to 82 °C).
  - Power conductors rated at 90 °C ("wet") and medium voltage cable rated at 105 °C ("dry") are permitted for use with HDPE conduit.
- **Ease of Installation**
  - Availability in long continuous lengths – HDPE conduit can be coiled for shipment thus permitting long continuous, unjointed installations runs.
  - Identification by colors and striping – HDPE can be colored to assist in uniquely identifying conduits within a bundle and during post-installation excavating
  - Lightweight and ease of handling – HDPE can be handled by hand or light equipment.
  - Watertight connections – HDPE conduit can be joined by fusion or mechanical fittings.

## 6 HDPE Conduit Product Offering

HDPE conduit is available in numerous configurations, lengths, colors, and with various features aimed at solving specific installation requirements. For example:

- Typically, conduit is provided in solid wall for OSP applications because of long lengths and stiffness, while corrugated conduit can be used for short OSP runs or ISP premise applications.
- Conduit can be color coded to allow easy end to end identification within a bundle.
- Multiple conduits can be packaged on a single reel allowing for multiple pathways to be installed simultaneously.
- Conduit can be provided in long continuous runs that minimize joints and facilitate faster installation.
- Conduit can be provided with
  - cable pre-installed during the conduit's extrusion in the factory for a one-step field conduit/cable installation,
  - a pull line (Section 10.1), factory installed for field installation of the cable,
  - inner wall ribs, lubrication, or both, lowering the coefficient of friction (COF) to facilitate longer cable installations,
  - a tracer wire making the dielectric conduit locatable, and
  - a high strength steel support strand for attaching to poles in aerial applications.

This section outlines some of the product choices and features available in the market place.

### 6.1 Solid or Corrugated Wall

Solid wall conduit is available in various standard wall thicknesses that can be matched to the application in order to assure the correct strength and toughness for installation and long-term service.

Corrugated innerduct, as shown in Figure 1, is flexible, lightweight and can be made of flame-retardant materials to be installed inside buildings (ISP) in accordance with the National Electrical Code (NEC) (see discussion of plenum and riser rated nonmetallic duct in Section 12.3).

**Figure 1 Corrugated Duct**

### 6.2 Color Choices

While there are a number of color and stripe combinations available, single runs of conduit are typically colored red (or black w/longitudinal red stripes) for power, orange (or black w/longitudinal orange stripes) for communications, and terra cotta for CATV (refer to PPI Statement V – *Recommended Color Code for Solid Wall Plastic Pipe and Conduit.*)

The various color schemes, as shown in Figure 2, can also provide distinction amongst raceway owners, which is beneficial as it is common for multiple communication raceway owners to co-locate in the same trench. If needed, special colors can be made available but minimum lengths may apply so consult with your HDPE conduit manufacturer for more details.

There are three methods for providing color identification: full wall color, co-extruded exterior color, and longitudinal striping. For longitudinal striping, the multiple stripes, typically 3 or 4, are co-extruded and placed at equally spaced intervals around the outside circumference of the conduit. For example, three stripes would be spaced at intervals of 120 degrees apart so as to optimize visibility when viewing from any direction. The combination of solid and striping allows for many combinations that can be used to differentiate individual ducts within a bundle once installed.

**Figure 2 Examples of HDPE conduit in various colors and with stripes**

### 6.3 Reel Packaging

Multiple ducts of different color/stripe combinations and sizes can be delivered on one common reel for a more efficient installation. Reels are wrapped in one of two manners: parallel wrapped with conduits re-spooled side-by-side (see Figure 3) or segment wrapped whereby the reel is compartmentalized for each color (see Figure 3).

**Figure 3 Two-Way (two colors) Parallel Wrapped (left) and Three-Way (three colors) Wrapped on a Segmented Reel (right)**

There are various reel designs, sizes and combinations available. Refer to the manufacturer's literature for reel sizes options and capacity offerings.

### 6.4 Reduced Coefficient of Friction

Installation distances of the cable within the conduit can be limited by the friction between cable and conduit. Lowering the coefficient of friction (COF) results in less stress being placed on the cable during installation, which often allows for longer lengths of cable to be installed more efficiently.

Conduit can be provided with ribs and/or lubricated to improve cable installation distances. Conduit can be factory lubricated or lubricated in the field. Ribbed conduit (spiral or longitudinally, as illustrated in Figure 4) reduces friction and promotes turbulent airflow when installing cables using the push/blow method.

**Figure 4 HDPE conduit with longitudinal ribbed interior**

### 6.5 Cable in Conduit (CIC)

Cable in Conduit (CIC) is a conduit with cable factory installed providing time and labor savings by allowing one-step placement of both conduit/cable assembly, as shown in Figure 5. Cable in conduit can be provided with fiber, coaxial, twisted pair and electrical power cables already installed. These cables are factory installed into the duct under controlled conditions, with thermal protection to ensure that the cable jacket is protected from the heat during conduit production. The integrity of the cable receives added protection during the field installation process from the surrounding HDPE duct.

**Figure 5 Example of CIC (cable in conduit) for a Highway Lighting Application**

### 6.6 Aerial Duct

Self-supporting duct, commonly known as Figure 8 Aerial Duct, incorporates an integral high strength steel strand in the assembly, used for suspension and support during and after aerial installation, as shown in Figure 6. Using aerial conduit with a factory assembled wire strand simplifies installation and eliminates the need for lashing. The conduit assembly for both self-supported and lashed aerial installations must have an adequate level of UV protection, typically carbon black added to the HDPE resin during extrusion, to protect it from degradation during its anticipated service life.

**Figure 6 Aerial Conduit with support Strand**

### 6.7 Locatable Duct

Locatable duct, as shown in Figure 7, has a copper wire extruded on the outside or within the conduit wall making it locatable. If digging is to be done in the area, a signal is placed on the tracer wire and the operator walks above the buried conduit using a location instrument to detect the signal. Typically, the locator provides a readout of the burial depth and the operator will spray paint markings on the ground to indicate the buried conduit pathway underground.

**Figure 7 HDPE conduit with embedded tracer wire**

Microducts are smaller HDPE conduits used for OSP applications, typically range in outside diameter from about 5 mm (¼ in.) to 27 mm (1 in.), with sizing always expressed in millimeters (i.e., OD/ID mm). Microducts are available in individual or bundled configurations with an oversheath for installation into larger HDPE carrier conduit or wall types rated for direct buried installations. They are also available with a locate wire, with a pull line or with cables factory installed.

Additionally, in a process called "overriding", and due to their small sizes and low coefficient of friction, microducts can be push/blown or pulled into conduits to add capacity where an existing fiber cable has already been installed.

Microducts are available in a variety of wall thicknesses; thinner walls are used to subdivide a larger conduit, and thicker walls are designed for direct burial. Air blown microfiber is often field installed in microduct bundles for FTTH (Fiber to the Home) installations, providing a continuous pathway from the node to the end user with a minimal number of splice points.

Flame retardant Microducts are also available in single and multiple configurations with a flame retardant oversheath, for ISP (inside plant) installations. They are available in specific material ratings formulated for application requirements such as riser, plenum or LSZH (low smoke zero halogen). They can be supplied with pull lines factory installed or in CIC configurations with equally rated cables factory installed.

## 7 Material Selection

The primary physical property advantages of HDPE conduit are flexibility, ductility and chemical resistance. Other physical attributes critical to the performance of HDPE conduit are tensile strength and stress crack resistance. However, the designing or specifying engineer should be aware that not all HDPE materials deliver the same level of performance in these areas, and it is critical to ensure that the material meets all the demands of the installation and service conditions. This section will briefly discuss these material considerations, but a more thorough discussion of HDPE technology is provided in Chapter 3 *Material Properties* of this Handbook. The minimum material performance requirements are typically defined within the appropriate product specification.

### 7.1 Physical Properties

The physical properties of HDPE materials used for conduit or pressure pipe are specified through the Cell Classification of the material as described below.

#### 7.1.1 Cell Classification Material Properties

The cell classification (per ASTM D3350[5]) is a 6-digit numeric "code" which describes a polyethylene material's performance level in six key physical characteristics. This 6-digit classification is often followed by a single letter suffix representing a color or UV stabilizer category. ASTM product specifications indicate either a range or the minimum requirements for each of the cell classes for that product or specific applications. For conduit, this cell classification is used in specifications such as ASTM F2160 *Standard Specification for Solid Wall High Density Polyethylene (PE) Conduit Based on Controlled Outside Diameter (OD)* and others (see Section 3). ASTM F2160 requires a minimum cell class of PE334480C or PE334480E, with the former a black compound and the latter a colored compound with UV stabilizer.

Compounds will typically have a thermoplastic designation code of PE3XXX[6] (per ASTM F412 *Standard Terminology Relating to Plastic Piping Systems)*. Occasionally, a higher stiffness compound may be desirable for boring applications such as a PE4XXX[6]; a PE4710 compound, a pressure piping grade, exceeds the ASTM F2160 minimum cell class requirements and can also be used in these applications.

The properties defined by the cell class are described below.

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[5] ASTM D3350 - Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

[6] Within the ASTM D3350 classification system, the first digit represents the material's Density cell class number and the second digit represents the Slow Crack Growth Resistance cell class number, as explained in this sub-section. The 3rd and 4th digits represent the Hydrostatic Design Strength (HDS) as discussed below, which is not required in conduit applications (See PPI Handbook of Polyethylene Pipe, Chapter 3, Table B.1.1).

**Density** – PE density generally has the greatest effect on many physical properties. For example, higher densities favor increased tensile strength and flexural modulus (e.g. stiffness), while lower densities generally favor impact resistance, flexibility and stress crack resistance (see SCG below). Density also affects coefficient of friction (CoF), with higher density typically related to lower CoF. Therefore, some degree of compromise may be necessary to balance properties required for a particular application. PE compounds used for conduit typically have a density between 0.940 to 0.950 g/cm$^3$ and are considered high density PE, or HDPE.

**Melt Index** – Melt Index (MI), a measurement of a polymer's molten flow properties (ASTM D1238[7]), is related to average molecular weight of the polymer chains. Generally, lower melt indices represent higher molecular weights, while higher values indicate lower molecular weights. For any given PE resin, a lower melt index (higher molecular weight) will normally have superior physical properties (i.e. slow crack growth).

**Flexural Modulus** – Flexural modulus is a measure of resin stiffness, or its resistance to bending or deflection under applied load. In PE conduit, these stiffness characteristics generally affect load-bearing capability, bending radius, and tendency to ovalize (when coiled or bent). Flexural modulus should be taken into account when determining the appropriate wall thickness for an installation.

**Tensile Strength/Yield Strength –** Tensile yield strength, or the point at which a stress causes a material to deform beyond its elastic region (irreversible deformation), is a critical property for many conduit installation methods involving pulling (e.g., directional drilling). Yield strength is a critical factor when designing the lengths of such installations and it is an important consideration in determining allowable pull loads. It is important to note that both flexural modulus and tensile strength are affected by temperature (both decrease with increasing temperature).

**Slow Crack Growth Resistance (SCG)** – ASTM D3350 allows for the use of either the ASTM D1693 - Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics (ESCR) method or ASTM F1473 - Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins, otherwise known as the PENT test, to measure properties of slow crack growth resistance. For PE conduit applications, ESCR is utilized. ASTM F2160 requires a cell class 8 requirement, which is defined as an ESCR test result of greater than 96 hours ($F_{10}$ > 96 hrs., Condition B, 10 % Igepal).

As one of the most important properties affecting the service life of HDPE conduit, a high slow crack growth resistance protects the conduit from the stresses of bends and rock impingement that can cause inferior conduit materials to crack and fail, particularly at higher temperatures. The ESCR test is a laboratory test which measures a material's ability to resist cracking under aggressive and accelerated conditions. As

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[7] ASTM D1238 - Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer

mentioned above, higher densities generally have a negative effect on ESCR, and, as a general practice, base resins with densities below 0.950 g/cm$^3$ have ESCR properties suitable for conduit applications.

**Hydrostatic Strength Classification** – The hydrostatic strength classification describes the material's resistance to failure under sustained internal pressure; this property is primarily used for pressure piping applications and is not required for conduit. PE conduit materials are therefore represented by a "0" (not pressure rated) in this category.

### 7.2 Other Material Properties

The cell classification does not address all performance requirements. Other important considerations are:

**Chemical Resistance** – PE is highly resistant to a wide range of chemical agents even at elevated temperatures. However, when installing in potentially aggressive environments, the user should refer to PPI Technical Report TR-19 *Thermoplastic Piping for the Transport of Chemicals,* which provides chemical resistance data for PE for a wide range of chemicals.

**Impact Resistance** – Impact resistance is related to the conduit's ability to absorb impact and resist cracking during handling and installation, particularly in cold weather. An advantage of PE over many other materials is its ductility at low temperatures. For example, PE's glass transition temperature (the temperature below which it is more brittle and glassier) is well below 0 °F, at approximately -166 °F (-110 °C)[8].

There are a number of impact tests for materials, like Izod or Charpy (see Chapter 3 *Material Properties* of this Handbook), but generally finished conduit and fittings are tested by a falling weight (tup) impact test (e.g., ASTM D2444[9], UL 651A) at low temperature — typically -4 °F (-20 °C). This test, commonly used in quality assurance, is a pass/fail test, in which any cracking or breaking is considered a failure.

**Stabilization** - Unprotected PE, like virtually all other polymers, is vulnerable to degradation due to prolonged exposure to heat, oxygen or ultraviolet (UV from sunlight) radiation, resulting in embrittlement and reduced service life. To prevent these damaging effects, HDPE conduit materials are typically formulated with a variety of stabilizing additives, ranging from antioxidants to UV stabilizers, to maintain the required long-term performance. The most common means of UV protection is to employ carbon black or a colorant in conjunction with additives in the resin such as the HALS (hindered amine light stabilizers) and/or UVA (UV absorber). For a more in-depth discussion on both antioxidants and UV protection, see Chapter 3 *Material Properties* in this Handbook.

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[8] Not a recommended installation temperature.
[9] ASTM D2444 - Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

Regardless of the type of UV protection used, the conduit must be adequately protected from UV attack to withstand normal outdoor storage conditions and, if intended for above ground outdoor use, long term outdoor exposure as discussed below.

Conduit destined for underground installation is designed to provide at least one year's protection from outdoor uncovered storage. If longer storage times are possible or anticipated, the user may specify additional stabilization or, preferably, should provide for a covered storage environment. Otherwise, if the conduit exceeds one year of uncovered exposure, it should be tested to ensure it continues to meet all physical property requirements (e.g. cell classification, impact resistance) prior to installation.

For long-term aerial exposure of black conduit, please refer to the applicable conduit product standard for specific carbon black requirements due to the heightened mechanical stress levels and continuous UV exposure.

## 8 Conduit Design Considerations

HDPE conduit and pressure pipe have similar attributes but differ in significant ways:

- Conduits do not have long-term internal pressure. External forces are unchecked by internal pressure so ovality that occurs during installation may not recover during service.
- Long-term stress rupture is not a factor so pressure rating and a hydrostatic design basis (HDB) is not required in material selection.
- Conduit inside diameter (ID) is chosen by cable occupancy, where internal clearances are critical, whereas, for piping applications, ID is based on volumetric flow requirements.
- Path of installation for conduit is very important – radius of curvature, vertical and horizontal path deviations (undulations) and elevation changes all significantly affect cable placement.

Determining the dimensions of conduit begins with determining the required conduit internal diameter to accommodate the required cables followed by wall thickness requirements for installation and service life considerations. This section reviews the conduit inside diameter and wall thickness design considerations for cable occupancy, cable installation method, and conduit installation method. Finally, the standard available sizes are discussed.

### 8.1 Internal Diameter Considerations

The inside diameter of the conduit is determined by the cable diameter, number of cables and conductors, and placement method (pulling or air-assisted pushing). Power cable is typically pulled, while some fiber optic cables are more likely to be "air blown". Determination of a conduit's dimensions begins with the largest cable, or group of cables or innerducts, intended for occupancy within the conduit.

Maximizing installation lengths can be accomplished by:

- Lowering the coefficient of friction (CoF) via lubrication or ribbed conduit,
- Minimizing the number of directional changes in the conduit run,
- Adhering to the suggested allowable cable fill percentages for the type of cable to be installed, and/or
- Positioning the cable feed at the end of the conduit run so that any planned directional changes are as late in the pull as possible.

### 8.1.1 Pulling Method

Pulling cables into underground conduits requires determining that there is sufficient free clearance and selecting the appropriate pulling method based on the types of cables (e.g. heavy power and copper communication cables (short lengths) and lower weight shielded or dielectric fiber cables (long lengths)).

Cable fill for cables typically follows the recommendations of Article 353 and Chapter 9 of the NEC document NFPA 70[10]. Varying allowable fill percentages are determined by comparing the cross-sectional areas of the conduit ID to the cable or cables to be installed, as shown in Equation 1. Those values for cables typically range from 31% fill for two cables to 53% fill for a single cable as shown in Table 1.

$$\%\ Fill\ for\ Power\ Cables = \frac{\sum Cable\ Area}{Conduit\ Area} \times 100 = \frac{\sum (Cable\ OD)^2}{(Conduit\ ID)^2} \times 100 \quad (1)$$

**Table 1 Percent of Cross Section of Conduit and Tubing for Conductors and Cables**

| Number of Cables in Conduit | Maximum Fill % |
|---|---|
| **1** | 53% |
| **2** | 31% |
| **3 or more** | 40% |

According to NEC Chapter 9 – Table 1, jamming can occur when pulling three conductors especially around a curve or when the cables twist. As shown below with Equation 2, the Jam Ratio is equal to the ID of the conduit divided by the OD of one cable. Jam ratios between 2.8 and 3.2 should be avoided and these correspond to fill ratios of 33.3% and 35.7%, respectively. The probability of jamming with four or more conductors is very low, provided the total fill ratio doesn't exceed 40%. See NEC Chapter 9 - Table 1 notes for more information on acceptable conduit fills levels.

$$For\ 3\ conductors, jamming\ can\ occur\ between\ 2.8\ and\ 3.2.$$

$$Jam\ Ratio = \frac{Conduit\ ID}{Conductor\ OD} \qquad (2)$$

[10] NFPA 70 - National Electrical Code (NEC)

### 8.1.2 Air-Assisted Blowing Method

The allowable fill percentage for fiber optic air blown fiber installations is calculated based, not on area, but on the relationship between cable OD and conduit ID, i.e., calculated by dividing the sum of the ODs of the cable by ID of the conduit times 100, per the Equation 3. Optimized fill percentages using this calculation method range between 50% minimum to 75% maximum.

$$\%\ Fill\ for\ Communication\ Cables = \frac{\sum Cable\ OD}{Conduit\ ID} \times 100 \qquad (3)$$

### 8.1.3 Push-Blow Method

Another installation option for lower weight fiber cable is the push-blow method. Push-blow installations allow dielectric fiber optic cables to be installed over longer distances compared to what can be achieved by pulling. Pulling fiber has limitations due to its "low" tensile strength. Conversely, push-blow installations do not stress the glass fibers. Under favorable conditions, unassisted distances of >5,000 ft. can be installed whereas typical unassisted pulling lengths are <1,000 ft.

The fill ratio for push-blow installations is also calculated per Equation 3. It is notable that the fill ratios for fiber cable installed by air-assisted methods have a minimum of 50% (contrasted by power cable maximum of 53%). When a cable meets increased resistance during pushing, the tendency is to form a helix, which transfers some of the axial load into the wall increasing friction. Assuring that the cable fill falls between 50%-75% optimizes the velocity of air flowing over the surface of the cable, allowing for increased installation lengths.

### 8.1.4 Future Placement Considerations

Using these guidelines, one can help to determine the optimized ID of the conduit or innerduct in relation to the OD of the cable or cables to be installed. When pulling cables, determining a conduit's ID for power, coaxial or multi-pair copper telecom cables is important because having sufficient clearance is critical to future cable placement success.

Innerducts are smaller diameter conduits, intended for placement into larger conduits or casings. Their purpose is to subdivide the larger conduit space into discrete continuous pathways for fulfilling current and future requirements for installation of fiber optic cables. In this case for the installation of innerducts, the fill-ratios defined for power cables would apply.

## 8.2 Conduit Wall Determination

Conduit and duct products come in a wide range of diameters, spanning ¼ in. (5 mm) microducts to 24 in. (610 mm) used for bore casings. Several conventions exist in the various available conduit standards that are used for defining HDPE conduit dimensions, i.e. SDR, SIDR, True Size and Schedule Size. The critical dimensions are OD or ID and the wall thickness. The available dimensional standards are detailed in the following subsections.

### 8.2.1 SDR Sizes

The Standard Dimension Ratio (SDR) is a sizing system where the relationship between the average outside diameter and the minimum wall thickness of the conduit is maintained constant through the different conduit diameters. The conduit OD is driven by the IPS (iron pipe size) system, where the actual OD may differ from the trade size. The minimum wall is determined by dividing the actual conduit OD by the SDR. Commonly used SDRs are 9, 11, 13.5, and 15.5. As the SDR number increases, for example SDR 9 vs SDR 13.5, the minimum wall thickness decreases for any given conduit diameter.

One advantage to SDR sizing is the conduit stiffness values remain the same for the entire range of diameters for a given SDR. Stiffness, as calculated per ASTM D2412[11], gives a measure of flexural stiffness of the conduit. Conduit stiffness equals the ratio of the applied load in units of pound-force per linear inch (lbf/in.) to the corresponding deflection in units of inches at 5% deflection. It should be understood, however, that although two conduits, 6 in. and 1¼ in. in diameter, may possess the same pipe stiffness, the amount of soil load required to induce a 5% deflection in each is considerably different. As a result, the sensitivity of smaller diameter conduits to underground obstructions is that much greater.

The tables in ASTM F2160 (ASTM F2160 Tables 5, 6 and 7) and in NEMA TC7 (NEMA TC7 Table 3) illustrate the difference in the load required to induce a 5% deflection in conduits having different diameters but common pipe stiffness values. These values were generated assuming a flexural modulus of 80,000 psi for the HDPE material. Units for pipe stiffness are in pound-force/inch of length/inch of deflection, lbf/(in.·in.), whereas those for the force or loads are presented as pound-force per inch of linear pipe, lbf/in. It is apparent that a fixed external load more easily deflects smaller diameter conduits. It is also important to remember that in long-term loading using an “Apparent Modulus” selected by duration, potentially 50 years, is appropriate and so smaller thin-wall conduits can be quite susceptible to localized loads brought about by buried obstructions. See Chapter 3 Table B.1.1. of this Handbook for more information.

[11] ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

Examples of minimum walls based on the SDR rating can be found in the Table 2 below.

**Table 2 Standard Dimensions for IPS Conduit**

| Trade Size | Average OD | | SDR 9 Wall Thickness Minimum | | SDR 11 Wall Thickness Minimum | | SDR 13.5 Wall Thickness Minimum | | DR 15.5 Wall Thickness Minimum | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | mm | in. | mm | in. | mm | in. | mm | in. | mm |
| **0.50** | 0.840 | 21.34 | 0.093 | 2.37 | 0.076 | 1.94 | 0.062 | 1.58 | 0.060(1) | 1.52 |
| **0.75** | 1.050 | 26.67 | 0.117 | 2.96 | 0.095 | 2.42 | 0.078 | 1.98 | 0.068 | 1.72 |
| **1.00** | 1.315 | 33.40 | 0.146 | 3.71 | 0.120 | 3.04 | 0.097 | 2.47 | 0.085 | 2.15 |
| **1.25** | 1.660 | 42.16 | 0.184 | 4.68 | 0.151 | 3.83 | 0.123 | 3.12 | 0.107 | 2.72 |
| **1.50** | 1.900 | 48.26 | 0.211 | 5.36 | 0.173 | 4.39 | 0.141 | 3.57 | 0.123 | 3.11 |
| **2.00** | 2.375 | 60.33 | 0.264 | 6.70 | 0.216 | 5.48 | 0.176 | 4.47 | 0.153 | 3.89 |
| **2.50** | 2.875 | 73.00 | 0.319 | 8.11 | 0.261 | 6.64 | 0.213 | 5.41 | 0.185 | 4.71 |
| **3.00** | 3.500 | 88.90 | 0.389 | 9.88 | 0.318 | 8.08 | 0.259 | 6.59 | 0.226 | 5.74 |
| **4.00** | 4.500 | 114.30 | 0.500 | 12.70 | 0.409 | 10.39 | 0.333 | 8.47 | 0.290 | 7.37 |
| **5.00** | 5.563 | 141.30 | 0.618 | 15.70 | 0.506 | 12.85 | 0.412 | 10.47 | 0.359 | 9.12 |
| **6.00** | 6.625 | 168.28 | 0.736 | 18.70 | 0.602 | 15.30 | 0.491 | 12.46 | 0.427 | 10.86 |
| **8.00** | 8.625 | 219.08 | 0.958 | 24.34 | 0.784 | 19.92 | 0.639 | 16.23 | 0.556 | 14.13 |
| **10.00** | 10.750 | 273.05 | 1.194 | 30.34 | 0.977 | 24.82 | 0.796 | 20.23 | 0.694 | 17.62 |
| **12.00** | 12.750 | 323.85 | 1.417 | 35.98 | 1.159 | 29.44 | 0.944 | 23.99 | 0.823 | 20.89 |

**Note:** The minimum wall thickness dimension for trade size 0.50 is 0.060.

### 8.2.2 SIDR Sizes

The Standard Inside Dimension Ratio (SIDR) is a sizing system where the relationship between the average ID for a given internal diameter trade size and the minimum wall thickness is maintained constant through the different conduit diameters. Using this method, the minimum wall thickness is determined by dividing the conduit's average ID by the SIDR number. Commonly used SIDRs are 9, 11.5 and 15 for HDPE conduit as shown in Table 3.

**Table 3 Standard Dimensions for SIDR Conduit**

| Trade Size | Average ID | | SIDR 9 Wall Thickness Minimum | | SIDR 11.5 Wall Thickness Minimum | | SIDR 15 Wall Thickness Minimum | |
|---|---|---|---|---|---|---|---|---|
| | in. | mm | in. | mm | in. | mm | in. | mm |
| 1.00 | 1.049 | 26.64 | 0.117 | 2.96 | 0.091 | 2.32 | 0.070 | 1.78 |
| 1.25 | 1.380 | 35.05 | 0.153 | 3.89 | 0.120 | 3.05 | 0.092 | 2.34 |
| 1.50 | 1.610 | 40.89 | 0.179 | 4.54 | 0.140 | 3.56 | 0.107 | 2.73 |
| 2.00 | 2.067 | 52.50 | 0.230 | 5.83 | 0.180 | 4.57 | 0.138 | 3.50 |
| 2.50 | 2.469 | 62.71 | 0.274 | 6.97 | 0.215 | 5.45 | 0.165 | 4.18 |
| 3.00 | 3.068 | 77.93 | 0.341 | 8.66 | 0.267 | 6.78 | 0.205 | 5.20 |
| 4.00 | 4.026 | 102.26 | 0.447 | 11.36 | 0.350 | 8.89 | 0.268 | 6.82 |
| 5.00 | 5.046 | 128.17 | 0.561 | 14.24 | 0.439 | 11.15 | 0.336 | 8.54 |

### 8.2.3 True Size

True Size conduit uses a variation of the SIDR sizing system where the ratio uses the average true trade size ID as a starting point for determining the minimum wall. There are two standard dimension ratios used for this method, either DR 9 or 11. As shown in Table 3 and Table 4 for example, the average ID for a 1¼ in. SIDR is 1.380 in. but for True Size it would be closer to the stated trade diameter of 1.250 in. as the minimum ID.

**Table 4 Standard Dimensions for True Inside Conduit**

| Trade Size | Average ID | | SDR 9 Wall Thickness Minimum | | SDR 11 Wall Thickness Minimum | |
|---|---|---|---|---|---|---|
| | in. | mm | in. | mm | in. | mm |
| 1/2 | 0.510 | 12.95 | 0.057 | 1.44 | 0.046 | 1.18 |
| 3/4 | 0.760 | 19.30 | 0.084 | 2.14 | 0.069 | 1.75 |
| 1 | 1.000 | 25.40 | 0.111 | 2.82 | 0.091 | 2.31 |
| 1-1/8 | 1.135 | 28.83 | 0.126 | 3.20 | 0.103 | 2.62 |
| 1-1/4 | 1.260 | 32.00 | 0.140 | 3.56 | 0.115 | 2.91 |
| 1-3/8 | 1.385 | 35.18 | 0.154 | 3.91 | 0.126 | 3.20 |
| 1-1/2 | 1.510 | 38.35 | 0.168 | 4.26 | 0.137 | 3.49 |
| 2 | 2.013 | 51.13 | 0.224 | 5.68 | 0.183 | 4.65 |

### 8.2.4 Schedule sizes

Schedules 40 and 80 are two more dimensional conventions available for HDPE conduit. The OD for schedule sizes follows the IPS dimensions for determining each diameter's OD, but the schedule sizing convention does not use a standard dimension ratio for determining a conduit's wall thickness and must be obtained from tables. For a given schedule and as OD increases, the ratio of wall thickness to OD decreases.

To help demonstrate these changes, relative dimension ratios for schedule diameters can be calculated by dividing the minimum wall for each size into its average OD. As shown in the Table 5 below, the relative ratio increases as the diameter of the conduit increases resulting in the wall thickness decreasing. This changing dimension ratio is important to understand because it means a schedule sized conduit's strength rating is changing over the diameter range. The net results are smaller diameters have very heavy walls with high strength but conversely the larger diameters have thinner walls with lower strength.

**Table 5 Standard Dimensions for Schedule Sizes 40 and 80**

| Trade Size | Average OD | | Schedule 40 Wall | | | Schedule 80 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Wall Thickness Minimum | | Calculated DR | Wall Thickness Minimum | | Calculated DR |
| | in. | mm | in. | mm | | in. | mm | |
| 0.50 | 0.840 | 21.34 | 0.109 | 2.77 | 7.7 | 0.147 | 3.73 | 5.7 |
| 0.75 | 1.050 | 26.67 | 0.113 | 2.87 | 9.3 | 0.154 | 3.91 | 6.8 |
| 1.00 | 1.315 | 33.40 | 0.133 | 3.38 | 9.9 | 0.179 | 4.55 | 7.3 |
| 1.25 | 1.660 | 42.16 | 0.140 | 3.56 | 11.9 | 0.191 | 4.85 | 8.7 |

| Trade Size | Average OD | | Schedule 40 Wall | | | Schedule 80 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Wall Thickness Minimum | | Calculated DR | Wall Thickness Minimum | | Calculated DR |
| 1.50 | 1.900 | 48.26 | 0.145 | 3.68 | 13.1 | 0.200 | 5.08 | 9.5 |
| 2.00 | 2.375 | 60.33 | 0.154 | 3.91 | 15.4 | 0.218 | 5.54 | 10.9 |
| 2.50 | 2.875 | 73.03 | 0.203 | 5.16 | 14.2 | 0.276 | 7.01 | 10.4 |
| 3.00 | 3.500 | 88.90 | 0.216 | 5.49 | 16.2 | 0.300 | 7.62 | 11.7 |
| 4.00 | 4.500 | 114.30 | 0.237 | 6.02 | 19.0 | 0.337 | 8.56 | 13.4 |
| 5.00 | 5.563 | 141.30 | 0.258 | 6.55 | 21.6 | 0.375 | 9.53 | 14.8 |
| 6.00 | 6.625 | 168.28 | 0.280 | 7.11 | 23.7 | 0.432 | 10.97 | 15.3 |

### 8.2.5 Considerations for Bore Casings

Bore casings, on the other hand, offer situations that can benefit from close ID control. Many times, several innerducts are tightly fit into a casing so SIDR sizes may be more relevant in these cases. The conduit wall in this case can be increased or decreased relative to external loads and stiffness requirements without jeopardizing the inside clearance fit. Internally sized dimension conduits tend to preserve the minimum ID above the nominal conduit size, whereas, externally sized conduits often fall below the nominal ID as the wall thickness increases.

### 8.2.6 Wall Thickness and Couplings

For most conduit installations, SDR sizing is utilized. One key advantage is that OD control lends itself to more controllable joint formation using external couplers because the ODs are fixed for each diameter across the entire range of SDR wall types. Whereas, for SIDR sizes, the OD range for a given conduit diameter fluctuates as the SIDR rating wall thickness changes. For this reason, it may be necessary to provide multiple coupler designs for a given SIDR diameter in order to accommodate the wide variance in ODs that occurs for a given diameter as the wall type changes.

Coupler performance is very important when air-assisted placement methods are used for placing the cable. This is because, any loss of air due to a leaky coupling will result in reduced the cable installation distances that can be achieved, negatively impacting cable installation efficiencies and increasing cost.

Due to greater conduit ovality in larger diameters that are coiled, effectively joining these sizes using mechanical couplers can be challenging without the use of rerounding tools. One effective method that is commonly used for joining larger diameters (Trade size 4 and greater) is to utilize butt fusion as a means of joining. Typically butt fusion equipment has clamps that hold, reround and align the ends during joining, which helps assure alignment and producing a superior high strength connection. In fact, butt fusion and electro-fusion are the only acceptable joining methods for horizontal directional drilling because the fusion joint’s tensile strength equals or exceeds the conduit’s full strength.

### 8.3 Short-Term and Long-Term Stress as Related to Installation Method

Selecting the appropriate wall thickness becomes a function of either the installation method or the nature of environmental stresses that the conduit will be exposed to over its service life. Frequently the stresses the conduit will experience during installation have a greater impact on determining the wall thickness than in-service conditions. For example, horizontal directional drilling may place very high tensile and external compressive loads on the conduit during installation resulting in the need for a heavier wall thickness to avoid damage during installation.

The viscoelastic nature of HDPE resin results in differences in the observed mechanical properties as a function of time and temperature. Chapter 3 of this handbook explains this in more detail, but, in summary, the apparent stress/strain behavior of the material is time–dependent under the influence of a sustained load. This is referred to as "creep" properties. In this regard, the "short-term" measured properties, such as those exhibited during a laboratory tensile test at a strain (stretching) rate of two inches per minute, should be distinguished from the "long-term" measured properties typical of conduit placement and sustained service loads.

Knowledge of the load-bearing capability of PE as a function of loading rate allows one to select appropriate strength values to substitute into design equations. Loads are applied to conduits both by the environment that they are placed into and by the placement means under which they are installed; the chief difference being the duration over which the load is applied.

For example, a common means to install multiple conduits is to directly plow them into the ground using either a railroad plow or tractor-drawn plow. During this installation process, a certain amount of bending and tensile stress is encountered over a rather short period of time (seconds to minutes). Whereas, after the plow cavity collapses about the conduit, the ground continues to settle with stones that may begin pressing directly against the conduit, thus setting up a long-term compressive load.

For this installation method, both long-term and short-term moduli are required to assess the deflection resistance. Initially the conduit may offer resistance to ovalization, but in time, the conduit may yield under the sustained load, resulting in a reduced pathway for the cable. Most conduit burial depths are a maximum of 36 in. so compressive loads at this depth are generally insignificant considering the typical wall thickness of conduit specified for the installation techniques of HDD or plowing.

Numerous approaches to placing conduits have evolved over the years. Each method presents its own unique set of challenges with respect to the potential for conduit damage, or installation related issues. One way to compare the potential sensitivity to damage of the various methods is shown in Table 6.

Here the potential for damage is depicted by a numerical scale ranging from 0 to 5, where 5 is the most severe condition, resulting in yielding and permanent deformation of the conduit; 4 is the potential for loads greater than 75% of yield stress; 3 represents loads greater than 50%; 2 representing greater than 25%; 1 less than 25%; and 0 representing no significant load at all. The shaded areas depict the most severe condition.

**Table 6 Relative Damage Sensitivity vs. Installation Method**

| Installation Method | Short-Term Loading | | | | Long-Term Loading | | Recommended SDR Range |
|---|---|---|---|---|---|---|---|
| | Tensile | Bending | Crushing | Impact | Crushing | Tensile | |
| Innerduct* | 3 - 5 | 3 | 2 | 1 | 1 | 1 - 2 | 9.0 – 13.5 |
| Horizontal Bore | 4 - 5 | 2 | 3 - 4 | 0 | 3 - 5 | 1 | 9.0 – 13.5** |
| Direct Plow | 2 | 3 | 4 - 5 | 1 - 2 | 4 - 5 | 1 | 9.0 – 13.5** |
| Continuous Trench | 2 | 2 | 3 - 4 | 1 - 2 | 3 - 4 | 1 | 9.0 – 13.5** |
| Open Trench | 0 | 0 | 1 - 3 | 1 | 1 - 3 | 1 | 11.0 – 17.0 |
| Aerial | 1 - 2 | 3 - 5 | 2 - 3 | 1 | 1 | 2 | 11.0 – 13.5 |

*** The term “innerduct” in this chart refers to the placement of HDPE innerducts into a buried 4” to 6” HDPE Casings or PVC conduit typical of the underground telecom plant. The SDR recommendation range attempts to select safe SDRs based upon the potential for stressful conditions.**
**** See PPI TR-46, PPI TN-48 and PPI Conduit Design Calculator.**

It should be noted that the above table is not intended to be representative of all conduits installed by these methods, but is indicative of what can happen when the wrong diameter, wall or material is used. If there is a question check with the supplier for specific design recommendations.

Perhaps the most serious and least controlled problem for cable placement is that of ovalization or kinking of the conduit. Ovalization also is a packaging condition that occurs when conduit is coiled: conduit flattens out as it is coiled. This condition can also be brought about through tensile yielding, severe bending, excessive sidewall loading, or probably more frequently, the point loading action of rocks in the underground environment. In direct plow or bore applications, one gets little feedback from the process to indicate that a potential problem is developing. For these applications, the most robust conduit design should be considered. See TN-61 - *Coilable HDPE Conduit Ovality and Coil-Set* for more information.

## 8.4 Bending Radii Limits Determination

Conduit experiences directional changes during placement, and pulling tension must be increased to complete the pull. It is important to determine the minimum radius to which the conduit can be bent without mechanically degrading the performance of the conduit. Table 7 provides the minimum unsupported bend radius for some common sizes.

**Table 7 Minimum Bend Radius based Pipe Installed in Open Cut Trench[12]**

| Dimension Radio, DR | Minimum Cold Bend Radius |
|---|---|
| 7, 7.3, 9 | 20 x Pipe OD |
| 11, 13.5 | 25 x Pipe OD |
| 17, 21 | 27 x Pipe OD |

Ovalization is independent of tensile strength or modulus, but is mostly influenced by diameter, wall thickness, and bending radius.

Ovality is calculated as:

$$\% \, Ovality = \frac{Maximum\ OD - Minimum\ OD}{Maximum\ OD + Minimum\ OD} \times 200$$

In addition to the potential for ovalization caused by installation, i.e., too tight of a bend, ovality is also a packaging condition. When larger diameter conduit is wound on a reel some initial ovality is apparent. ASTM F2160 specifies manufacturing ovality of ≤7 % for ≤2 in. conduit and ≤10 % for greater than 2 in through to 3 in. diameters. Larger diameters can have ovality of up to 20 % resulting from being wound on a reel or coiled so rerounding is suggested in these situations. See PPI TN-61 for more information on conduit ovality and coil-set.

## 9 Conduit Installation

This section reviews various underground installation methods, above ground installation methods (aerial) and installation of innerducts within existing ducts or casing pipes. Considerations related to the mechanical stresses and limits for each of the methods are discussed. The next section provides information on the installation of cables within ducts.

PE conduit can be wound onto reels with conduit lengths several thousand feet long. The length and flexibility allow navigation around unexpected obstructions below ground or within existing ducts and casings. Therefore, manufactured bends or elbows can be virtually eliminated. The few joints that are required can be made reliably through a number of options.

HDPE conduit is suitable for all methods of duct and cable installation, including trenching, direct plow and installation into existing populated larger conduits and casing pipes. Also, the flexible nature of HDPE conduit facilitates directional bore installations to traverse under obstacles like rivers or highways. Special HDPE products and accessories are also available for above ground or aerial applications.

### 9.1 Below Ground Installation

Generally, the three primary underground installation (or “OSP/Outside Plant”) methods are trenching, plowing and boring, described in general terms below.

[12] Source: PPI Handbook of Polyethylene Pipe- 2nd Edition, Chapter 7, Table 4.

Conduits intended for buried applications are commonly differentiated into two classes, rigid and flexible, depending on their capacity to deform in service without cracking, or otherwise failing. HDPE conduit can safely withstand considerable deformation without fracturing and is, therefore, classified as a flexible conduit.

Flexible conduits deform vertically under earth load and expand laterally into the surrounding soil. The lateral movement mobilizes the soil's passive resistance forces, which limit deformation of the conduit. The accompanying vertical deflection permits soil-arching action to create a more uniform and reduced soil pressure acting on the conduit. HDPE stress relaxes over time to decrease the bending moment in the conduit wall and accommodates local deformation (strain) due to imperfections in the embedment material, both in the ring and longitudinal directions.

The relationship between pipe stiffness, soil modulus (stiffness), compaction and vertical loading is documented by the work of Spangler and Watkins[13]. The pipe stiffness, as measured by ASTM D2412, and Spangler's Iowa formula provide a basis for prediction of conduit deflection as related to dimension ratio and resin modulus. It should be noted, however, the duration of loading affects the pipe stiffness, so the long-term modulus should be used. Additional information pertaining to soil embedment materials, trench construction and installation procedures can be found in Chapter 7 *Underground Installation of Polyethylene Piping* of this Handbook.

Flexible conduit has the potential to fail due to stress cracking when localized forces (for example, from a large sharp rock) exceed the material's ability to relax and relieve stress. Although current HDPE resins suitable for conduit applications have excellent stress relieving properties to avoid these failures, the design process should include consideration of the conduit resin's stress crack resistance, as well as the selection of appropriate embedment material and compaction. See Chapter 7 of this Handbook for more information.

### 9.1.1 Trenching Methods

There are many variations on trenching installations, but generally the two main variations are the traditional "open trench" method and "continuous" trenching.

#### 9.1.1.1 Open Trench/Continuous Trench

As the name implies, open trench installations involve digging an open trench using a backhoe, laying the conduit directly into the trench, and then placing an initial cover using the appropriate embedment material, as detailed below. Use of the appropriate embedment material and compaction to cover 6-8 inches over the conduit crown is critical to protect the conduit from damage due to the surrounding soil.

In Continuous Trenching, the conduit payoff moves along with the trenching process. This installation is accomplished with specialized trenching machines that cut the trench and remove the soil in a single action and can be used to place

[13] See Chapter 6 of PPI Handbook of Polyethylene Pipe- 2nd Edition

multiple conduits over long or short distances.

#### 9.1.1.2 Digging the Trench

The trench should be dug as straight, level and free of protrusions as possible. Avoid direction changes tighter than the conduit's allowable bend radius (see Table 7). When field forming a bend for a change in trench direction undercut the inside corners to assure the radius of the bend is correct. Should there be a significant grade change, slope the trench bottom leading into and out of the grade change to support the conduit and maintain a recommended bend radius.

Perpendicular trenches to the main trenchline may be required for connections to access or enclosure locations. Trench intersections should be excavated to provide adequate space to make sweeping bends to assure the minimum bend radius is not exceeded for the conduit.

Excavate the trench to the desired depth, and remove all rocks and large stones from the bottom of the trench to prevent damage to the conduit. Push some clean fill (fine material, without stones) into the trench and compact to provide a firm level trench bottom for the conduit as it is installed in the trench.

#### 9.1.1.3 Placing the conduit

A good practice to ensure long-term protection of underground facilities is to utilize proper bedding for conduit. Sand or gravel provides a more stable embedment around the conduit, protection against damage from sharp rocks, and allowing water to drain away from conduit easily.

An important consideration for open-trench installations of HDPE conduit is that conduit should be straightened to remove any residual "coil memory". Coil memory can create a helical path as the conduit is placed in an open trench. If installed and left unaddressed, this will cause greater resistance during cable installation, and shorten the cable installation lengths that can be accomplished.

Conduit pay off can be accomplished by pulling the conduit into the trench from a stationary reel or by laying the conduit into the trench from a moving reel, usually attached to a trailer. Laying the conduit out along the trench path prior to installation can help to reduce coil memory by allowing it to relax. Care should be taken to pull off the conduits slowly to prevent them from overturning creating excess slack as the conduit is "paid-out" possibly causing the conduit to become tangled.

Spacers should be used when placing multiple ducts in a trench. As shown in Figure 8, spacers organize and prevent the ducts from twisting over and around each other. By keeping the ducts in straight alignment, cable-pulling tensions will be reduced. When water is present in the trench, or when using extremely wet concrete slurry, floating of the conduit can be restricted through the use of anchored spacers.

Figure 8 Example of a Duct Spacer

#### 9.1.1.4 Backfilling

It is best to place the select soil, free of large rocks or clumps and that is easily compacted, directly on and around the conduit to a height of 6 inches over the conduit crown. DO NOT place large rocks directly on the conduit. Allow at least 6 inches (15.3 cm) of clean, uniform soil above the conduit crown, after which the natural backfill can be returned to the trench. The apparent change in soil condition also provides warning as any digging nears the conduit structure. This should not replace the practice of placing warning tape, but rather should serve as a supplement.

Fill the trench and compact as required to provide compaction and prevent the trench backfill from settling.

During backfill, warning tape should be placed typically 1 to 3 feet above the conduit.

### 9.1.2 Direct Plow

Plowing is the preferred installation for long continuous runs where soil conditions, space and an unobstructed route permit (e.g. in rural areas). As shown in Figure 9, plowing installations use a plow blade (pulled by a tractor or mounted to a railroad car) to cut a furrow in the earth and place the conduit at the required depth through the plow’s chute. The key distinction between plowing and continuous trenching is that trenching involves the actual removal of soil from the trench, whereas plowing only displaces soil as the plow is dragged through the ground while laying-in the conduit.

Consult the equipment manufacturer for specific recommendations on plow blade and feed tube designs. It is strongly recommended to have a professionally engineered single or double feed tube plow blade with a tube at least 0.5 inch (1.25 cm) larger than the largest conduit size and a radius no smaller than the minimum bend radius (see Table 7) of the largest conduit size.

PPI Technical Report TR-7 (Pipe Stiffness and Flattening Tests in Coilable HDPE Conduit and Its Relationship to Burial Depth in Conduit Applications), uses pipe design and soil mechanics to show SDR13.5 or heavier wall conduit is adequate to resist the compressive forces generated by external soil loading.  However, in plowing installations, the significant bending over the dozer and through the plow test the deflection and buckling resistance of the conduit, as illustrated in Figure 9.  Therefore, a minimum SDR11 is recommended for plowing installation.  Where rocky soils are encountered, SDR9 or heavier conduit should be considered to overcome uneven and point loading.

Local regulation may require for a warning tape to be plowed in simultaneously at a depth of 1-3 feet above the crown of the conduit. Most plow manufacturers make plow blades capable of burying the HDPE conduit and tape at the same time

#### 9.1.2.1 Plowing Variations

There are several variations of plowing installations. A few are described briefly below:

- Vibratory Plowing – This method uses a vibrating blade and may allow use of a smaller tractor than used for static plowing.
- Rip and Plow – This method may be required when significant obstructions (for example, roots) are anticipated and uses an additional lead plow (without conduit) to cut an initial furrow in the ground and clear obstructions ahead of the primary plow with conduit.
- Pull-Plow Method – Instead of installing from a reel fed down through the plow chute, conduit is pulled from a stationery reel behind the plow as the furrow is cut. Typically for this method the plow blade is designed with an expander for creating a hole ahead of the conduit as it is being pulled into place.

**Figure 9 Example of Vibratory Plowing of Conduit**

### 9.1.3 HDD (Horizontal Directional Drilling) aka "Directional Bores"

HDD allows the installation of conduit under obstacles that prevent use of the plowing or trenching installation methods, for example under rivers or highways. The HDD method has become ubiquitous in urban areas where trenching would cause severe disruption to traffic and cause significant restoration costs. This installation method capitalizes on several unique features of HDPE conduits. These features are flexibility, tensile strength and long lengths enabling directional bores over very long distances.

HDD is accomplished using a steerable head drilled through the earth to create a pathway for the conduit. The equipment operator can control the depth and direction of the bore. A detailed discussion of this installation method is presented in Chapter 12 *Horizontal Directional Drilling* of this Handbook. Also, consult the manufacturer of the brand of HDD equipment being used for detailed operating procedures and safety precautions.

Designing the directional drilling pathway should include consideration of tensile forces and bend radii to which the conduit will be subjected. Flexible conduits installed in continuous lengths are susceptible to potential tensile failures if the wall thickness is under designed, as shown in **Figure 10**. The allowable tensile force (aka "safe pull strength") is calculated based on the yield strength of HDPE with a safety factor. The engineer should also account for the allowable bend radius, especially on unsupported bends to prevent ovalization and kinking.

**Figure 10 Tensile Failure of Conduit Due To Overstress During Pulling**

For conduit installation, HDD methods are, by definition, “mini-HDD” meaning the diameters are limited to less than or equal to 8 in. and the bore lengths of less than 1,000 ft. This contrasts with “maxi-HDD” where pipe diameters can exceed 30 in. and lengths can be measured in miles. Mini-HDD for conduit design is based on less investigative information and therefore is more conservative. The PPI PCD (Power and Communications Division) has published software to guide the contractor or designer to determine the wall thickness required for various diameters and bore distances, visit the PCD page at www.plasticpipe.org for a link to the calculator. Also see PPI Technical Report TN-48[14] on mini-HDD. The software is based on PPI TN-48 and PPI TR-46 *Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High-Density Polyethylene Pipe*.

The following subsections provide an overview of key aspects of HDD installation. Refer to PPI TR-46 and TN-48 for more details.

#### 9.1.3.1 Setback

Operation of HDD equipment is beyond the scope of this chapter; however, as illustrated in Figure 11, the following are some general considerations for directional bores. (A full discussion of drill rig set up and set back distances are discussed in PPI TN-46)

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[14] PPI TN-48 Guidelines for Choosing Wall Thickness for HDPE Conduit Based on "Mini-HDD"

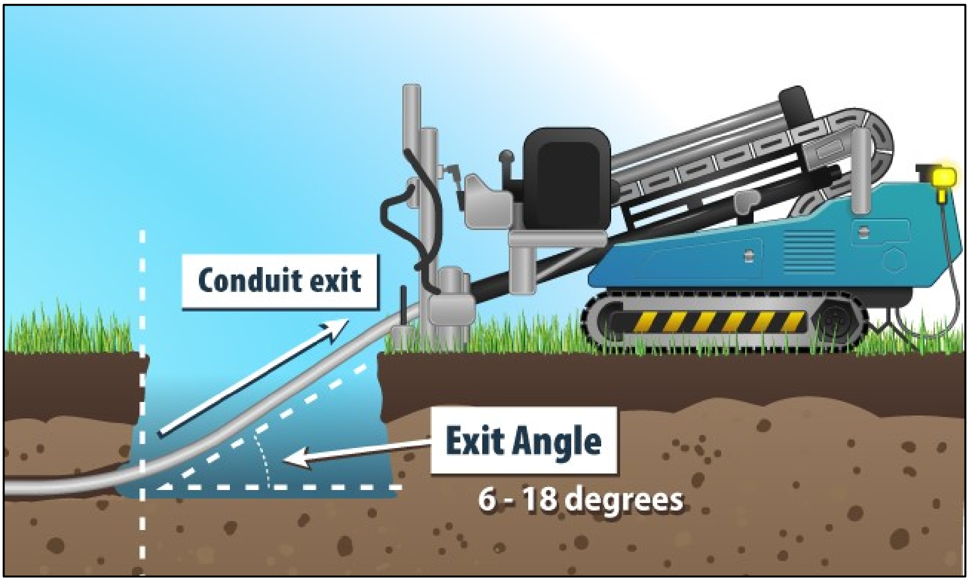


**Figure 11  Considerations for mini-HDD of Conduit**

Generally, the setback distance is governed by the site conditions, the drill rod diameter (larger diameter drill rods have less curvature than small diameter drill rods), the allowable entry angle and the depth of the bore path. Position the machine back far enough so the maximum bore depth can be obtained without over-bending the drill string or the HDPE conduit being installed (see minimum bend radius Table 7). Depending on the rig size and entry angle, the distance may vary from 3-20 ft. (1-6 m) behind the entry point.

The distance between the leading edge of the machine and the point where the drill pipe enters the ground should be as short as possible. The entry angle is usually 8-16 degrees, although entry angles up to 20 degrees have been used on some larger diameter projects.

#### 9.1.3.2 Drilling Fluids

Friction from the drilling and backreaming process creates heat. Drill head tracking electronics are sensitive to high temperatures and must be protected. Heat will build up if a constant flow of drillings fluids out of the annular space is not maintained. Moving the drill head in the bore path without the use of drilling fluid may also build up damaging heat, reducing component life.

Soils that are cut away by the drill bit or the backreamer must be moved in order to make room for the HDPE conduit. The drilling fluids mix with cuttings into a flowable slurry that can be moved out of the bore path during the backreaming step.

Drilling fluids maintain the integrity of the bore path especially in loose or soft soils. An example is bentonite slurry in sandy soils. The bentonite forms and stabilizes the bore wall to help prevent the walls along the bore path from caving-in around the drill string or HDPE conduit as it is being pulled back through.

Additionally, drilling fluids provide the necessary lubrication to enable the conduit to slide with less friction in sticky soils, such as clays and silts. The drilling fluid significantly reduces friction and the amount of torque required to rotate both the drill rod and backreamer. Drilling fluids also cool and reduce frictional wear on the drilling components extending their useful life.

#### 9.1.3.3 Backreaming

The function of the backreamer, illustrated in Figure 12, is two-fold; 1) enlarging the bore hole size enough to allow for the pullback of conduit or bundle of conduits, and 2) mixing and removal of the bore hole cuttings with the bentonite slurry. The result is a borehole with bentonite slurry large enough to accommodate and lubricate the conduit package on the pull back. The backreaming process is essential to the successful completion of the bore. Not only is it necessary to use the proper drilling fluid, it is also important to use the adequate amount of drilling fluid.

Good slurry flow requires, at a minimum, a 50/50 ratio of drilling fluids to solids. A higher drilling fluid to solids ratio can be beneficial especially in drier, more reactive soils.

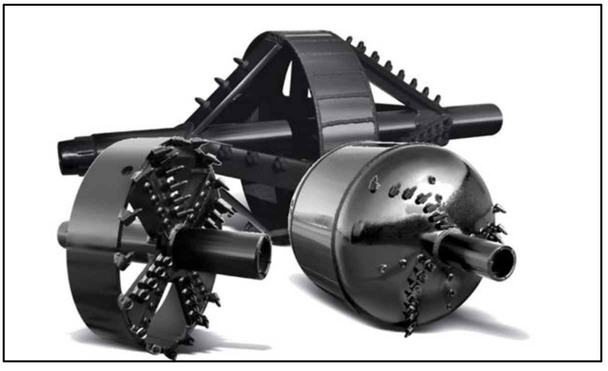

**Figure 12 Backreamers**

#### 9.1.3.4 Torque Limiter

The drill rig torque limiter's essential function is to ensure the drill will not build excess thrust/rotation pressures over what the operator has deemed and selected as the drill limits (i.e., red lines). It is critical to note that these limits measure system pressure at the rig and **not at the connection point** (e.g., break-away swivel or product connection) and should not be confused with the tensile pullback forces being experienced by the conduit. Overstressing the conduit (pulling stresses higher than the safe pull (tensile) strength) is one of the results of a failed bore installation. As the pullback progresses and more conduit is in the ground, bore pullback forces could increase as well.

### 9.2 Innerduct Installation into Existing Conduit or Casing (Conduit Network Pulling)

A large conduit can be subdivided by pulling in several smaller conduits (innerducts). These innerducts provide opportunity for multiple network owners along the pathway. Some innerducts can also be left empty for future cable placement or populated with fiber cable but not "lit" (known as dark fiber).

In the telephone and electrical utility industries, the underground network is often comprised of 3, 4, and 6 in. conduit banks. These "rigid" conduits are constructions of clay tile, cement conduit, or more recently, PVC conduit. They are usually separated by manhole vaults or buried pull-boxes.

Department of Transportation (DOT) regulations often require casing pipes as additional protection for buried conduits in road bores and traffic areas. Although steel casings have been used in the past, it is becoming more prevalent to horizontally bore under roadways, or waterways, and pull back an HDPE casing into which HDPE innerducts are installed.

The placement of manholes and pull-boxes and distances between them are largely a function of the following constraints:

- Location of branch circuit intersections
- Lengths of cables (or innerducts) available on reels
- Physical access limitations
- Path difficulty for placement of cable or innerducts
- Surface environment
- Method of cable placement (mid-assist access)

There are a number of variables that influence loading and selection of innerducts when pulling into conduit structures:

- Diameter of conduit and innerduct, and number of innerducts to be installed
- Clearance or fill ratio
- Length of the conduit run
- Direction changes of the conduit run, i.e. sweeps
- Type of pipe casing, which determines the coefficient of friction between the casing and innerducts
- Jam ratio combinations, see Section 8.1.1
- Pull speed and temperature
- Elevation and innerduct weight

It is outside the scope of this chapter to address these constraints and variables in detail. Some direction on pull placements of inner ducts can be learned from traditional cable placement methods. Several good references on this subject exist, including *Guide For*

*Installation of Extruded Dielectric Insulated Power Cable Systems Rated 69KV Through 138KV* [15], *Underground Extruded Power Cable Pulling Guide* [16].

Some important installation steps are discussed in the following subsections.

### 9.2.1 Preparation

Before placement of the innerduct inside the conduit can be started, it is important to have all of the necessary equipment to protect the innerduct. The use of sheaves, bending shoes, rolling blocks (45 and 90 degrees) and straight pulleys are required for protection of the innerduct during installation. It is important that they all meet the proper radius for the innerduct size. The use of a pulling lubricant will greatly reduce the tension and stress on the innerduct as it is being pulled into an existing conduit. Ball bearing swivels are needed for attaching the winch line to the innerduct harness system.

### 9.2.2 Proofing

An important step that should be taken prior to innerduct installation is "proofing" the existing conduit to ensure that all obstructions are cleared and that pathway continuity and alignment is acceptable. It is recommended that a flexible proofing mandrel roughly 80% of the inner diameter of the casing pipe be pulled through prior to placing the innerduct.

For shorter run lengths, proofing conduit can also be performed by pushing a fiberglass fish and pulling back a flexible mandrel that has been attached to the fish tape end. Any problem areas should be felt as the fish tape is pulled back and should then be marked on the fish tape so that the distance to the problem is recorded and, if necessary, can be located for repair. If the fiberglass fish makes its way through the conduit without any difficulties then the conduit has "proofed-out" and no repairs should be necessary.

### 9.2.3 Friction Considerations and Length Recovery Allowance

The stress of pulling innerduct through existing conduit will vary. Factors such as the length of the route, the number of directional changes, along with the age and condition of the conduit will contribute to the amount of friction. As innerduct is being pulled into place these factors are critical to determining the amount of lubrication to be used. The effect of the pulling stress will cause the innerduct to elongate (i.e., stretch) in proportion to the amount of stress, but should be no more than 5% of the total length placed provided the innerduct is not over stressed as it is pulled into place. For this reason, it is important to monitor the tensile load being placed on the innerduct during installation. Accounting for elongation is important by pulling additional slack to compensate for the distance the conduit ends will pull back

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[15] AEIC CG4, Guide For Installation of Extruded Dielectric Insulated Power Cable Systems Rated 69KV Through 138KV, Association of Edison Illuminating Companies, 2nd edition, 1997.
[16] AEIC CG5, Underground Extruded Power Cable Pulling Guide, Association of Edison Illuminating Companies, 3rd edition, 2015.

during recovery to the original length. If possible allow the conduit to relax over night to assure full recovery prior to cutting and coupling.

## 9.3 Above Ground/Aerial

There are many applications for aerial conduit, which include, but are not limited to, road crossings, rail crossings, trolley line crossings, and water crossings. Aerial conduit provides an efficient means of supporting and protecting cable. It also provides one or more pathways for easily replacing and adding cables without requiring encroachment in often hazardous or difficult to access locations.

A critical consideration for aerial applications is UV protection. For this reason, only conduit materials with special carbon black pigments should be used. Please refer to the applicable conduit product standard for more information on UV protection.

### 9.3.1 Installation

There are two preferred methods for aerial installation of conduit. One is the back-pull method from a stationary reel up into place through a series of pre-positioned blocks and rollers along the route. The other is the drive-off moving reel method where the conduit is hoisted up into position at various intervals. Circumstances at the construction site and equipment/manpower availability will dictate which placement method to use.

### 9.3.2 Expansion/Contraction Considerations

As a rule of thumb, exposed conduit that is unrestricted can expand or contract about 1 in. for every 10 °F change in temperature for every 100 feet in length.

For lashed conduit, there is a greater likelihood of conduit to move within the lashing. Therefore, design consideration must be given to the expansion/contraction potential of the HDPE conduit.

Expansion/contraction concerns are less likely with the use of self-supporting conduit because the conduit is integrally connected to the steel strand which helps restrict the movement of the conduit.

### 9.3.3 Back-Pull/Stationary Reel Installation Method

The back-pull from a stationary reel method is the usual method of aerial conduit placement. This method is also best suited for locations where the strand changes from the field side of the pole to the street side of the pole and where there are excessive obstacles to work around. The conduit is run from the reel up to the strand, pulled back by an overlash cable puller that only travels forward and is held aloft by the cable blocks and rollers. Once the section of conduit is pulled into place, it is lashed and then cut.

### 9.3.4 Drive-Off/Moving Reel Installation Method

The drive-off/moving reel method may realize some manpower and time-saving in aerial conduit placement and lash-up. This method is used where there is existing strand and it is on one side of the poles, typically roadside. The conduit is attached to the strand and payed off a reel moving away from it. The conduit is being lashed as it is pulled.

#### 9.3.5 Self-Supporting Conduit

Installation of self-supporting conduit can be accomplished by both of the above methods, the difference being that the support strand is an integral part of the conduit. This product not only simplifies installation by eliminating the step of independently installing a support strand, it improves the controllability of the expansion-contraction properties of the conduit.

#### 9.3.6 Over-lashing Existing Cable

Over-lashing conduit onto existing cable plant is similar to installing conduit onto new strand. However, there are some unique aspects.

A sag and tension analysis should be performed to see if the new cable load will overwhelm the strand. Also, over-lashing conduit on top of sensitive coaxial cables may influence the cables signal carrying capability due to rising lashing wire tensions that may result from contraction-induced movement of the conduit. It is best to seek the help of engineering services in planning an aerial plant.

### 9.4 General Installation Safety and Structural Considerations

This section discusses various conduit installation options in general terms and should not be interpreted as a step-by-step guide or "operations manual." The user should contact the equipment manufacturer for more detailed instruction, as operating procedures will vary with equipment. Refer to the Section 8 *Conduit Design Considerations* of this chapter for more information. Additionally, refer to PPI TN-58 *HDPE Conduit & Duct Handling Guide* for guidance on the proper methods for loading, unloading and handling of conduit and reels.

**SAFETY NOTE:** The consequences of striking gas or power lines (above and below ground) during installation can be dangerous, possibly deadly. Before digging, it is critical to ensure that all existing underground service lines (gas, water, power, etc.) in the vicinity are located and marked. It may be necessary to pot hole or physically expose existing obstacles prior to starting installation. It is recommended, and may be the law, to contact the local "Call Before You Dig" agency to ensure these provisions are made. Furthermore, prior to installation, consult NEC, NFPA and NESC[17] codes, as well as any applicable local codes.

**SAFETY NOTE:** ALWAYS test and ventilate manholes prior to entering into them and follow OSHA confined space requirements.

Regardless of the installation method, mechanical stress is of great concern during conduit placement. Exceeding the maximum allowable safe pulling tension or not respecting the minimum allowable bending radii can damage conduit. Consult the conduit supplier for allowable pulling tensions.

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[17] National Electrical Safety Code

When planning the conduit pulling placement, notation and consideration should be given to the number of sweeps, bends and location of directional changes that will be encountered.

Tail loading is the tension on the conduit caused by the conduit's weight in addition to the force required in turning the reel plus resistance from reel brakes, if used. Tail loads can be reduced using minimal braking during the pay-off of the conduit. No braking is preferred as it is preferred that the reels be rotated either mechanically or by hand to maintain some slack in the conduit as it pays from the reel to minimize the required pull force.

Breakaway swivels (shown in Figure 13), or some form of tension monitoring should be placed on the conduit to ensure that the conduit's safe working pulling tension specified for the diameter/wall type is not exceeded. Swivels should be placed between the winch line, or drill rod, and pulling grip joined to the conduit. If pulling multiple conduits, it is recommended to use a staggered pulling harness in conjunction with a breakaway swivel.

**Figure 13 Break-Away Swivel**

## 10 Cable Installation

With cable-in-conduit products (CIC), the cable comes pre-installed in the duct. Where not previously installed or where additional cables may be desired, installing cables in conduit or innerduct can be accomplished in a number of ways. These include:

- Pulling cables into the conduit using a pull line or rope with puller
- Blowing cable into the conduit using specialized equipment that pushes the cable in conjunction with a high volume jet of air to pull or help propel the cable.

The following subsections detail these methods and then discuss the importance of lubrication with cable installation.

### 10.1 Placement Planning

Curvature in the conduit run is the greatest deterrent to long pulls. Some curvature is unavoidable due to path layout, e.g. elevation changes, direction changes, etc.

On the other hand, sloppy installation techniques can introduce more curvature than would otherwise be planned. For example, open trench work without proper tensioning and bedding can lead to installations that severely limit cable placement.

Equations for calculation of accumulated frictional drag have been derived for pulling in cables and can be found on the worldwide web or the cable manufacturer's literature. These calculations are comprised of multiple combinations of straight sections and sweeps added together for estimating the total pulling load placed on the cable in a conduit section to be pulled end to end. If the cable has appreciable weight, the transition to sweep up or sweep down in any direction results in significant differences. Additional consideration should be given to multiple conductor power cables, certain combinations of cable multiples and free volume result in jamming configurations.

Push-blow techniques are also greatly affected by friction. As noted previously, pre-lubricated ducts, or very light applications of silicone emulsions, produce the best results. Techniques that predominantly rely on air to accelerate the cable work best with lightweight cables. As cable weight increases, systems with greater pushing power and piston seals provide improved performance.

A split insert is two halves of a metal fitting that seals between the cable and the conduit. It also seals between the conduit and the blowing machine within the chamber where the air is to be injected. Insert sizing is sized for the conduit/cable sizes to be installed using the air-assisted or push-blow installation methods (see Section 10.6.1.3). In pulling cables, a greater free volume in the conduit is better and maximum fill ratios based on cable and duct diameters are around 60 percent (see Section 8.1). Conversely, maximum fill ratios in air-assisted and push-blow installations are closer to 75 percent fill and the minimum is approximately 50% (see Section 8.1). These parameters minimize axial movement of the fiber cable, which increases frictionally generated stress, while the upper bound limit promotes efficient airflow through the conduit.

Placement planning for fiber cable installation is critical because the cable lengths are so long. Typically, one would locate a point along the route possessing similar accumulated frictional drag in either direction. Part of the cable is then installed to one end of the run, then the cable is laid out in a figure-8 to recover the opposite free end. The free end is then installed into the other end of the run. It is not uncommon to place 3,000 to 6,000 feet over any given span, and to gang placement equipment at mid-assist intervals along the path to deliver over 20,000 feet continuously in one direction. Using proper combinations of conduit design, installation method, lubrication and placing equipment, it is possible for crews to install over 40,000 feet of cable per day.

## 10.2 Pulling Cable into Conduit

The traditional method of installing cables in conduit, particularly power cables, has been to attach a pull rope, or line, to the cable and pull the cable into the conduit using cable pulling equipment. This placement method requires pulling equipment to do the actual pulling, to apply lubricants to reduce friction, and devices that measure the amount of tension being applied to the cable. Pull ropes/tapes are available with sequential footage marks. This type of tape is useful in determining the progress of the cable pull.

Empty conduit would require a pull line to be installed. This is accomplished by blowing/vacuuming a pull line directly or blowing a lightweight line through the conduit using compressed air. If a lightweight line is used then this line is typically used to haul a pull line or a winch line into the conduit to pull the cable. A pulling mechanism with a take-up reel is used to haul the pull line with the cable attached. The puller should have a calibrated apparatus to monitor the amount of tension being placed on the cable during the pull. This device is extremely critical for fiber and coax cables, which are highly sensitive to tensile forces during the pull. Check with the cable manufacturer to determine the maximum amount of tension a specific type of cable can safely withstand.

Conduit may also be supplied with a pre-installed pull line/tape. This line is typically either a round twisted rope or a flat woven tape. These pull lines come in a wide variety of tensile strengths that range from 500 – 6,000 lbf (1,000, 1,250 and 2,500 lbf pulling tapes are typical). Pull lines are also available pre-lubricated to reduce friction.

When the cable is attached to the pull line, it is recommended that a swivel attachment be used between the two. This swivel will allow the cable and pull line to move independently in the conduit during the pull and prevent unnecessary twisting of the cable or pull line.

Reducing friction potentially allows longer cable pulls and reduces the risk of damage to a cable during the pull. Not all cables require the use of cable pulling lubricants. Self-lubricated cable and non-lubricated cables used in conjunction with cable pulling lubricants reduce the amount of friction placed on the cable during a pull.

The use of mid-assists may be required on very long pulls. Mid-assist equipment can be as simple as a person pulling on the cable midway or it can be a capstan type device that provides a controlled amount of pulling tension to the cable to reduce the tension on the cable and increase the potential pull length of the cable.

If the conduit is in a manhole, protective devices are needed to guide the cable into the manhole and then into the conduit. These guides protect the cable from damage to the cable sheath and/or insulation.

### 10.3 Air-Assisted (aka Blowing and Jetting)

In recent years the practice of pulling cable has frequently been replaced with a newer method that uses compressed air to blow the cable into the conduit. Section 0 provides a detailed outline of the blowing procedure while this section provides an overview. Cable blowing requires specialized equipment that utilize high volume air compressors. There are two categories of air-assisted cable placement: Low Volume/High Pressure, and High Volume/Low Pressure.

With Low Volume/High Pressure, a dart seal is attached to the end of the cable and compressed air is introduced into the duct building pressure behind the seal placed on the end of the cable, forcing the dart forward and creating a tensile pull on the end of the cable. At the same time, the cable is pushed into the conduit through a manifold seal using a tractor pusher. The cable experiences simultaneous push and pull forces. Low Volume/High Pressure is also used for jetting into microducts minus the seal on the end of the cable. Volume is less important in the smaller microducts but high pressure is needed to overcome pressure resistance and to create enough airflow to assist propelling the lightweight microcables through the microduct.

With High Volume/Low Pressure, the cable is tractor fed into the conduit, again through a manifold seal, but this time it has no dart seal. Instead, cable progress is based on the viscous drag of high volume air alone. With these methods of cable installation, much longer lengths of cable can be placed than traditional cable pulling methods and the tension applied to the cable is significantly reduced.

When blowing cables into conduit, the use of corrugated conduit is not recommended. Corrugated conduit causes turbulence of the air that disrupts the flow of air in the conduit reducing the distance a cable can be blown.

The conduit joint/coupling needs also to be capable of withstanding the pressure of the air being introduced. Generally, the maximum back-pressure used is in the range of 125 psi for standard conduit sizes but for microducts the pressure could reach more than 200 psi.

Caution should be exercised when using compressed air to pressurize the conduit as a loose joint connection or a buildup in pressure and a sudden release can lead to injury due to the catastrophic failure of the conduit wall or connection.

### 10.4 Cable Installed by the Conduit Manufacturer (Cable-in-Conduit)

Some producers of conduit have the capability of installing cable while the conduit is being extruded. Each conduit producer has specific size and length limits, and it is necessary to discuss with the producer the type of cable you desire to be installed: its size, type of material and length.

Most producers can lubricate the conduit during this process to allow easy movement of the cable in the conduit for future removal and replacement if needed.

Cable can be tested prior to and following installation to guarantee the integrity of the cable. Check with the conduit producer for specific information on testing the cable.

The applicable specifications for Cable-in-Conduit by the manufacturer are ASTM D3485 and UL 1990.

### 10.5 Coefficient of Friction in Conduit Systems

Coefficient of Friction is a critical limiting factor in determining the type and length of the cable installation. Although only an overview of cable installation is provided in this guide, this section has been made available as a background reference on frictional properties. Check with manufacturers for additional detailed installation information.

Definitions:

- **Friction:** the nature of interaction occurring between two surfaces. The basis of friction has its roots in the mechanical and physical-chemical makeup of the interface created by bringing together two surfaces.
- **Coefficient of Friction, CoF:** the ratio of the force required to move a body relative to the normal, or clamping force, acting to keep the bodies together. In the case of fiber optic cables, BellCore GR-356[18] for conduit recommends a maximum of 0.20 for lubricated conduits, and GR-3155[19] for microducts recommends a maximum CoF of 0.15.
  - **Static CoF:** the ratio of forces required to bring about the onset of motion between two bodies at rest with each other.
  - **Kinetic CoF:** the ratio of forces acting on a body already in motion. It is essentially a measure of the effort required to keep the body in motion.

### 10.5.1 Friction Reduction

Friction reduction can be promoted by reducing mechanical interactions, grounding electrostatic charges, reducing polar interactions, selecting dissimilar polymers, and employing methods and mechanisms that act to dissipate heat. Although many times little can be done to control the composition of cable jacket materials, choices can be made to select friction-reducing conduit designs and lubricating mechanisms.

The use of lubricants is strongly recommended during the placement of the conduit or cable, or may be included in the manufacturing process of the conduit. Typical lubrication methods include:

- **Water-soluble lubricants** are available in many different forms including low viscosity free-flowing liquids, creamy consistencies, and stiff gels. Low viscosity liquids are best suited for placement of long lengths of lightweight cables, such as fiber cables. Heavier, cream-like consistencies are useful on lightweight power conductors. Stiff gels are used in vertical applications in buildings or where high sidewall loads are expected in placement of heavy power cables or innerducts.
- **Polymeric water-soluble lubricants** are commonly used in the field to lubricate the placement of cable, or of the conduits themselves. In this case the lubricant is applied either ahead of, or in conjunction with, the advancing cable. Water-soluble polymer chemistries include a number of different enhancements including surface wetting and cling; modification via fatty acids or their derivatives; or by inclusion of various friction-reducing oils, including silicones.

Conduits may be **pre-lubricated** during the manufacturing process by incorporation of lubricants directly onto the conduit inner wall or via a lubricant-modified

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[18] BellCore/Telcordia GR-356 Generic Requirements for Optical Cable Innerduct, Associated Conduit, and Accessories

[19] BellCore/Telcordia GR-3155 Generic Requirements for Single/Bundled Microducts and In-Living Unit (ILU) Cable Pathways

coextruded layer. The most common type of lubricant used for this type of application is a silicone polymer, although other agents such as mineral oils, fatty acid derivatives and glycols have also found use.

Pre-lubrication finds particular value with fiber cable push-blow systems. Because the sidewall loads with these techniques are quite low compared with pulling, and the distances so great, the viscous drag contributed by water-soluble lubricants can be detrimental. The ultra-light amount of lubricants employed by factory pre-lubrication methods can be a real advantage.

The geometry of the inner surface of the conduit can also play a role in friction reduction. As the normal load increases, the CoF is found to decrease, unless the surface is damaged in such a way so as to increase the contact area, or heat is allowed to build up at a rate faster than it can be conducted away. Ribs formed on the inner conduit wall are a common design feature to reduce friction. Rib designs can be classified as:

- **Longitudinal ribbing** results in a reduction of the contact surface between the cable and the conduit wall from an area of contact to a line of contact. Decreasing the area of contact under the same sidewall load results in a higher localized normal force. Within a limited range of sidewall loads, the CoF is found to go down – at least until the loading results in localized damage to the jacket sheath.
- **Spiral ribbing** further reduces the contact area from a line to a series of points. In addition, because the advancing cable is alternatively on and off the ribbing, there is an opportunity for cooling and re-lubrication. Constantly changing the direction of the spiral eliminates the tendency to accumulate spiral-induced torque in the cable.
- **Transverse ribbing,** or corrugated profiles, results in similar friction reducing geometries. However, there is a tendency for field-added lubrication to be scraped off the cable by the corrugations. In addition, the high degree of flexibility requires careful placement of the duct to reduce the buildup of friction due to additional path curvature.

### 10.5.2 Field Effects of Friction

Burn-through results when the winch line or cable develops so much frictional heat that it melts its way through the conduit wall. There are a number of factors that exacerbate this condition including: sidewall load/pressure, pull speed, conduit and pull-line coefficient of friction.

Aside from lubrication, sidewall loading/pressure may not be easily reduced; however, speed of pulling is controllable by the operator. Because PE and other thermoplastics are such good insulators, frictional heat build-up can go unchecked. Slower pull speeds combined with water-based lubricants or reduced COF pull ropes can help reduce the rate of heat accumulation.

PVC elbows are commonly used for transitions out of the underground plant. Unfortunately, PVC not only has a higher CoF than HDPE conduit but also tends to soften with the onset of heating at a much faster rate. On the other hand, HDPE conduit has a lower inherent CoF (about 0.35 vs. >0.40 for PVC) as well as a higher heat capacity due to its semi-crystalline nature.

Pull-line/rope construction also plays a significant role in burn-through. Polypropylene ropes or even PE pull-lines exhibit low CoF at low sidewall loads, but rapidly cut through both PVC conduit and PE conduit when the load increases. The tendency of these materials to soften, combined with high structural similarity to PE, limit the pull load range over which they may be used. Polyester and polyaramid (e.g. Kevlar®) pull lines, particularly in tape form, offer greater protection from burn through. Some pull rope manufacturers provide reduced CoF constructions for this purpose.

Some of the factors that impact burn-through are:

- **Sidewall loading/pressure** results any time a cable or pull-line is pulled about a sweep or bend. Dividing the tension in the pull-line by the radius of the bend may approximate the magnitude of the load. Obviously, the smaller the radius, the greater the magnitude of load.
- **Speed,** as noted above, is a critical variable in the operator's hands that can often spell the difference between success and failure. Speeds that are too low can result in a lot of mechanical interaction, whereas an excessively high-speed results in heat build-up.
- **Compatibility** (of the pull line and conduit material**),** in conjunction with high sidewall loading/pressure, can be a problem – not only for higher relative friction, but also is a key determinant in burn-through.
- **Contamination** with inorganic soils roughens or damages the surfaces of both conduit and cable jacket and increases the mechanical interaction between them. In addition, the embedment of small particles increases hydrogen bonding with water that may be in the conduit, further enhancing the interaction of jacket with conduit.

### 10.6 Cable-Air Installations

Cable-air installations, in which air is used in pre-installed ducts, are referred to by several different names; HASB (High Air Speed Blown) cable or cable jetting, and Air-Assisted installation or Push-Pull installation. These installation methods are divided into two types or methods:

- Cable jetting or HASB - A method for installing cable in pre-installed duct utilizing a balance between a low strain pushing force and high-speed air flow along the cable outer surface. Also known as push/blow. With this method there is virtually no pulling force at the cable end as the drag forces that move the cable are distributed equally along the entire length of the cable thereby eliminating traditional pulling forces at the cable-end, as illustrated in **Error! Reference source not found.** . This method allows for virtually stress-free installations and is very efficient in ducts where multiple bends and undulations are present.

- Push-Pull or Air-Assisted Installation – As illustrated in Figure 15, an air capturing device (parachute, carrier or piston) is attached to the cable end. With this method the mechanical pusher forces the cable into the duct where air is captured at the cable-end creating a pulling force on the cable. Pulling forces exerted are less than those when winching but significant enough to allow for friction between the cable jacket and duct inner wall where bends are present which will typically slow or reduce speed and/or distance. This method is most efficient where duct runs are relatively straight and less efficient where bends and undulations are present.

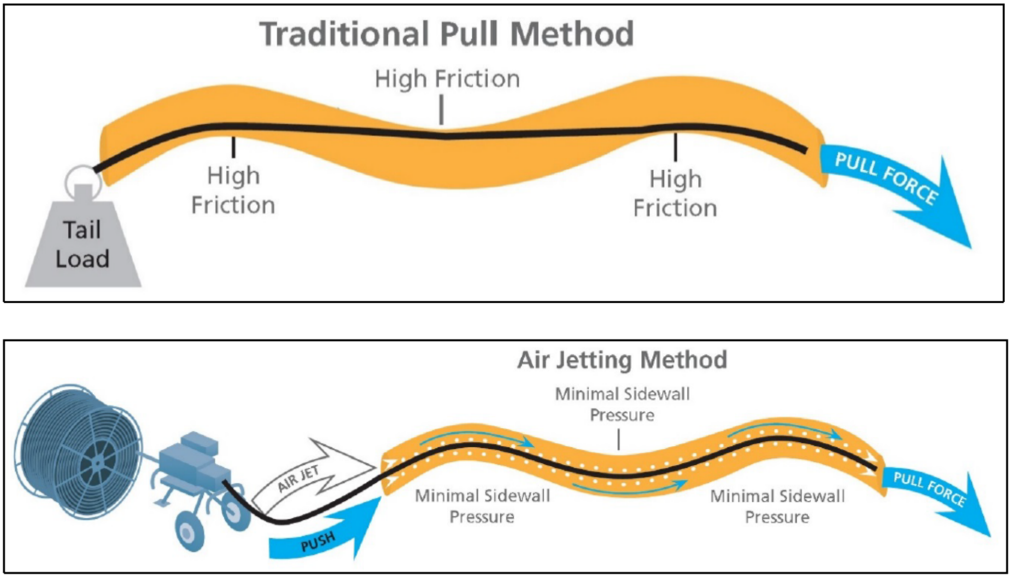


**Figure 14 Comparison of Traditional Pull Method to Cable Jetting Method - Showing How Friction is Reduced with Air Jetting**

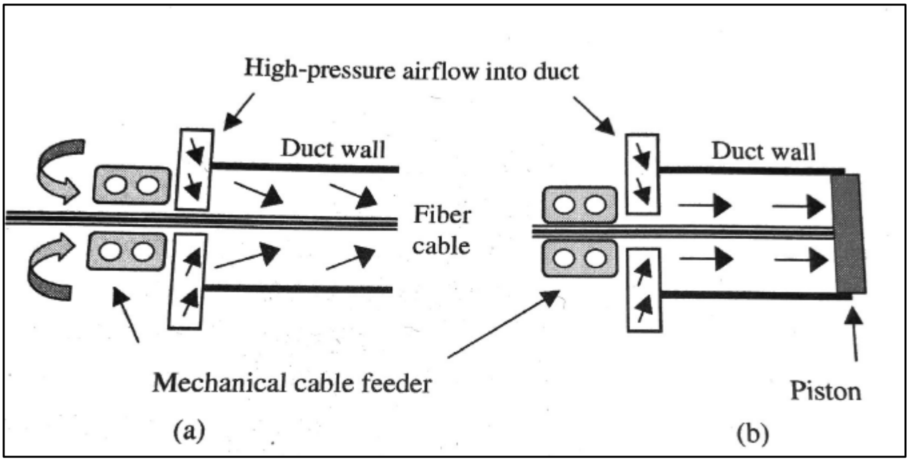


**Figure 15 On left, Push-Blow (aka Jetting) Method. On right, Push-Pull Method**

The following subsections provide detailed considerations when conducting cable-air installations.

### 10.6.1 Phases of a Successful Cable Air Installation

The following subsections break the cable-air installation into the primary steps of:

- Preparation
- Machine selection, setup & crash test
- Cable-duct fill ratio
- Air testing the duct
- Lubricating the duct

#### 10.6.1.1 Preparation

A site survey and/or review of a workprint of the installation should be reviewed by the project owner and the cable installation company (if not one and the same) to determine overall lengths to be installed and distances between manholes/handholes for equipment placement. These will also determine splice points and slack loop locations. It should be determined, if not already known, that the duct is properly spliced with air-tight couplers and whether there are any "open" points or problem areas in the duct route to be anticipated. Cable reels should also be checked to ensure that sufficient lengths are available for the job as designed and that the proper cable type and fiber count is per specification. Installing the wrong cable can be a costly mistake.

Prior to set-up of the blowing equipment, see Table 8 to ensure that air compressors are sufficiently sized for the duct into which the cable will be installed. Also ensure that all personnel have proper safety equipment (e.g. safety glasses, ear protection, hard hats and vests) and are properly trained in the use of blowing equipment and air compressors by the manufacturer and/or suppliers of the equipment.

**Table 8 General Air Compressor Size Recommendations for OSP Ducts & Cable Installations**

| Duct ID (inch) | Capacity (CFM) | Pressure Range (psi) |
|---|---|---|
| **0.625 - 1.00** | 185 | 100 - 175 |
| **1.00 - 1.25** | 250 | 100 - 175 |
| **1.25 - 1.50** | 375 | 100 - 175 |
| **1.50 - 2.00** | 450 | 100 - 175 |
| **2.00** | 600 - 750 | 100 psi |

**Note:** Pressure ranges are general recommendations only. Consideration must be given to the condition and integrity of the duct system and couplers used in the duct system. DO NOT exceed operating pressures recommended by the manufacturer of cable-air installation system or the duct manufacturer. (From Sherman + Reilly Fiber Optic Cable Placing Manual)

Air compressor requirements for microcable/microduct installations require significantly lower capacity ratings (85 to 200 CFM) at higher pressures as designated by the equipment manufacturer, e.g. 85 CFM @ 230 psi for a 7 mm microcable installed in a 12.7/10 mm microduct. Follow the specific duct and equipment manufacturer recommendations.

#### 10.6.1.2 Machine Selection

There are many different machine models available for a variety of cable-air installations, inside plant (ISP) and outside plant (OSP) alike, covering fiber/cable diameters as follows:

- Air-Blown Fiber (ABF): <1 mm OD
- Microcable: 1 mm to 12 mm OD
- Standard Outside Plant: cables ranging from 3 mm to 36 mm OD

Examples are shown in Figure 16. Due to this vast range of fiber/cable sizes, no one machine is suitable for all types of installations. The various machine models are also designed for specific size ducts or inner ducts commensurate with fiber/cable sizes listed above as follows:

- ABF Tubes/Ducts: 3 to 7 mm OD for cables <1 mm
- Microducts: 5 to 27 mm OD for cables 1 to 8 mm
- Outside Plant (OSP) Ducts: ¾ to 2.0 in. ID or 1.05 to 2.375 in. OD
- Outside Plant (OSP) Cables: 0.40 to 1.40 in. OD

**Note:** Some cable manufacturers designate cables up to 12 mm as microcables

**Figure 16 Cable Jetting Machines**

#### 10.6.1.3 Machine Set-Up

All brands of jetting and blowing equipment are slightly different; however, they are all designed to fit multiple duct and cable sizes or outer diameters. Selecting the correct duct and cable inserts whether for OSP, ISP or microducts is important, as detailed below. Cable inserts, illustrated in Figure 17, provide the appropriate sealing between cable and conduit.

**Figure 17 Example of Cable Insert**

#### 10.6.1.3.1 OSP or Inner Duct Insert Selection

It is extremely important to properly measure both duct and cable diameters. Not having the proper size insert to perform the installation can result in a costly delay. It is important to note that standard OSP ducts, although referred to by their inner diameter, must be fitted to the outer diameter of the duct, i.e., a 1¼ in. SDR rated duct may have an inner diameter (ID) of 1.25 in. / 31.75 mm, but it is the outer diameter (OD) of 1.66 in. / 42 mm to which the machine's duct insert must be fitted. To clarify, what is referred to as an inch and a quarter duct does not dictate the correct insert and selection. Always measure the OD of the duct to be fitted, otherwise a massive blow-out or leak is probable.

#### 10.6.1.3.2 Microduct Insert Selection

As some microducts were designed to be installed into innerduct or OSP ducts, they are referred to by their outer diameter rather than inner diameter. Being referred to by their OD helps to determine the fill ratio inside of the larger protective duct's inner diameter. This makes the insert selection easier since the OD of the microduct matches exactly to the size/number on the duct insert, i.e., 12 mm microduct is fitted into a 12 mm insert.

#### 10.6.1.3.3 Cable Insert Selection

Cables may be identified by fiber count or outer diameter. They are fitted by outer diameter. When jetting or blowing cables, the fiber count is NOT significant to the operator when choosing the cable insert. All that is important is that the OD of the cable must match the proper cable insert. Most cable inserts cover a small range of cable diameters to which various size cable seals are available for a precise fit. For example, a 0.75 in. / 19.05 mm OD cable requires an 18 - 22 mm range insert. To fit this cable properly a #20 mm seal is selected, which is slightly larger than the 19.05 mm cable. The seal selected is always slightly larger than the cable OD to channel airflow properly but not bind on the cable creating friction. A seal too tight creates friction and can inhibit production, whereas a seal too large (over 1.5 mm larger than the cable OD) can cause air loss which will also inhibit production.

Finally, all other sealing materials must be in place in the air chamber and the machine should be clean and all moving parts properly lubricated. The proper sized drive, rollers or tracks must be selected and tensioned properly.

#### 10.6.1.3.4 Crash Testing

Prior to beginning any cable-air installation, it is recommended to perform a "crash test." A crash test is used to determine the maximum push force allowable on any cable and duct combination to avert any operator error in over-driving or damaging a fiber cable on the actual job due to a manual operator error in exerting excessive push forces. The crash test is performed with a short piece (10-15 ft) of the subject cable and duct. Although some machines are designed with auto safety shut-off mechanisms, it is always a good idea to pre-determine the maximum limits of push force. This test will instruct operators not to exceed push force limits required for any given cable installation and is the best insurance against potential on-site fiber damage that can be very disruptive and expensive. Consult the manufacturer of your equipment for detailed instructions on performing a crash test.

**Note:** The smaller the fill ratio (cable OD to duct ID ratio), or with the installation of small cables in large ducts, the greater the risk of cable damage from excessive push force. This is especially true with dielectric, non-armored cables.

#### 10.6.1.3.5 Cable-Duct Fill Ratios

As discussed previously in Section 8, the optimum OSP cable-to-duct fill ratio is 2:1, i.e., a cable with an outer diameter of 0.50 in. would have optimum placing performance in an inner duct with an inner diameter of 1.0 in. or 50% fill. As the outer diameter of the cable is increased in the 1.0 in. ID duct, the installation performance will tend to decrease in terms of relative speed and distance. As also mentioned previously, there are many other performances affecting variable such as cable stiffness, weight, etc., but, as a rule, as the cable diameter increases the performance will decrease. As fill ratios exceed 80%, a rapid decrease is usually seen in performance.

Microcables in microducts typically have a slightly higher fill ratio than OSP cable in innerduct installations. Since the introduction of microcable/microduct technology around 1999, most cable manufacturers began producing microcables with fill ratios rising from 50% to near the 65% range. This was somewhat dictated by the necessity to install as many microducts as possible into the protective inner duct for economic maximization. Sometimes maximizing the number of microducts adversely affected the inner diameter of the microducts which created the higher fill ratio. That said, higher fill ratios with microduct is common and unless unusually high, performance tends to be acceptable.

#### 10.6.1.3.6 Installing Microducts into Outside Plant Innerducts or Protective Ducts:

Microducts, from 7 - 27 mm outer diameter, are designed to be jetted or blown, not pulled if placing over longer distances, as illustrated in Figure 18. Due to their smaller outer diameter, excessive pull tensions can more easily be reached causing damage. Typically, microducts that are pulled should be pulled over shorter distances to avoid damaging the microducts during installation. Most microducts have a tensile strength rating of between 50 - 450 lbf so pulling tensile loads need to be carefully monitored. Microducts < 18 mm must be pressurized to approximately 100 psi to provide improved resistance to the compressive loading of the pusher's conveyance belts for better pushing performance.

When jetting into innerducts, single microducts or bundles of microducts may be installed. If multiple microducts (bundles) are to be installed in a single innerduct, the jetting/blowing equipment requires special tracks and inserts to perform this special function. Cable installation crews need special training for this application. Contact your cable installation equipment provider for proper instruction in safely installing and handling these microducts.

**Figure 18  Jetting Microduct**

Alternatively, as shown in Figure 19, there are pre-bundled microduct products available in the market that are already incased in an outer HDPE sheath. All that is necessary is installation of the microcables into each individual microduct making up the oversheathed microduct bundle. The oversheathed multi-duct can be bored (HDD), plowed or trenched.  Additionally, it can be pulled into a conduit with a pull line, or a rod can be pushed through the end of the conduit and then the over-sheathed product pulled back. It should be noted that oversheathed units themselves, under 1.40 in. in diameter may be installed with a cable air system in ducts 2 in. ID or smaller.

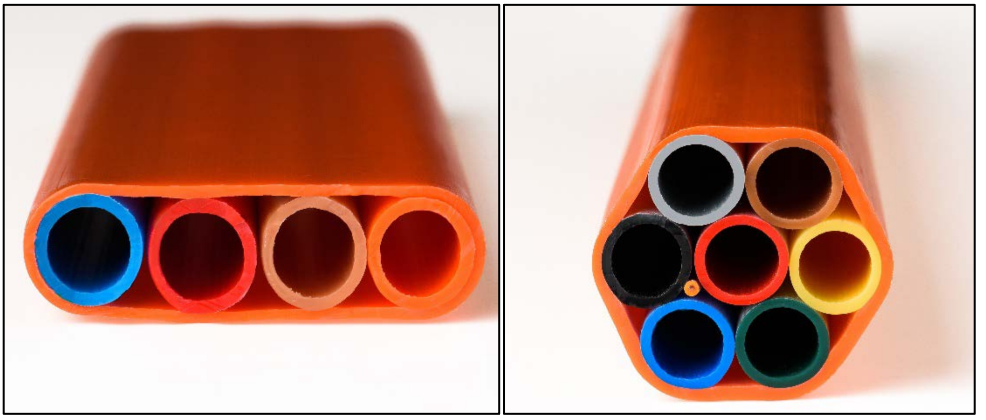

**Figure 19 Oversheathed Microduct Product**

### 10.6.1.4 The Installation

#### 10.6.1.4.1 Air Testing the Duct

Prior to installing the cable, the duct should be air tested to be sure there are no leaking or improperly assembled couplers within the duct route. Test each duct section by putting air on the system and assessing air loss by observing the air pressure gauge on the machine and/or feeling the air at the exit end of the duct section. Low air pressure gauge measurements on duct sections over 1,000 ft or more indicate probable air loss. Little or no air velocity at the duct end indicates air loss as well.

The air should be allowed to run for several minutes to determine pressure/flow loss and to detect if there is any water or debris in the duct system. The next step is to introduce a foam spreader or plug into each duct run. This will help to dislodge any water and/or debris. If water is present, continue to blow foam spreaders through the duct until the water is only a fine mist at the duct-end before starting the cable install.

**Safety Note:** Be sure the duct open end is clear and routed in a way such that it is aimed safely away from any person or object that might incur damage as a result of the expulsion of high velocity, high-pressure air, debris and/or water.

#### 10.6.1.4.2 Lubricating the Duct

It is always recommended to use cable jetting or blowing lubricants as it will insure the best co-efficient of friction reduction for the installation regardless of the type of material of which the duct is made. Maximum CoF values are 0.2 for conduit and 0.15 for microducts[18]. Any values above this will incrementally reduce the speed and performance of the cable installation. Follow the lubricant manufacturer's instructions for the quantity of lubricant to be used (depending upon the ID of the duct) followed by a foam spreader. The jetting lubricant can also be dispensed with an automatic lubricating device as offered by some equipment manufacturers.

**Important Note:** NEVER use PULLING lubricants with cable air installations. Air will turn the pulling lubricant into a sticky friction generating material. Use lubricants specifically formulated for air blown fiber installation.

#### 10.6.1.4.3 The Cable Installation

In most cases a few hundred feet of cable may be installed mechanically, without air, in the lubricated duct to help determine a reasonable installation speed, prior to adding air into the duct system. Typically, as the cable begins to slow, the air valve is opened slightly and the cable speed will increase. As shown in Figure 20, the operator monitors the speed, distance, push-force, and air pressure making adjustments to push force and air pressure commensurate with the equipment manufacturers training program and instructions. The specific manufacturer's instruction for the product should always be followed. In the instance of air loss, a coupler failure, compressor, or drive system failure immediately stop the operation and notify all parties of the stop. Correct the problem and safely resume the operation.

**Figure 20 Microcabling**

### 10.6.1.5 Cascading (Use of Multiple Placing Units)

Cascading is the usage of several jetting/blowing machines in series for the purpose of installing extremely long lengths of cable. The average distance under normal conditions for one machine is approximately 3,500 to 5,000 ft. This number can vary depending upon many variables as discussed below in Section 10.6.1.7. An example of cascading effectively would be the use of 3 machines to install a 15,000 ft reel of cable in one section with no splices except at cable ends. Cascading allows for production that was unheard of when pulling cables. There are cases of over

100,000’ of cable being installed in one day by one crew with three (3) machines.

#### 10.6.1.6 Placing Slack Coils

Slack coils, or slack loops, may be placed very quickly using the cable-air method compared to pulling slack loops where the cable to be stored had to be carried with the pullers from hole to hole. The cable-air method for this process is very simple:

- The cable is jetted/blown to the end of the section leaving enough at the end for a splice, usually 50 to 100 ft.
- The duct is opened by removing a split coupler at the manhole/handhole closest to the end of the run where a slack coil is desired.
- The installation resumes at a slow speed until the desired amount of cable is coiled at that location and stored for a future splice.
- If more slack coils are desired, the operation continues to move back toward the cable reel end of the job following the same process.

This is a very simple, safe and fast procedure, as illustrated in Figure 21.

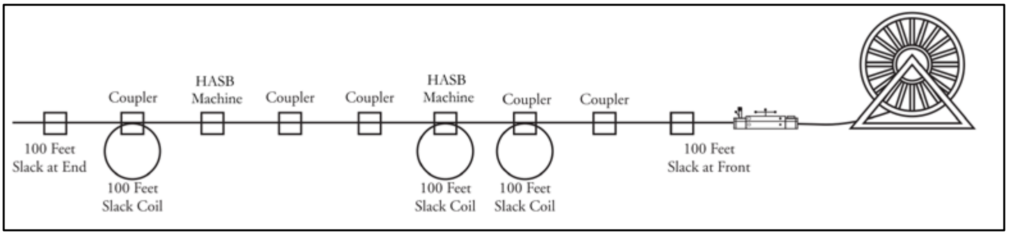


**Figure 21 Example of Slack Coil Placement**

Additionally, by using split couplers (see Figure 22), it is possible to return and open the conduit at those junctures for installing slack loops. Slack loops of from 50 to 100 feet are frequently placed at intermediate access locations, where a full cable splice is not required. Slack loops are placed at locations where only some of the fibers in a cable are to be accessed.

**Figure 22 Split Coupler Example**

#### 10.6.1.7 Variables and Parameters Affecting Installation Lengths

There are many factors that can affect installation distances. Table 9 provides the most significant parameters, some of which are controllable and some which are not. Some manufacturers offer software programs that, with proper data input for the cable installation project, can estimate achievable distances.

**Table 9 Factors Affecting Installation Length for Cable Jetting**

| | |
|---|---|
| Cable Outer Diameter | Cable Weight |
| Cable Stiffness | Intrinsic Cable Curvature |
| Duct Inner Diameter | Coefficient of Friction |
| Undulation Amplitude | Undulation Period |
| Installation Method | Compressor Volume and/or Pressure |
| Compressor Capacity | Pushing Unit |
| Pulling Support | Number of Curves |
| Horizontal Trajectory | Bundle |
| Resident Cables in Conduit | Air Temperature |

The programs will calculate a distance achievable. The only parameters not listed that can have a significant effect on the outcome are heat and humidity. There is currently no viable way to calculate this factor, as there are many variables within these parameters that are unknown until time of the actual installation. There are, however, some cable installation devices that have this capability 'on-board' the device to be used at the installation site.

**Note:** Compressed air can contribute significant heat during installation. For this reason, it is an advisable practice, especially in warmer climates, to utilize an air cooler for cooling the air temperature prior to injection into the conduit.

#### 10.6.1.8 Maintenance

Maintaining the good working condition of jetting/blowing equipment is imperative. This ensures that all mechanical working parts are clean and lubricated, which reduces friction inherent in the machine and is just as important as cleaning and lubrication inside the duct. A machine that is binding-up will overheat thereby reducing performance. A dirty machine will also introduce contaminants into the air chamber causing the cable seals to bind restricting airflow resulting in overheating of the motors. Jetting units should be pressure washed and lubricated on a regular basis to provide optimum performance.

### 10.6.2 Summary

There are many duct and cable installation types and techniques available for "Enterprise" (i.e. ISP), or OSP installations. HASB and Push-Pull installations are the methods of choice, proven by a 25-year experience model as the safer method of installing fiber due to the minimal tensile stresses and the increased speed of installation.

## 11 Joining Methods

Conduit can be joined by a variety of heat fusion and mechanical methods. Since conduit does not experience any long-term internal pressure and acts only as a pathway for power or other cables, the owner of the system may be tempted to neglect the importance of specifying effective couplings. However, an integral part of any conduit system is the type and quality of joining method used. Proper engineering design of a system will consider the type and effectiveness of these joining techniques.

### 11.1 Joint Selection Considerations

The owner of the conduit system should be aware that there are joint performance considerations that affect the system's reliability well beyond initial installation. Some of those might include:

- Pull-out resistance, both at installation and over time due to thermal contraction/expansion and ground movement must be considered. This is critical for "blow-in" cable installations, which will exert an outward force at joints, but less so for pulling installations, which will tend to exert the opposite force. Once conduit is installed, temperature fluctuations are moderated by the surrounding soil, therefore pull-out forces due to temperature expansion/contraction are mitigated. Pull-out resistance due to expansion and contraction should not be confused with the safe pull strength required in HDD (Horizontal Directional Drilling). For HDD, either butt- or electro-fusing the joint are acceptable methods for joining the conduit if the joint is going to pulled into the bore.
- Internal pressures for "blow-in" installations are typically between 125 to 200 psi for a short period. Consider how much leakage can be tolerated without reducing the distance the cable can consistently be moved through the conduit.
- Infiltration leakage, allowing water and/or silt to enter the conduit over time, can create obstacles for cable installation and repair or in above ground installations can cause the water to freeze and compress the fiber optic cables.
- Corrosion resistance is important as conduit systems are often buried in soils exposed to and containing alkali, fertilizers, and ice-thawing chemicals, insecticides, herbicides and acids.
- Cold temperature brittleness resistance is required to avoid problems with installation and long-term performance in colder climates during installation.

### 11.2 General Joining Provisions

HDPE-to-HDPE joints may be made using heat fusion, electrofusion or mechanical fittings, as detailed below. The use of mechanical couplings are often preferred over fusion joints for diameters up to 6". Mechanical couplings allow HDPE conduit to be joined to other junction boxes or other hardware utilized by the communication and electrical industries.

The user may choose from many available types and styles of joining methods, each with its own particular advantages and limitations. Contacting the various manufacturers is advisable for guidance in the proper applications and available styles for joining.

## 11.3 Mechanical Fittings

PE conduit can be joined by a variety of available styles of mechanical fittings, each with its own particular advantages and limitations. This section will not address these advantages or limitations but will only offer general descriptions of many of these fitting types and how they might be utilized. PPI recommends that the user be well informed of the manufacturer's intended applications, performance limits, andjoining procedure for the particular mechanical fitting being used.

### 11.3.1 Barbed (i.e. Hydraulic Press-on) Mechanical Fittings

Barbed fittings are available in various materials and configurations for joining conduit sizes 2 in. and smaller, as shown in Figure 23 (left). Installation involves pressing the fitting over the ends of the conduit to be joined using a special tool. The inside of these fittings contains sharp, inward-facing barbs that allow the conduit to be pressed-in, yet dig into the outer surface of the conduit and resist removal when pulled. They offer excellent tensile strength for plowing operations, and, if installed correctly, have very good internal pressure characteristics for cable blowing applications.

**Figure 23 Barbed Coupler**

### 11.3.2 Threaded Mechanical Fittings

Threaded mechanical fittings are available in various materials and configurations for conduit sizes 2 inch and smaller, as illustrated in Figure 24. Some are designed with sealing capabilities while others are not. The internal thread designs of these fittings are typically tapered similar to pipe threads, with a left-hand thread on one end and a right-hand thread on the other to cut thread paths on the conduit's outer surface. This thread design allows the operator to thread the fitting onto the ends of both conduit sections simultaneously. Some variations of threaded fittings may also be pressed on the conduit ends and used as barbed fittings. The user should consult the fitting manufacturer to determine if this alternate installation method is recommended.

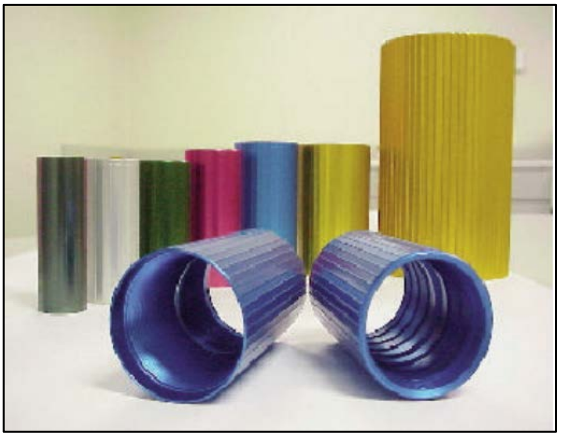

**Figure 24  Threaded Coupler**

### 11.3.3  Compression Coupler

Compression couplers apply compression to the outside wall of the conduit to retain the conduit and create the joint, as shown in Figure 25. As with the other mechanical fittings, compression fittings are also available in numerous designs and for different size ranges. While compression fittings used in the PE pressure piping industries, such as water or gas, typically require internal stiffeners, conduit systems typically do not as stiffeners may create obstacles for cable being blown through the conduit. For any fitting style being considered, consult the fitting manufacturer for available sizes and written instructions on use.

**Figure 25  Compression Coupler**

### 11.3.4  Expansion Joints

Expansion joints are designed primarily for aerial conduit installations. The primary purpose of this fitting design is to absorb thermal expansion and contraction in the conduit system created by ambient temperature changes, which can be extreme in above ground installations. System designers should determine the number of expansion joints required based on the expansion length provided by the fitting and a calculation of the conduit's overall thermal expansion factor for the length of above ground section being joined.

## 11.4 Heat Fusion

The principle of heat fusion is to heat two surfaces to a designated temperature and fuse them together by application of a force sufficient to cause the materials to flow together and mix. When fused in accordance with the manufacturer's recommended procedure and allowed to cool to nearly ambient temperatures, the joint becomes as strong or stronger than the conduit itself in both tensile and pressure properties.

The three primary heat fusion methods used in joining PE conduit are butt, socket, and electrofusion. Butt and socket fusion joints are made using "hot irons" designed specifically for PE joining, while with electrofusion fittings heat is internally generated by electrical current applied to embedded wires within the fitting. More specific information on heat fusion joining practices can be found in Chapter 9 *PE Pipe Joining Procedures* of this Handbook, as well as in ASTM F2620 for the hot iron methods (butt and socket fusion) and in ASTM F1290 for electrofusion.

PPI recommends that users precisely follow the qualified fusion procedures established by the manufacturer of the particular heat fusion joining equipment and fittings being used.

### 11.4.1 Butt Fusion Joining

Butt fusion joints are produced without need of special fittings, using specially developed butt fusion machines, that secure, face and precisely align the conduit for the flat face hot iron fusion process. In the process, the ends of the two conduits to be joined are heated until molten and then brought together and allowed to cool creating a strong joint, as illustrated in Figure 26. It should be noted that the butt fusion process produces an internal bead of equal or larger size than the visible outer bead that can cause restrictions and interfere with cable placement. If internal restrictions are a concern for the cable installation, alternative-joining methods may be more appropriate. As shown in Figure 27, the use of a metal end cap with a rounded end will mitigate potential damage of the fiber, and normally "deflect" off any internal bead during cable installation.

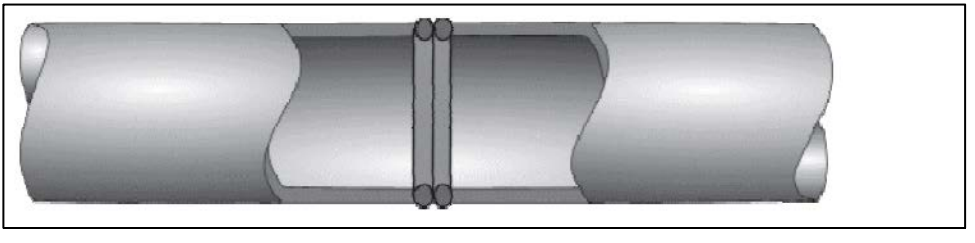

**Figure 26 Illustration of Typical Butt Fusion Joint**

Figure 27 Metal End Caps for Fiber Optic Cable

### 11.4.2 Socket Fusion Joining

This technique requires the use of specially designed hot irons to simultaneously heat both the external surface of the conduit and the internal surface of the socket coupling. Specially designed hand tools are available to maintain alignment and the stab depth of the hot irons until the materials reach fusion temperature. These tools also help secure the heated conduit end and coupling as the joint is made. Design requirements for socket fusion are provided in ASTM D2683 for fittings and in ASTM F1056 for socket fusion tools. As with butt fusion, socket-fused joints may have an internal bead that can interfere with cable placement.

### 11.4.3 Electrofusion Joining

Electrofusion is somewhat different from the hot iron fusion method described previously, the main difference being the method by which heat is applied and the location of the resulting fusion. Electrofusion involves the use of a special electrofusion socket fitting that fits over the ends of the conduit. The fitting has an embedded wire coil. Using a specialized external electrofusion control box, electrical current is supplied to the wire coil heating and melting the inside of the socket and the outside surface of the conduit until they fuse together, as illustrated in Figure 28 . The resulting joint is water tight and as strong as the conduit. No internal bead is generated with electrofusion.

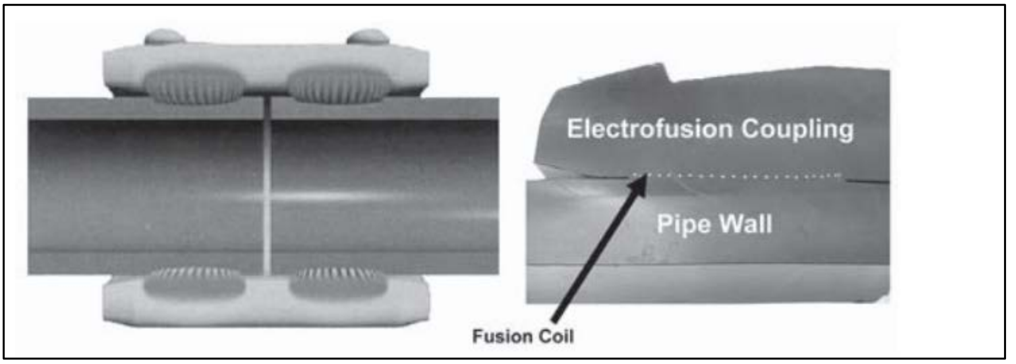


**Figure 28 Illustration of a Sectioned Socket Electrofusion Joint**

### 11.5 Repair Operations

Repair fittings, as the name implies, are often designed specifically for use in repair situations. The nature of the damage will often dictate what types of joints are needed for repairs. For example, of one type of design, a clamp-on style may be preferred when damage is limited and removal of the cable for repair is not necessary. There is a PVC tongue-and-groove semi-circle product that can be made water tight with caulking or two-part epoxy glue. However, in more severe damage situations, where new cable and conduit sections must be installed, many of the joining methods described earlier in this section may be suitable. Ultimately, the type of repair fitting or joint installed should maintain the integrity of the conduit system, prevent infiltration and provide sufficient resistance pull-out from thermal expansion/contraction.

## 12 Special Applications

The following subsections provide an introduction to some specialized products and applications for conduit. For more information, consult with your conduit supplier.

### 12.1 Corrugated Duct

Corrugated conduit has properties that generally make it easier to work with in difficult and confined environments. The corrugated profile of the wall, see Figure 1, provides a greater degree of flexibility and the lack-of-memory that makes it easier to handle when used in confined spaces and other restricted environments, such as “inside plant-premise” applications.

Corrugation design (or profile) greatly affects the properties of the conduit such as compressive resistance and tensile strength. The ASTM standards that cover SIDR and SDR conduit designs do not apply to corrugated duct. All corrugated conduit specifications are specific to the producer. Generally, a minimum ID and a maximum OD is specified. Products vary from manufacturer to manufacturer so check with the source of supply for detailed dimensional and performance specifications.

Corrugated conduit is not appropriate for use in direct buried applications because of its limited crush resistance and the difficulty of laying it in a straight path. It should not be installed using directional drilling equipment due to limited tensile strength and the fact that the corrugations will create significant friction and stretch during the pullback causing the conduit to separate.

Corrugated conduit is also not appropriate for use when cables are to be installed using air-assisted placement as it is relatively thin-walled and may not be able to handle the air pressure of air-assisted placement. The corrugations also create significant air turbulence that is counterproductive to the air-assisted placement systems and reduce the distance cables can be blown.

### 12.2 Multi-Cell Conduit

Multi-cell conduits are designed to meet special needs and unique job situations. There are a number of designs available to meet most of these special needs. Multi-cell conduit can be a product that is installed as an innerduct inside of existing conduits designed to maximize the available space in a vacant or occupied conduit, or it can be a fully assembled conduit with internal conduits that, when installed, provides a multi-channel conduit without the need to install any other innerducts. Some multi-cell designs can be direct-buried like HDPE conduit using standard installation methods (plowing or open trenching). (See TN-59 “Comparison of HDPE Conduit and Fabric Divider as Innerduct” for further information.)

### 12.3 Armored Conduit (Rodent and Mechanical Protection)

When placing cables underground, there are occasional concerns about the need for greater mechanical protection of the cable(s) inside from the cutting and gnawing by animals. Armored Conduit is HDPE conduit that has a layer of metal for additional protection against animal attack.

Armored conduit also provides greater mechanical protection against cuts and abrasions from accidental strikes during excavation of adjacent utilities.

### 12.4 Conduit Building Entry Electrical Applications

Electrical/Building Code regulations vary greatly regarding the placement of conduit into a building. Codes require the use of conduit constructed of a material that is listed for use in specific building areas, and these codes limit the use of HDPE conduit beyond a specific distance after entry through an exterior wall. The greatest variation in local code is the location of the transition from HDPE conduit to a conduit that meets the code requirement (distance from the exterior of the wall). Check your local codes for local amendments.

### 12.5 Premise (Flame Retardant) Comm/Data Applications

In addition to using conduit for installing fiber optic/communication cables in the underground, there are a few other very specialized applications for conduit type products.

With the growing market for data communications systems and IOT (internet of things) within buildings, there has been a concurrent growth in the use of fiber optic/communication cables in buildings as well. As these installations typically place fiber optic/communication cables in the same cable trays and vertical risers as other communications cables and electrical cables, designers and installers have been concerned about identifying and protecting these fiber optic/communication cables. Manufacturers have responded with the development of several types of conduit for building use, or as it is known in the industry, premise wiring.

Premise wiring generally uses plenum air spaces, vertical riser shafts and general-purpose areas to run cables throughout buildings. The types of conduit developed are specific to these environments. Because premise wiring falls into areas generally thought of as locations having greater human health and safety concerns, the NFPA 70 and Underwriters Laboratories have addressed the characteristics needed by conduits to be safely used in premise wiring. These conduit products are generally not made of HDPE due to the flame spread and smoke requirements; however, future innovations may bring acceptable HDPE-based products to this market in the future.

Initial development produced the *Plenum Raceway*, a specialized conduit that meets more stringent Underwriters Laboratories UL 2024 requirements for minimum flame spread and smoke generation than riser rated conduit. Plenum Raceway can be a corrugated conduit or microduct made from plastic materials that do not support flame and produces very low smoke. At this time, PVDF (polyvinylidene fluoride) is the material of choice for Plenum Raceway.

Similarly, *Riser Raceway* was developed for premise wiring applications to be installed in specific locations such as in riser shafts. Riser Raceway meets the Underwriters Laboratories UL 2024 requirements for vertical flame spread. The Riser Raceway requirements are lower than Plenum Raceway. Riser Raceway can also be a corrugated conduit or microduct.

*General-Purpose Raceway* was developed for premise wiring applications in general purpose applications. General-purpose raceway meets the Underwriters Laboratories (UL 2024) requirements for flame spread and has lower requirements than Riser Raceway. General-purpose raceway is typically a corrugated conduit or microduct, which is currently produced from either PVC or polyamide materials.

All conduit products for use in riser, plenum, or general raceway applications are required to be marked with the application specific product standard and a Listing

Mark from a nationally recognized independent certification laboratory (e.g. UL, ETL[20], CSA, etc.,) to demonstrate that the product has been tested and meets the requirements for installation in the specific application. Plenum Raceways are permitted to be placed in a riser application. Plenum and Riser Raceways are permitted to be placed in a general-purpose application. The uses of Plenum or Riser Raceways do not eliminate the use of a Plenum- or Riser-rated cable.

As the use of fiber optic/communication cables in premise wiring increases there will likely be other specific needs that may generate other types of conduit for use in building wiring systems. Inside plant microducts are now produced for premise and raceway product meeting UL 2024 standards. Fiber cable can be air blown into microduct.

### 12.6 Underwater Applications

The term underwater is used to describe marine, or submarine, applications. The three basic methods of placing an underwater conduit are laying the conduit on the bottom, plowing and jetting the conduit into the sub-aqueous terrain, or horizontal directional drilling under the waterway. Each method has its own unique requirements based on the type of waterway, length, environmental issues, and federal, state and local requirements. There may be instances when all three methods will be required within the same installation.

Conduit placed on the bottom of waterways should be black to prevent UV damage. For a complete discussion of underwater installations see Chapter 10, *Marine Installations*, of the Handbook.

### 12.7 Bridge Crossing Applications

Bridge structures can range from a simple conduit placed in the bridge structure when the bridge is built to a major retrofit of an existing bridge that does not already contain a conduit or structure in place to secure a single conduit or conduits.

Bridge structures, new or old, require specially designed support systems to ensure structural integrity and meet all federal, state and local requirements.

The expansion/contraction considerations with HDPE make it a less than ideal product for exposed bridge crossings. Generally, FRP conduit (Fiberglass Reinforced Pipe) is a better alternative for bridge conduit as it has beam strength, is produced to “low smoke zero halogen” standards, and can be designed to be bullet proof.

## 13 Summary

The information contained in this chapter should help the reader to understand the fundamental properties of polyethylene (HDPE) conduit. A basic understanding of

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these properties will aid the engineer or designer in the use of HDPE conduit and serve to maximize the utility of the service into which it is ultimately installed.

While every effort has been made to present the fundamental properties as thoroughly as possible, it is obvious that this discussion is not all-inclusive. For further information concerning HDPE conduit, the reader is referred to a variety of sources including the conduit manufacturers' literature, additional publications of the Plastics Pipe Institute and its website, and the references at the end of this chapter.

## 14 Glossary of Terms

Table 10 provides a glossary of terms commonly used within the conduit industry.

**Table 10 Conduit Specific Industry Terminology & Abbreviations**

| Term | Definition |
|---|---|
| Air Blown Fiber (ABF) | A process using compressed air and hand-sized equipment to feed low count unreinforced fiber cable into microducts, where the flow of compressed air over the fiber propels and pulls the fiber through the conduit. See Jetting. |
| Community Antenna TV (CATV) | Cable TV service, typically offered through coaxial or fiber cable to provide service delivered from a satellite headend. |
| Cable-in-Conduit (CIC) | A product offering where the conduit is offered pre-installed with the chosen cable type. |
| Canadian Standards Association (CSA) | Canadian Standards Association is a standards organization developing and publishing standards used in North America. CSA, a recognized laboratory, also certifies products for end-use. |
| Casing | A larger diameter pipe used to protect smaller conduits or cables when installed underneath roads, rivers or other obstacles. |
| Coax Cable | A cable used in the cable TV industry for TV or data transmission. |
| Conduit | A typically plastic pipe pathway used to protect fiber, power or coax cable. This term is interchangeable with “Duct”. |
| Corrugated Conduit | Conduit or pipe with a thinner wall with a corrugated profile to give it compressive strength and flexibility. |
| Dark Fiber | Dark fiber refers to unused fiber-optic cable. Often times companies lay more fiber cable, or conduit, than what is immediately needed in order to provide additional capacity for future needs. The unused capacity can be leased, sold or made available to other entities who want to establish optical connections among their own locations. |
| Department of Transportation (DOT) | A governmental department having jurisdiction over specifications and requirements for articles used in transportation. |
| Direct Burial | A construction method of placing cable or conduit by traditional methods into the ground(as opposed to plowing or directional drilling HDD). |
| Duct | See Conduit. |
| Environmental Stress Crack Resistance (ESCR) | Environmental Stress Crack Resistance is a measure of the long-term resistance to cracking of the polyethylene material. It can be measured through a test method that accelerates crack failure in polyethylene by inducing a stress and placing the specimen in a surfactant at high temperatures then observing when cracking initiates. |

| Term | Definition |
|---|---|
| Fiber Optic Cable | A cable comprised of very thin glass fibers with unique refractive characteristics that can be used to transmit data by a color laser initiated lightwave device. |
| Fiber-To- The-Home (FTTH) | A generic term for any broadband network architecture using optical fiber to provide all or part of the local distribution network used for connections directly to the subscriber. Frequently referred to as last mile telecommunications. |
| FRP Conduit | Rigid conduit of fiber reinforced plastic material used most often in bridge locations requiring greater strength or highly corrosive environments. Often specified as bullet proof. |
| General-Purpose Raceway | Conduit used inside buildings with some smoke and fire resistance. See Plenum and Riser-Raceway. |
| High Density Polyethylene (HDPE) | High density polyethylene is a durable plastic material used in the manufacture of conduit. A plastic material, composed mostly of ethylene used in the manufacture of durable conduit. |
| Horizontal Directional Drilling (HDD) | A method of placing conduit by drilling horizontally with a steel threaded drill string (assembled pipes) that have directional change capabilities and can be guided to circumvent underground obstructions. Conduit is then attached to the daylight end of the drill string and pulled back through the borehole to provide a clear pathway for cable to be inserted. See Maxi HDD and Mini HDD. |
| Innerduct | A smaller duct used to subdivide a larger duct or casing. |
| Inside Plant (ISP) or /Premise (ISP) | The communication and electrical sub structure in a building. Raceways in this environment have special fire and smoke retardant requirements. |
| Jetting or Push Blow | A method of blowing fiber cable that employs high volume and air pressure within a conduit to float cable along with a track system to simultaneously push the fiber cable through the conduit. Also see “push/pull” method of fiber cable placement. |
| Listing Mark | A UL, ETL, CSA or similar mark, from a nationally or internationally certifying agency used to designate conduit that was tested by a certified third-party laboratory in accordance electrical standards defined by the National Electric Code. |
| Maxi HDD | Horizontal Directional Drilling of large diameter casings of various pipe or conduit materials in lengths in excess of 1000’. Requires extensive subsurface planning and engineering. |
| Microduct | A very small diameter polyethylene conduit (from 4mm to 27mm) used for installation of micro fiber cables. Used in FTTH applications to deliver low count fiber directly to the premises of offices or homes. Sometimes oversheathed in a package of multiple microducts to add more micro fiber cables as additional capacity is needed. |
| Mid-Assist | A capstan (mechanical installation equipment) used to assist in extending the installation length at an intermediate location. It consists of placing cable in the middle of two runs. |
| Mini HDD | Horizontal Directional Drilling of conduit, up to 12 inches in diameter for short lengths up to 1000 feet. This method is used with less field information and therefore uses a very conservative calculation for selection of conduit wall thickness. |

| Term | Definition |
|---|---|
| Outside Plant (OSP) | Communication or power cable either buried or aerial, providing data or power distribution system. |
| Overriding | A method of placing a microduct into a conduit currently occupied by a fiber cable to provide an additional pathway or pathways for increasing capacity. |
| Plenum Raceway | A conduit inside buildings rated for placement in a plenum airspace, typically horizontally. Plenum rated conduit has very low smoke and superior fire resistance requirements qualifying it for use in this application. Tested in accordance with UL 2024. (see Riser Raceway). |
| PVC Conduit | A conduit produced from poly(vinyl chloride) polymer, typically provided in rigid lengths from 10 to 20 feet long. |
| Pull Line (aka Mule Pull Tape) | A polymer flat woven tape or rope typically made of polyester or polypropylene strands placed inside conduit (either during extrusion manufacturing or inserted in the field) used to pull cable into the conduit. |
| Reaming or Backreaming | The act of widening a bore hole in a drilling operation. Backreaming is the practice of pumping in a bentonite slurry and rotating the drill string with a backreamer to widen and form the bore hole wall. |
| Riser Raceway | Inside building conduit used in vertical shaft and other approved locations to connect communication broadband cables between floors. Riser conduit has reduced smoke and fire spread requirements, but not as stringent as Plenum Raceway. |
| Rock Impingement | Term used to describe a rock in direct contact and impacting the outer surface of the conduit in a buried application, potentially damaging the conduit. |
| Rodded | A fairly stiff fiberglass rod that can be pushed inside a conduit. It can be used for proofing the integrity of a conduit's pathway. |
| Slow Crack Growth (SCG) | A potential long-term brittle failure mode of polyethylene conduit under stress. See also ESCR. |
| Strand | Stranded high strength steel wire used to aerially support conduit or cable between poles or other structures. |
| Supervisory Command and Data Acquisition (SCADA) | A computerized system architecture using computer and communications equipment that allows remote monitoring, data acquisition and control of critical components in networks or infrastructure from a centralized control center. |
| Tail Loading | The amount of tension required to be placed on a conduit being pulled from a reel, for example in an HDD application or cable into a conduit. |
| Ultraviolet (UV) Protection | Ultraviolet light/sunlight which may adversely affect plastic conduit if not adequately formulated for the duration of storage and application. HDPE conduit is can be protected from UV degradation by adding carbon black (black conduit) or other specialized additives for longer term protection of colored conduit. |
| Viscoelastic | Viscoelastic is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied. Elastic materials strain when stretched and immediately return to their original state once the stress is removed. |

## 15 References

Association of Edison Illuminating Companies (AEIC):

CG4 Guide For Installation of Extruded Dielectric Insulated Power Cable Systems Rated 69KV Through 138KV, Association of Edison Illuminating Companies, 2nd edition, 1997

CG5 Underground Extruded Power Cable Pulling Guide, Association of Edison Illuminating Companies, 3rd edition, 2015

ASTM International:

D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer

D1693 Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

D2239 Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter

D2412 Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

D2444 Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

D2447 Solid-Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)

D2683 Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter- Controlled Polyethylene Pipe and Tubing

D3035 Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

D3485 Standard Specification for Smooth-Wall Coilable Polyethylene (PE) Conduit (Duct) for Preassembled Wire and Cable

F412 Standard Terminology Relating to Plastic Piping Systems

F1056 Standard Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings

F1290 Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings

F1473 Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

F2160 Standard Specification for Solid Wall High Density Polyethylene (PE) Conduit Based on Controlled Outside Diameter (OD)

F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings.

BellCore/Telcordia:

GR-356 Generic Requirements for Optical Cable Innerduct, Associated Conduit, and Accessories

GR-3155 Generic Requirements for Single/Bundled Microducts and In-Living Unit (ILU) Cable Pathways

CSA International:

C22.2 NO 327 HDPE conduit, conductors-in-conduit, and fittings

National Fire Protection Association (NFPA):

70 National Electrical Code (NEC), Chapter 9

National Electrical Manufacturers Association (NEMA):

TCB 4 Guidelines for the Selection and Installation of Smooth-Wall Coilable High-Density Polyethylene (HDPE) Conduit

TC 7 Smooth-Wall Coilable Polyethylene Electrical Plastic Conduit

Plastics Pipe Institute, Inc.:

Handbook of Polyethylene Pipe

MS-5 Model Specification for HDPE Solid Wall Conduit

TR-19 Thermoplastic Piping for the Transport of Chemicals. Underground Extruded Power Cable Pulling Guide

TR-46 Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High Density Polyethylene Pipe

TR-47 Pipe Stiffness and Deflection Testing of Coilable HDPE Conduit as Related to Burial Depth

TN-48 Guidelines for Choosing Wall Thickness for HDPE Conduit Based on "Mini-HDD" (Horizontal Directional Drilling)

TN-50 Guide to Specifying HDPE Conduit

TN-58 HDPE Conduit and Duct Handling Guide

TN-59 Comparison of HDPE Conduit and Fabric Divider Installed as Innerduct

TN-61 Coilable HDPE Conduit Ovality and Coil-Set

Statement V – Recommended Color Code for Solid Wall Plastic Pipe and Conduit

Underwriters Laboratories, Inc.:

651A Schedule 40 and 80 High Density Polyethylene (HDPE) Conduit

651B Continuous Length PE Conduit

1990 Nonmetallic Underground Conduit with Conductors

2024 Standard for Cable Routing Assemblies and Communications Raceways

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