PIPE STIFFNESS AND DEFLECTION TESTING OF COILABLE HDPE CONDUIT AS RELATED TO BURIAL DEPTH

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Foreword

This technical report was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical report is to provide information about industry terms related to pipe stiffness and deflection, particularly of HDPE conduit, and to describe technical differences between HDPE and PVC conduit as related to these terms and properties.

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Table of Contents

Table of Figures

List of Tables

PIPE STIFFNESS AND DEFLECTION TESTING OF COILABLE HDPE CONDUIT RELATED TO BURIAL DEPTH

1.0 <u>INTRODUCTION</u>

High-density polyethylene (HDPE) conduit is the preferred material to house and protect electrical power and telecommunications cables within. It offers unmatched corrosion and chemical resistance, is flexible and durable, and is available in long reel lengths to reduce joints and installation time. HDPE conduit is available in a variety of sizes, colors, dimensions and lengths.

Continuous length coilable HDPE conduit has enjoyed tremendous growth, not only as a protection for electrical cable, but largely due to the huge expansion of the communications industry in North America and abroad to protect fiber optic cable. HDPE's availability in long lengths, combined with its ductility, strength, and durability make it ideally suited for trenchless installation technologies such as horizontal directional drilling (HDD). Buried cables installed within HDPE conduit are protected from damage caused by storms, wildlife, vegetation, vehicles, and vandalism, when compared to aerial cables. Conduit also extends the life and reliability of underground cables by providing added protection against ground movement or unstable soil. These permanent raceways also allow for easier and less costly future cable replacements.

HDPE conduit has been used for decades with great success due also to its low coefficient of friction, resistance to corrosion, excellent chemical resistance, and ability to remain ductile (flexible), even at low temperatures. HDPE conduit can be provided on coils or on steel reels in long lengths, ideal for trenchless or plowing installation technologies. For example, a reel of nominal size 1 ¼ HDPE conduit can contain as much as 8,500 feet (2,590 m). Larger diameter HDPE conduit (e.g. nominal size 8 or greater) is available in straight lengths, also known as "sticks", up to 50 feet (15.2 m) long.

Polyvinyl chloride (PVC) is an alternative plastic material used for conduit. It is a more rigid material with lower flexibility, and is not coilable. PVC is normally supplied in straight lengths limited to 10 feet (3.04 m) or 20 feet (6.1 m), with individual pieces joined using solvent cement.

This Technical Report will provide information about industry terms related to pipe stiffness and deflection, particularly of HDPE conduit, and describe technical differences between HDPE and PVC conduit, as related to these terms and other properties.

2.0 PIPE STIFFNESS FOR HDPE CONDUIT AND RELATED TERMINOLOGY

Although HDPE conduit, also known as polymer raceway, is a flexible material, it must provide sufficient Pipe Stiffness to resist both short-term and long-term deflection when buried underground.

Pipe Stiffness (PS) is defined as the value obtained by dividing the force per unit length of specimen by the resulting deflection (typically 5%), in the same units, and at the prescribed percentage deflection. This is expressed as pounds-force per inch of length per inch of deflection or LbF/(in.· in.).

PS may also be expressed as LbF/in.^{2} or psi, although pipe stiffness is not a pressure or a stress value, and should not be confused with those values.

$$PS = \frac{F}{\Delta y} \qquad \textit{[Eq. 1]}$$

where:

      PS = Pipe Stiffness (LbF/(in.· in.) or LbF/in.^{2} or psi)
      F   = Force (pounds per lineal inch)
      Δy = vertical deflection (inches)

Requirements for evaluating Pipe Stiffness of HDPE conduit and related test methods are clearly described in industry product standards such as ASTM F2160[1], NEMA TC 7[2] and UL 651A[3].

When HDPE conduit is considered for underground installations, there have been cases where Pipe Stiffness (PS) and the term "Crush Strength" are used to determine strength relative to other materials, regardless of their property differences. In reality, "Crush Strength" is a term that is often misapplied to thermoplastic pipes (e.g. HDPE and PVC). Crush Strength implies a brittle failure when compressed, such as buckling or cracking of the pipe wall, whereas flexible piping materials such as HDPE can actually deflect in excess of 25% with no signs of wall buckling, cracking or splitting.

Terms such as "Pipe Stiffness", "Deflection Load" or "Minimum Deflection Load" are the correct and more appropriate engineering terms to describe how much deflection a flexible conduit can withstand without damage.

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[1] ASTM F2160 *Standard Specification for Solid-wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)*

[2] NEMA TC 7 *Smooth-Wall Coilable Electrical Polyethylene Conduit*

[3] UL 651A *Schedule 40 and 80 High Density Polyethylene (HDPE) Conduit*

For example, these are the terms used in industry standards for HDPE conduit:

- ASTM F2160 – "Pipe Stiffness, Compression and Recovery"
- NEMA TC 7 – "Pipe Stiffness, Compression and Recovery"
- UL 651A – "Minimum Deflection Load"

Note #1:   "Crush Strength" does not have a defined formula in the reference ASTM standards.

3.0   RELATIVE PIPE STIFFNESS – HDPE AND PVC

When HDPE conduit is compared to PVC conduit for pipe stiffness (PS) at similar diameters and wall thicknesses, PVC will inherently have a higher PS value[4], attributed to the flexural modulus (*E)* of that material being more than twice that of standard HDPE conduit materials[5] when measured in accordance with ASTM Test Method D790[6].

However, this in no way indicates that HDPE will perform inadequately in a buried application.

In fact, while pipe stiffness has applicability in calculations of burial depth (see Section 5.0), it should not be used to compare dissimilar materials. That is why each material has the required pipe stiffness for that material specified in the relevant product standard/s (see Section 2.0).

Also, too often, engineers mistakenly consider "Crush Strength" to determine allowable burial depth of flexible conduit. This technical report provides the reader with detailed information showing that HDPE conduit's pipe stiffness is sufficient for typical burial depths.

4.0   POLYMER RACEWAY PRODUCT SPECIFICATIONS

The inconsistencies of existing national specifications referencing stiffness and flattening have created confusion, even for comparable materials. In ASTM Standard Test Method D2412[7], Pipe Stiffness (PS) is defined as "the value obtained by dividing the force per unit length of specimen by the resulting deflection in the same units at the prescribed percentage deflection".

Testing is typically conducted at a prescribed loading rate, at a prescribed percentage deflection, such as 0.5 inch per minute (typically 5% deflection). The test measures the conduit's resistance to ring deflection as it is being compressed between two parallel steel plates.

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[4] ASTM D3034 for PVC specifies a cell class indicating a modulus (*E*) for PVC of 400,000 to 440,000 psi.

[5] ASTM F2160 for HDPE specifies a modulus (*E*) for HDPE used in conduit at 80,000 to 160,000 psi.

[6] ASTM D790 *Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastic and Electrical Insulating Materials*

[7] ASTM D2412 *Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*

This parallel plate test empirically determines pipe stiffness (PS) of a particular conduit size, wall type (e.g. SDR 9, Schedule 40, SIDR 15), and material, whereas an alternative "calculated" method uses a material's modulus and dimension ratio. These calculated values are listed in tables within industry standards (e.g. ASTM F2160, NEMA TC 7, UL 651A) as minimum performance requirements.

HDPE conduit for power and telecom applications is manufactured in accordance with consensus-based nationally developed standard specifications ASTM F2160, NEMA TC 7, and/or UL 651A, written specifically for solid wall conduit. These standards specify the material, properties, dimensions, performance testing, and quality assurance testing requirements for HDPE conduit.

4.1. ASTM International
ASTM Committee F17 on Plastic Piping Systems publishes standards for many types of pipes. The following are pipe stiffness requirements for HDPE and PVC conduit from ASTM standards, respectively:

4.1.1. **ASTM F512 (2017)** *Standard Specification for Smooth-wall Poly(Vinyl Chloride) (PVC) Conduit and Fittings for Underground Installation* requires a minimum pipe stiffness at 5% deflection of inside diameter when tested according to ASTM D2412.

4.1.2. **ASTM F2160 (2016)** *Standard Specification for Solid-wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)* requires a minimum pipe stiffness at 5% deflection of inside diameter, when tested according to ASTM D2412. Minimum values depend on wall type, and are consistent for all diameters for wall types which are based on dimension ratio (DR).

4.2. National Electrical Manufacturers Association (NEMA)
NEMA publishes specifications for polymer raceway (conduit) used in electrical applications. The following are pipe stiffness requirements for HDPE and PVC conduit from NEMA standards, respectively:

4.2.1. **NEMA TC 7 (2016)** *Smooth-Wall Coilable Electrical Polyethylene Conduit* requires a minimum pipe stiffness at 5% deflection of inside diameter, when tested according to ASTM D2412. Minimum values depend on wall type, and are consistent for all diameters for wall types which are based on dimension ratio.

4.2.2. **NEMA TC 6 & 8 (2013)** *Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installations* requires a "duct stiffness" test with a minimum load required, based on 5% deflection of inside diameter, when tested according to ASTM D2412.

4

4.2.3. **NEMA TC 2 (2013)** *Electrical Polyvinyl Chloride (PVC) Conduit* requires a "deflection resistance" test with a minimum load required, but no deflection limit indicated. TC 2 also requires a flattening test to 40% of the outside diameter of the duct, with no visible splitting or breaking.

4.3. Underwriters Laboratories Inc. (UL)
UL publishes specifications for both PVC and HDPE conduits housing electrical cables in accordance with the NEC (National Electric Code), also known as NFPA 70:

   o **UL 651 (2018)** *Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings* requires a minimum crushing load for each diameter of conduit without flattening (deflection) more than 30%.
   o **UL 651A (2017)** *Schedule 40 and 80 High Density Polyethylene (HDPE) Conduit* requires a minimum deflection load for each diameter of conduit without flattening (deflection) more than 30% for diameters up to and including 1, and 25% for diameters 1 ¼ and larger.

Note #2: See *PPI TN-50 Guide to Specifying HDPE Conduit* for more information about industry standards for HDPE conduit

The industry standard values listed above demonstrate that since HDPE and PVC are different materials, corresponding values in specifications are determined independently for each material. Further, the long-term "field performance" of a particular conduit material may be independent of its pipe stiffness, since several other factors, as noted above, contribute to toughness and durability in the ground.

5.0 BURIED FLEXIBLE PIPE DESIGN

Both HDPE and PVC conduit materials use flexible pipe design methodology, as opposed to rigid pipe design methods used for older materials such clay or concrete.

Open cut installation standards for plastic pipes and polymer raceway require proper backfill procedures. Flexible pipe and conduit deflects under load, and as they deflect, they mobilize passive resistance into the surrounding soil, and with the materials' inherent stiffness, resist further deflection. A full discussion of the methodology of calculating burial depth in flexible pipe is not the purpose of this report. However, a general discussion will assist the reader in determining that pipe stiffness and deflection should not be the overriding variables in choosing which material is suitable for protection of fiber optic and power cables in conduit applications.

Simplified, the four types of calculations for buried flexible pipe design, applicable for HDPE conduit, are as follows:

5.1.   Ring Deflection
This concerns the deflection of the pipe due to earth and live loads, and is calculated to determine if the ring deflection exceeds the recommended values.

The formula to calculate ring deflection is the *Spangler Modified Iowa Formula* which uses a form of pipe stiffness to give approximations of the deflection of solid wall plastic pipe or conduit under earth loads.

From ASTM D2412, Appendix X1:

$$x = \frac{D_e \, K \, W_c}{0.149 \, PS + 0.061 \, E'} \qquad \textit{[Eq. 2]}$$

where:

x = *deflection of pipe (in.)*
D_e = *deflection lag factor*
K = *bedding constant*
W_c = *vertical load per unit of pipe length (LbF/in.)*
PS = *pipe stiffness (LbF/(in.· in.) or LbF/in.^{2} or psi)*
E' = *modulus of soil reaction (psi)*

From ASTM D2412 Appendix X2, pipe stiffness can be calculated at a particular deflection by:

$$PS = \frac{E \, I}{0.149 r^3} \qquad \textit{[Eq. 3]}$$

where:

PS = *pipe stiffness (LbF/(in.· in.) or LbF/in.^{2} or psi)*
E = *material flexural modulus (psi)*
I = *moment of inertia (LbF·ft·s^2)*
r = *pipe radius (in.)*

Note #3: Material Flexural Modulus (E) = 80,000 psi for HDPE materials meeting ASTM F2160

See ASTM F2160 for the requirements for "Minimum Load for Pipe Stiffness Test" values for each diameter and wall type of HDPE conduit.

Checking PS values also serves as a useful Quality Control test.

5.2. Compressive Ring Thrust
Compressive ring thrust is the radial compressive force around the circumference of the pipe. Failure occurs when the compressive stress in the wall exceeds the yield stress of the material. Pipe stiffness does not have any direct application in compressive ring thrust.

5.3. Buckling
Excessive compressive stress along the pipe wall may cause a pipe wall to buckle. Although the buckling calculation does involve the modulus and moment of inertia, it is not directly related to the pipe stiffness calculation. Buckling will rarely be a factor in determining the burial depth for conduit applications, as HDPE conduit has a thicker wall than SDR 21 wall type, and burial depths are far shallower than 25 feet (7.6 m).

5.4. Flexibility Factor
Flexibility factor (FF) describes the stiffness of the pipe required to adequately and properly backfill the structure. It is important in large diameter (e.g. greater than 12 in.) pipes with thin walls, and in profile pipe in deep fill applications. It is not a controlling factor in conduit applications, since conduit uses thicker walls compared to drainage pipe, and it is buried at depths far shallower than 25 feet.

6.0 BURIAL DEPTHS FOR HDPE CONDUIT

Although pipe stiffness plays an important factor in the design requirements of HDPE conduit, other variables often override it as the critical factor. For example, in the majority of telecom and power installations, the burial depth is relatively shallow and the typical installation stresses frequently dictate the strength requirements, rather than in-situ earth loading.

HDPE conduit is generally installed using three distinct methods: open cut/continuous trench, plowing, or horizontal directional drilling (HDD).

6.1. Open Cut/Continuous Trench
Open cut trenching is a commonly used method in the installation of telecom and power conduits in continuous trenches (see **Figure 1**). When HDPE conduit is installed using open cut techniques using similar methods of installation as flexible stormwater and sewer pipes, designers can apply the same principles in determining the anticipated earth loading strength requirements.

The PPI *Handbook of Polyethylene Pipe 2nd Edition* chapters called "Design of PE Piping Systems"[8] and "Underground Installation of PE Piping"[9] describe a design window where constrained buckling becomes the determining factor in choosing the pipe strength and depth of cover allowed. HDPE pipe is limited to SDR 21 or a thicker wall, and no bucking calculations are required, because critical buckling for this wall thickness passes with a safety factor of 2 or greater.

Figure 1: Open Cut Continuous Trenching Installation of HDPE Conduit

Coiled HDPE conduit for power and telecom applications is rarely manufactured with a wall thickness less than SDR 15.5 in small diameters and SDR 13.5 in larger diameters (e.g. nominal sizes 4 in. to 6 in.) because of the potential for excessive ovality and kinking as it is coiled or wound onto the reel during manufacturing. In these cases, the manufacturing process dictates a heavier wall in order to properly wind the conduit without kinking.

Note #4: Schedule 40 HDPE conduit in diameters up to and including 3 in. has a wall thickness greater than SDR 15.5. Schedule 40 HDPE conduits in diameters larger than 3 in. and Schedule 80 conduit in 6 in. diameter have wall thickness ranges that are less than SDR 15.5. These wall types are not recommended for coiling, due to ovality and kinking concerns.

Nearly all conduit installations, even open cut, are far shallower than 20 feet and are well within the parameters of the allowable design window established in the *Handbook of Polyethylene Pipe*.

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[8] PPI *Handbook of PE Pipe 2nd Edition*, Chapter 6 **"Design of PE Piping Systems"**

[9] PPI *Handbook of PE Pipe 2nd Edition*, Chapter 7 "Underground Installation of PE Piping"

Other design window parameters that can be found in the *Handbook* are:

- o Similar to pressure-rated pipe, HDPE conduit is manufactured from HDPE resin and evaluated in accordance with ASTM Standard Specification D3350[10]. The minimum cell classification for conduit produced according to ASTM F2160 is 334480C or E, whereby the minimum modulus and tensile properties of the specified cell classification are designated as 4, representing a minimum modulus value of 80,000 psi and a minimum tensile strength of 3,000 psi, respectively. Because these cell values are the same as those required in pressure-rated resin, the resulting mechanical properties for the finished conduit will be similar as those of pressure pipe.
- o No surcharge loading.
- o Acceptable embedment materials are typically coarse-grained soils, compacted to a minimum of 85% proctor density yielding an E' of 1,000 psi, assuming prism loading. The native soil also must be stable. These parameters are important! In an open cut application, it is assumed that the conduit will be backfilled properly, as it should be for drainage pipes and pressure pipes. It should be noted these backfill conditions are easily achieved.
- o Unit weight of soil does not exceed 120 pounds per cubic foot (pcf) (some soils and gravels can exceed 120-pcf).
- o Installed in accordance with ASTM Standard Practice D2321[11].

For open cut applications, HDPE conduit typically has a wall thickness thicker than SDR 17 due to manufacturing considerations or "construction survivability" requirements, so the values in **Table 1** are extremely conservative.

Table 1: Design Window Maximum & Minimum Depths of Cover *

Dimension Ratio	Min. Depth of Cover with H-20 Load	Min. Depth of Cover without H-20 Load	Maximum Depth of Cover
7.3	3 ft.	2 ft.	25 ft.
9	3 ft.	2 ft.	25 ft.
11	3 ft.	2 ft.	25 ft.
13.5	3 ft.	2 ft.	25 ft.
17	3 ft.	2 ft.	25 ft.
21	3 ft.	2 ft.	25 ft.

*Values represent depths below grade for which no additional calculations are required, due to earth loading with properly followed installation techniques. Conduits are suitable for deeper burial depth, provided a sufficient E' is accomplished during installations. Calculations would be required for depths greater than 25 feet (7.6 m).

[10] ASTM D3350 *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*

[11] ASTM D2321 *Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications*

6.2. Plowing Method of Installation

Another method of installing HDPE conduit is via plowing. Plowing is where a static or vibratory "shoe" cuts through the ground, splitting and compressing the soil to make a pathway for the conduit. The method uses equipment which feeds the conduit over the machine (see **Figure 2**), making the long continuous length, flexibility, and bend radius of HDPE conduit both a feature and requirement.

Plowing can expose rocks and other obstructions, so conduit with an SDR of 13.5 or thicker (i.e. numerically lower) is normally specified due to these "installation stresses". After the shoe passes, the soil is expected to expand and consolidate around the pipe.

Figure 2: Plowing Installation of HDPE Conduit

The Modified Spangler Formula[12] is the standard calculation that can be used to determine whether a pipe has sufficient strength to withstand earth and live loads (refer to the previous discussion of burial depth calculations).

If one assumes no contribution from the soil, meaning E'= 0 (*an extremely conservative approach*), the formula reverts to the "Watkins and Anderson Formula"[13] (not shown).

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[12] Spangler, M.G. (1941), *"The Structural Design of Flexible Pipe Culverts"*, Bulletin 153, Iowa Engineering Experiment Station, Ames, IA.

[13] Watkins, R.K. & Spangler, M.G. (1958), *"Some Characteristics of the Modulus of Passive Resistance of Soil-A Study in Similitude"*. Highway Research Board Proceedings 37: 576-583, Washington.

Modified Spangler Formula:

$$y/D = \frac{0.0125\ P}{(E/12(DR-1))^3} \qquad \text{[Eq. 4]}$$

where:

y = *horizontal deflection (inches)*
D = *mean diameter (inches)*
P = *vertical load (lb/ft^2)*
E = *material modulus (psi)*
DR = *dimension ratio (unitless)*

Using a 5% deflection limit and E (modulus) of 28,200 psi at 50 years (very conservative assumptions), the height of cover can be calculated for various wall thicknesses:

- o SDR 15.5 Conduit
  - Height of cover = 3.7 feet (1.12 m)
- o SDR 13.5 Conduit
  - Height of cover = 5 feet (1.52 m)
- o SDR 11 Conduit
  - Height of cover = 11 feet (3.35 m)

As stated above, most power and electrical conduits are specified to be buried at approximately three foot (0.91 m) depth, especially in plowed applications where they are often installed in cross-country networks or along highway rights-of-way. Rarely are they buried deeper than four feet (1.21 m).

So with regards to the earth load forces and pipe stiffness, HDPE conduit in SDR 13.5 wall thickness is more than adequate in nearly all plowed applications, even with the most conservative assumptions. It should be noted that designers and contractors sometimes choose SDR 11 conduit (thicker wall than SDR 13.5), because of severe installation stresses due to soil conditions (e.g. rocks).

6.3. Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) has enjoyed explosive growth over the past decades, as the technology has allowed power and telecom conduit and cables to be installed with minimal traffic disruption and surface damage. HDPE is the material of choice for HDD installations because of its long lengths, which significantly reduce the number of required joints and conduit access points over long distances (See **Figure 3)**.

Figure 3: HDD Installation of HDPE Conduit

In many situations, the tensile strength and modulus of HDPE conduit can allow pull lengths of over 1,000 feet (304.8 m). Furthermore, the flexibility of HDPE typically allows the conduit to be directed and curved around underground obstructions, within the capabilities of the boring equipment.

Design of the pipe wall thickness for HDD applications can be complex and is determined by many variables. The one parameter related to the pipe stiffness would be a collapsed or deformed borehole. Loads are defined by either a deformed/collapsed borehole, or an open borehole (no earth load on the pipe).

In the case of a deformed or collapsed borehole, the soil above will mobilize arching. In this case, there will be no additional loading on the pipe, beyond the mud pressure. In a severe borehole collapse, the upper limit of earth pressure will be the soil prism above the pipe. Prism loads are most likely to develop under shallow applications; therefore, the earth loads will be minimal.

On long HDD applications, the tensile forces of pullback are perhaps the most critical factor in choosing the wall thickness of the conduit. Along with the frictional and mud pressure forces, the conduit has bending forces where it has deflected laterally to avoid obstructions, or from the depth of the bore to the ground surface, requiring higher tensile strength.

12

For HDD projects, selecting the proper wall thickness (i.e. SDR, SIDR or Schedule) of HDPE conduit requires due consideration and design calculations which take multiple factors into account. ASTM Standard Guide F1962[14] provides detailed design criteria related to *Maxi-Horizontal* HDD design and installation, while PPI TR-46[15] provides detailed design criteria related to *Mini-Horizontal* and *Midi-Horizontal* HDD design and installation.

PPI TR-46 indicates that commonly used wall types DR 7 to DR 17 are often sufficiently strong for burial depths up to 15 feet (4.5 m). Conduit wall thickness thinner than DR 13.5 is rarely used in power and telecom applications. Pipe stiffness has minimal relevance in these cases. HDD installations are not conducive to the short length of PVC conduit, so a comparison to PVC pipe stiffness seems immaterial. PPI TR-46 also provides guidance on wall thickness safety factors for various bore conditions for HDD installations.

PPI's **Conduit Design Calculator** online software tool performs HDD calculations to estimate the safe pull strength, calculated tensile load, and safety factor according to Mini-Horizontal Directional Drilling design criteria. This software tool is available at www.conduitcalc.com.

7.0 CONCLUSION

Pipe Stiffness is an important material property for manufacturing quality control and assurance of conduit, and demonstrates a material's strength and ductility. However, pipe stiffness values should be related to the specific material (HDPE or PVC) and wall thickness, and not a single arbitrary target.

Pipe stiffness testing for HDPE conduit should be at 5% deflection in accordance with ASTM D2412 and product standards such as ASTM F2160, NEMA TC 7 and UL 651A. Test values should be compared to the calculated values at the minimum material modulus specified for HDPE (e.g. 80,000 psi) within industry standards.

These test conditions have precedence in many flexible pipe specifications, including ASTM F512 for PVC conduit, NEMA TC 7 for HDPE conduit, and AASHTO M 294 for Corrugated PE Pipe. The appropriate PS values are listed in the product standards.

Furthermore, deflection is not a direct indicator of the allowable burial depth of conduit, as no one would design flexible pipes with deflections of 15%, let alone 30%, because of the reduced capacity (internal size) of such severely compressed conduits.

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[14] ASTM F1962 *Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings*

[15] PPI TR-46, *Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High Density Polyethylene Pipe*

Deflection tests do, however, give an indication of the flexibility of a pipe. Therefore, deflection tests are mandatory in all industry specifications for HDPE conduit.

HDPE conduit has enjoyed great success as a protector of our power and telecom infrastructure. In HDPE conduit applications, the "installation stress", not the pipe stiffness or depth of cover, is typically the dictating factor in selecting the required pipe strength and wall thickness, and arbitrarily requiring HDPE conduit to meet a certain pipe stiffness, based on a specification for another material, would negate the many beneficial aspects of proven high density polyethylene materials.