GUIDELINES FOR CHOOSING WALL THICKNESS FOR HDPE CONDUIT BASED ON "MINI-HDD" (HORIZONTAL DIRECTIONAL DRILLING): USING THE PPI CONDUIT DESIGN CALCULATOR

TN-48

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Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute. The members have shown their interest in quality products by assisting independent standard-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

This technical note has been prepared to provide guidance, to those responsible for the selection and installation of HDPE conduit, on the appropriate selection of conduit based on installation considerations. This document was not intended to provide system design information. Go to the PPI website at www.plasticpipe.org for different system design documents.

This document was extensively revised in 2021 with the issuance of the PPI Conduit Design Calculator. As the calculations are now performed by the Conduit Design Calculator, the calculation methodology has been updated and moved to an appendix. The main body of the Technical Note now provides guidance and examples based on the Conduit Design Calculator.

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PPI intends to revise this report from time to time, in response to comments and suggestions from users of this note. Please send suggestions for improvements to PPI. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

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GUIDELINES FOR CHOOSING WALL THICKNESS FOR HDPE CONDUIT BASED ON "MINI-HDD" (HORIZONTAL DIRECTIONAL DRILLING): USING THE PPI CONDUIT DESIGN CALCULATOR

1.0 OVERVIEW

CDC is the acronym used for the PPI *Conduit Design Calculator*, a web based interactive tool for conduit users available at www.conduitcalc.com. The CDC output assists in the selection of the appropriate conduit product by providing the user with an estimate of the Tensile Load with comparison to the Safe Pull Strength for conduits for a range of wall thicknesses, and the associated Safety Factor. The purpose of this document is to provide new CDC users guidelines on its use.

The CDC is intended for Mini-HDD (Horizontal Directional Drilling) applications with calculation limits of 1000 feet bore, depths of 15 feet and conduit diameters of 12 inches.

Note that the CDC calculation results are only one factor in product selection. Heavier wall conduit may be warranted depending on the installation environment or other operational factors, such as soil and surface loads. The appropriate wall thickness should be chosen based on the greater of the long term (such as soil loading) and short term loads associated with the Mini-HDD operations.

Following the background section, a **step-by-step guide** to using the calculator is provided. This is followed by 4 **examples** to illustrate usage. **Appendix A** provides the basis of the calculations utilized within the CDC.

2.0 BACKGROUND

The basis of the CDC is to calculate and compare the "Safe Pull Strength" of the conduit to the "Calculated Tensile Load" of the bore resulting in a pass/fail and safety factor. The Safe Pull Strength of the conduit is a straightforward calculation: It is simply the tensile strength of the HDPE raw material (directly related to the density) multiplied by the area of the conduit[1]. The Calculated Tensile Load is a bit more complicated. It considers the bore length, depth, buoyant weight and drill rod diameter. Furthermore, curvature (bends) in the bore path result in friction and increased tensile load within the borehole. Both planned and unplanned bends have a significant impact on increasing tensile forces and are considered in the calculation. Calculation details are provided in **Appendix A**.

[1] See PPI TN-63 Safe Pull Strength Calculations for Conduit: Including Derating Factors.

For reference, the former PPI Technical Report 46[2], which is the basis for the CDC, describes the design, selection considerations, and installation procedures for the placement of HDPE Conduit pipe using "Mini-HDD" equipment. "Mini-HDD" is a more conservative approach for less critical and demanding field conditions than are warranted by "Maxi-HDD" as described in ASTM F1962 *Standard Guide for Use of Maxi-Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings.* For example, as part of this software, limits on the depth (15 feet), length (1,000 feet) and conduit diameter (12 inches) are incorporated into the available input choices of the CDC. Furthermore, there are choices for estimating unplanned curvature along the pathway, allowing the user to choose how much confidence they may have in their knowledge of the jobsite conditions. Maxi-HDD, on the other hand are major events such as long pulls, deep depths and large diameter. These require extensive analysis, as provided in ASTM F1962.

Note 1: PPI TR-46 (2009) was withdrawn in favor of PPI MAB-7, with the latter having its scope narrowed to PE4710 only and with a specific focus on municipal water mini-HDD installation. Nonetheless, MAB-7 remains an excellent and pertinent source of reference for mini-HDD, when the material differences between regular grade conduit and PE4710 pressure pipe are properly considered.

3.0 STEP BY STEP GUIDE

These basic job details are required to use the calculator:

- Conduit material type
- Conduit diameter type and wall thickness (i.e. DR) – best first guess
- Conduit diameter
- Bore path details
- Bore length
- Bore depth
- Drill rod diameter

Each of these inputs is discussed further below. Listed below is a step by step methodology to use the calculator along with an explanation of the various inputs.

[2] PPI Publications are available free of charge from www.plasticpipe.org..

3.1. Accessing the Conduit Design Calculator

The first step is accessing the software. There are several options:

- Click on hyperlink www.conduitcalc.com or enter it into your browser directly.
- Navigate to the PPI website (www.plasticpipe.org). From the home page, choose the "divisions" drop down and choose "Power and Communications". Find and click on the icon shown below on any PCD page.

- Directly type into your browser, www.plasticpipe.org/conduitcalc.

These bring you to a user agreement. Click on "agree" to use the calculator.

Regardless how you get there, **bookmark the page** so that you can find it easily next time.

3.2. Terminology & Calculator Limits

Once you are on the CDC calculator main page, you can view the basis and limits for the inputs from the typical HDD boring schematic. This schematic also shows the terminology used in the calculator. Look for the schematic button in the upper left-hand corner of the page to access the schematic shown in **Figure 1**.

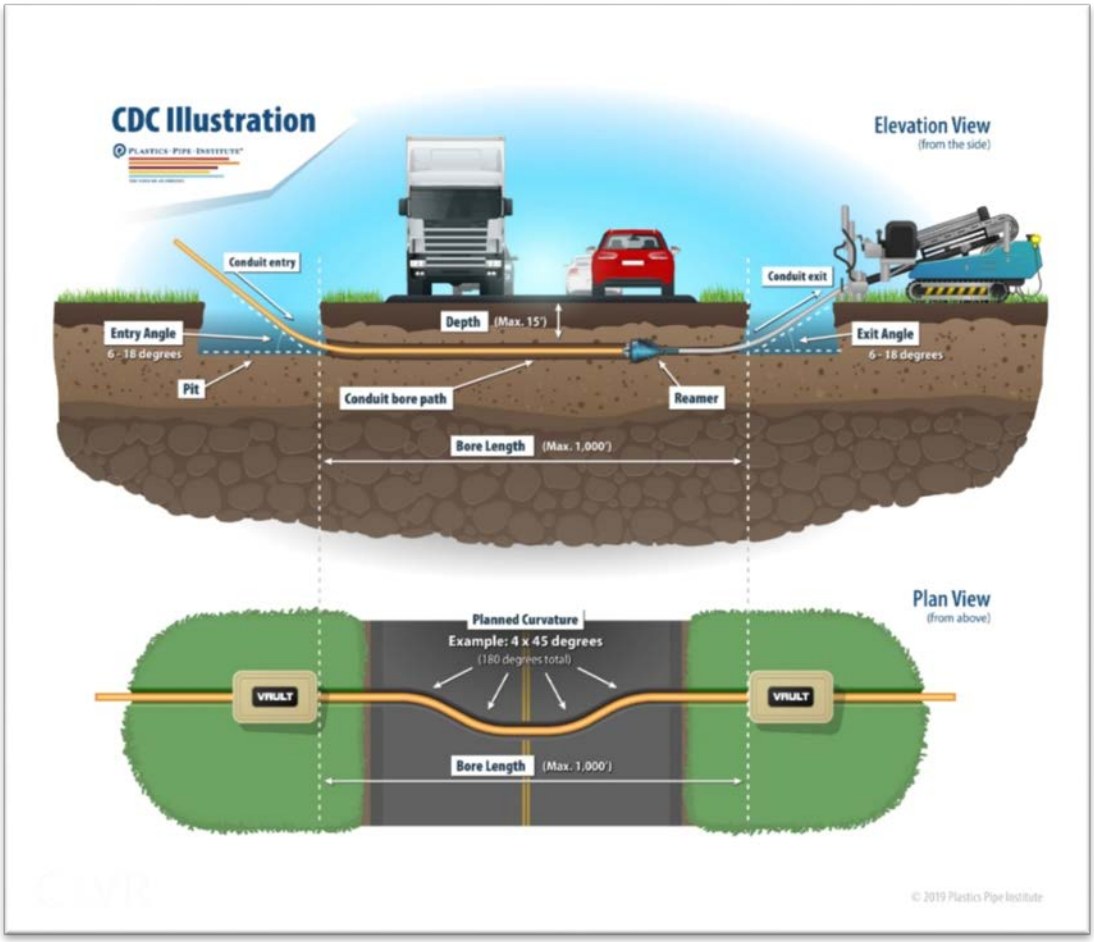


Figure 1 - Schematic of Typical Mini-HDD Installation

This illustration shows the various inputs, as well as the limits of the “Mini-HDD” methodology. Namely:

- Entry and exit angles from 6-18 degrees. Steeper angles will stress the conduit beyond the intended application of this software. In those cases, a Maxi-Directional HDD calculation from ASTM F1962 would be required.
- Maximum bore depth is 15 feet.
- Maximum bore length is 1000 feet, not counting the entry/exit lengths.
- Finally, there is an illustration of how to compute the “deliberate/planned bends (curvature) in bore path”. (The significance of bend/curvature in the bore path will be discussed further in this document)

Close the image when done.

3.3. Units of Measure

At the top of main body of the software, as shown in **Figure 2**, the user should choose imperial/U.S. or metric units. The default is imperial/U.S. units.

Note 2: Choosing metric units will require inputs of length and depth in meters. Outputs will show pull strength in Newtons. However, the diameter choices will still show in inches as this is the normal (nominal) choice in specifications for conduit.

Figure 2 - Working Units Selection and Project Description Entry Box

3.4. Project Information

As shown in **Figure 2**, the next input is project information. This is optional but recommended. This allows for tracking and is useful for associating the calculation results with a specific project when printing or emailing the results record.

3.5. Conduit Selection

The next few entries relate to starting selection of the conduit to be used as defined by the project requirements. As shown in **Figure 3**, these include the HDPE material type, conduit diameter type, starting wall type, and conduit diameter. Each of these is discussed below.

Figure 3 - Conduit Selection Choices

3.6. HDPE Material Type

The first input is a drop-down choice of raw material type. The two choices are "Standard Industry HDPE Conduit" or "Higher Strength Conduit Material". These are important as they identify the tensile strength of the raw material which will determine the wall thickness and safe pull strength of the conduit. (See Note 2 in the left-hand margin of the CDC for further details.)

- Standard industry conduit (per ASTM F2160, UL651A and NEMA TC7) has a minimum cell classification[3] of 334480C or E. The fourth digit, underlined, of the cell class corresponds to the specified minimum yield strength, specifying a minimum yield strength of 3000 psi (21 MPa) for standard strength industry conduit compound.
- Occasionally a higher strength grade may be specified or needed for the installation. If using a higher strength conduit material, the fourth digit of the cell class with be greater than 4, typically 5 corresponding to a minimum yield strength of 3500 psi (24 MPa).

Note 3: The conduit print line is not required to include the PE cell class (only the general term HDPE is included); if needed (e.g., for tensile calculations), contact the conduit manufacturer for the conduit compound yield strength.

[3] The numbers respectively represent density, melt index, tensile strength, modulus, stress crack resistance, hydrostatic burst strength, and colorant. "C" is for black conduit and "E" is for colored conduit. The above nomenclature and values for each property are found in ASTM D3350.

3.7. Diameter Type & Wall Type

The next two choices are the Diameter Type and Wall Type. In combination with the OD of the conduit, these inputs will determine the material area of the conduit, and the resulting safe pull strength of the conduit. It should be noted that the actual outside diameter, inside diameter and wall thickness of conduit may not correspond exactly to dimensions suggested by the nominal size trade name so it is important to understand the different conventions that are used for describing conduit size and wall thickness.

The different diameter types and wall types are:

- **IPS / SDR** is a designation for conduit diameter type based on the standard Iron Piping Sizes. The actual diameters are slightly larger than the trade names would suggest. The wall thickness is defined by the ratio of the actual outside diameter to the wall thickness. This ratio is termed Standard Dimensional Ratio (SDR) for standardized ratios, or sometimes just DR for non-standard ratios. Common standard ratios are SDR13.5, SDR11, SDR9 with each being about 25% higher in strength than the former as the wall thicknesses increase. Note the conduit inside diameter decreases with this progression.
- **IPS / Schedule** is also a pipe size designation system (outside diameters and wall thicknesses) originated by the iron pipe industry. The outside diameter matches that of the IPS system; however, the wall thickness follows a *Schedule* where a higher *Schedule* number results in a thicker wall, e.g., Schedule 80 conduit has a thicker wall than Schedule 40 conduit.
- **True Sized / SDR** is a designation for conduit diameter type where the actual inside diameter closely matches the nominal trade size name. For example, a True Sized Nominal Size 2 conduit will have an average inside diameter of 2.000 inch. The wall thickness is based on the ratio of internal diameter to wall thickness. Typical True Sized conduit may be available in SDR 11 and SDR 9.
- **SIDR** is a designation for a conduit diameter type where conduit inside diameter is slightly larger than the trade name would suggest. As the name would suggest with Standard Inside Diameter Ratio (SIDR), wall thickness is based on the ratio of internal diameter to wall thickness, with typical wall thickness ratios of SIDR 15, SIDR 11.5 and SIDR 9.
- **EPEC** – Short for Electrical PolyEthylene Conduit (EPEC) is a diameter type defined by an outside diameter based on IPS pipe sizing and wall thicknesses based on SDR or Schedule. The sizes are similar to the IPS / SDR and IPS / Schedule sizes above but may have different tolerances. These designations are used in UL and NEMA standards specifically.

See industry standards such as ASTM F2160, NEMA TC 7, or UL 651A for actual conduit dimensions, and ASTM D3485 or UL 1990 for cable in conduit dimensions.

Use the drop-downs to first select the conduit diameter type. This selection will be based in part on the availability from your supplier, type of installation and the fill ratio. Note that the calculator does not provide options for the EPEC diameter type but these can be approximated based on the other diameter and wall types. Select from:

- o IPS
- o True Sized
- o SIDR

Then select the specific wall type from the Wall Type drop-down box. The options will be different based on the selected Diameter Type. Note the calculator output will provide several wall types that may be suitable; however, the user is asked for an initial input which should be based on size availability and cable pulling requirements.

3.8. Diameter

The final dimensional input is the nominal trade size of the conduit. The trade size should be determined by the cable OD to be inserted in the conduit and depends on the method of cable installation.

- o Power or fiber cable fill ratios installed by the pulling method are based on the area of the cable (or cables in the case of power cable) and the inside area of the conduit. NEC code outlines the allowable recommended fill ratios for power cable.
- o The “push/blow” and “jetting” methods of installing fiber cable (not used in power cable applications) are determined using the ratio of the OD of cable vs ID of the conduit. Generally, a higher fill ratio is allowed for the “push/blow” and “jetting” methods of fiber cable.

Fill ratios are also discussed in detail in Chapter 14, Section 9 of the *Handbook of PE Pipe*.

Important Note: The calculator may recommend several different wall thicknesses than originally inputted. The wall thickness change may impact the conduit inside dimension and the resulting cable fill calculation. Repeat the cable fill calculation in these cases to ensure the fill ratio remains acceptable. A conduit diameter change may be required.

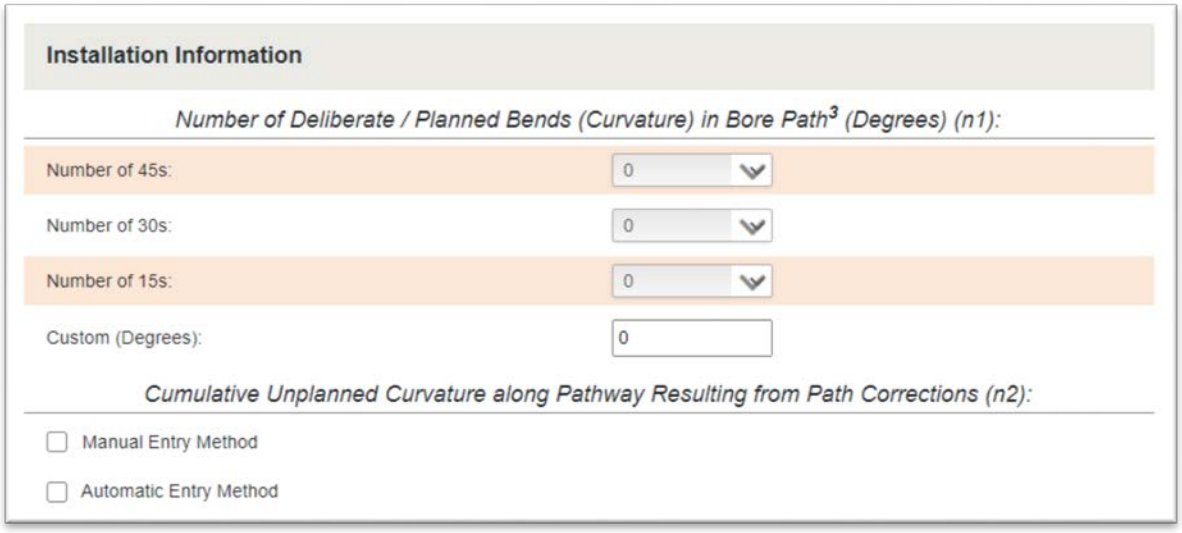


Figure 4 - Installation Bend Choices

3.9. Installation Bends – Planned & Unplanned

Project installation inputs are now considered. Bends are considered in this section and other installation information in the following section.

Directional changes in the pathway result in a capstan-like effect that results in higher friction with the soil. These can significantly increase the tensile forces as the conduit is pulled.

Note 4: An entry or exit angle of 6 to 18 degrees is assumed and already accounted for by the software. Entry angles greater than 20 degrees can result in significant tensile forces and are beyond the scope of the software. The user is referred to ASTM F1962 on Maxi-HDD.

There are two considerations in path changes, i.e., bends or curvature; planned/deliberate and unplanned.

- The first input is **planned changes** in direction, for example, a direction change to avoid underground utilities that have been marked, see **Figure 1**. The user will input the number of planned directional changes of 45, 30 and 15 degrees. (This variable is n_1 -see Appendix A formulas.)
- Second to consider are “unplanned” directional changes, see **Figure 1**. There are two options, a manual entry method and an automatic entry method.
  - The manual entry method allows the user to input a guess number of total unplanned directional changes in degrees. (The variable is n_2 -see Appendix A formulas.)

- When selected, the automatic method gives the user three options related to the confidence the user has in their knowledge of the route path, see **Figure 5**. The first option is “a well-planned installation with good knowledge of route path obstacles”, or a low probability of unplanned corrections-noted as Type 1. Second is the option for “reasonable knowledge of route path” noted as Type 2. Finally, the third option is “poor knowledge of route path with a high potential for unplanned route corrections”, noted as Type 3. (The variable is n_2 -see Appendix A formulas.)

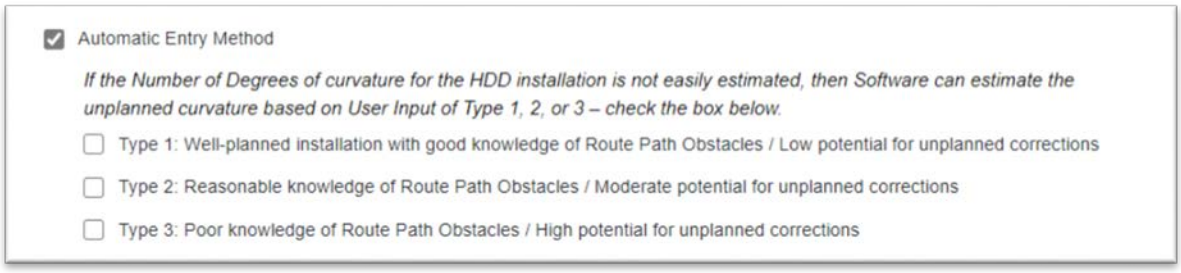


Figure 5 - Unplanned Bends - Automatic Entry Method Choices

3.10. Other Installation Details – Depth, Length and Drill Rod Diameter

As shown in **Figure 6**, the remaining entry details are maximum depth of installation, bore length and drill rod diameter

Inputs are the bore length and depth (refer to the diagram on how to determine the bore length and depth). Maximum length is 1,000 feet and maximum depth is 15 feet.

Finally, the drill rod diameter is considered. There are five options from 1½” to 4” rod diameter.

- A larger diameter drill rod will have less potential to bend, meaning it will result in a lower total amount of directional change. Conversely, a small diameter rod can bend more, and could accommodate more severe directional changes. These affect the variable *n* in the formulas. The drill rod factor is used in the Automatic Entry Method (n_2). (See appendix. Formula 2.a.3)

Figure 6 - Other Installation Choices

The CDC assumes that the borehole is back-reamed to enlarge it before conduit is pulled through, and that drilling fluid is used to hold the borehole open and assist in pulling out the cuttings, according to standard industry practices such as those found in the PPI Handbook of PE Pipe, Chapter 12, section on Pilot Hole Reaming. During back-reaming and pullback, the drilling fluid creates a dense slurry that applies hydrostatic pressure symmetrically around the conduit. MAB-7, Appendix B, indicates wall thicknesses from SDR 9 to SDR17 should be sufficiently strong to depths of 15 feet. Thinner walls such as SDR 21 or Schedule 40 in diameters 4" and larger are not recommended.

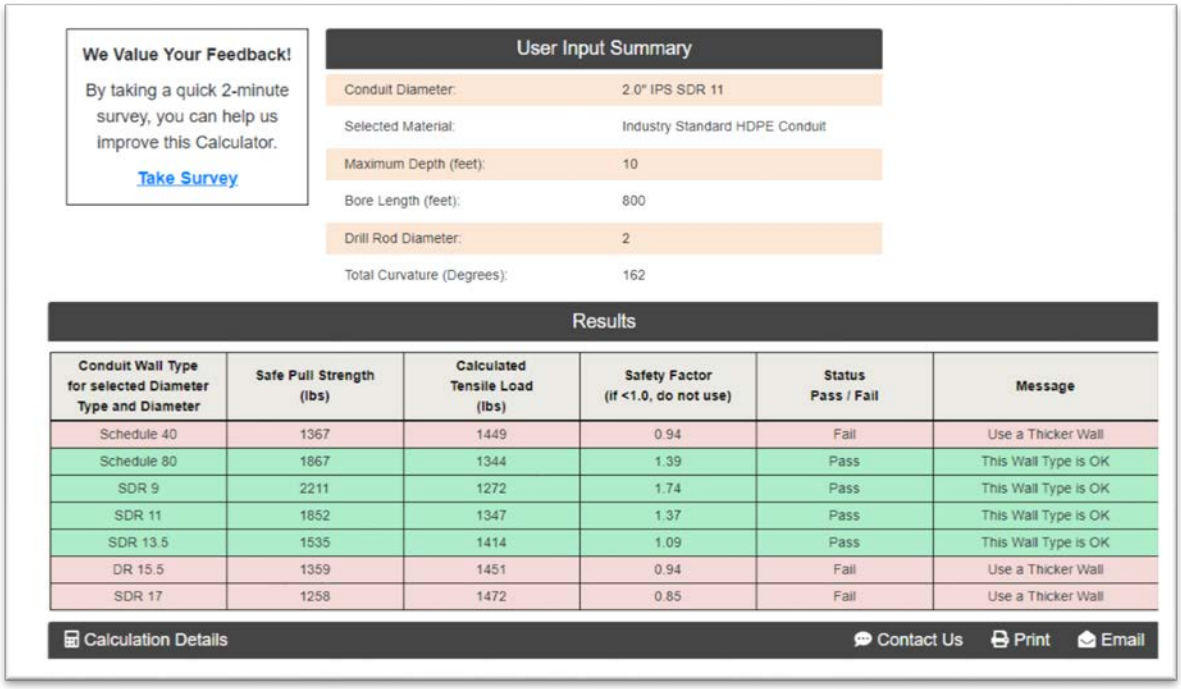
3.11. Results Report

Once all the inputs have been entered, hit the "calculate" icon. A results page will appear, see **Figure 7** for a typical example.

A **User Input Summary** of the inputs appears where the user can confirm their inputted variables. Note the "total curvature" is a calculation based on the user inputs of planned and unplanned directional changes.

Below the summary, the results appear in a **Results** matrix. Included are the conduit wall type (thickness) for the chosen diameter, safe pull strength, calculated tensile load, safety factor, pass/fail determination, and color highlights whether the wall type is adequate. Note that several alternative wall types are be illustrated, allowing the user to choose a higher wall thickness/safety factor if desired. (For example, in the Scenario 1 Calculation below, SDR 13.5 has a safety factor of 1.09. The user might consider moving to a heavier wall conduit.)

The bar at the bottom of the Results matrix allows the reader to **print** or **email** the entire software document in addition to the final results. Furthermore, an icon "**calculation details**" will show the formulas used in the determination of the proper wall thickness and safety factors. These formulas are also in the Appendix A at the end of this Technical Note.



We Value Your Feedback!

By taking a quick 2-minute survey, you can help us improve this Calculator.

Take Survey

User Input Summary

Conduit Diameter:	2.0" IPS SDR 11
Selected Material:	Industry Standard HDPE Conduit
Maximum Depth (feet):	10
Bore Length (feet):	800
Drill Rod Diameter:	2
Total Curvature (Degrees):	162

Results

Conduit Wall Type for selected Diameter Type and Diameter	Safe Pull Strength (lbs)	Calculated Tensile Load (lbs)	Safety Factor (if <1.0, do not use)	Status Pass / Fail	Message
Schedule 40	1367	1449	0.94	Fail	Use a Thicker Wall
Schedule 80	1867	1344	1.39	Pass	This Wall Type is OK
SDR 9	2211	1272	1.74	Pass	This Wall Type is OK
SDR 11	1852	1347	1.37	Pass	This Wall Type is OK
SDR 13.5	1535	1414	1.09	Pass	This Wall Type is OK
DR 15.5	1359	1451	0.94	Fail	Use a Thicker Wall
SDR 17	1258	1472	0.85	Fail	Use a Thicker Wall

Calculation Details Contact Us Print Email

Figure 7 - Illustration of the Results Page and Examples Base Scenario 1 Results

4.0 EXAMPLES

The following example scenarios and calculations are provided to illustrate the use of the calculator. A base scenario and calculation example are provided first. Subsequently, three scenarios with one input/variable changed illustrate the effect of bends/curvature and drill diameter have on the wall thickness required:

4.1. Base Scenario 1

1. Select IP/US units, as well as a project description, e.g. Base Scenario 1.
2. Use “Industry Standard HDPE Conduit”, IPS diameter type, SDR 11 wall type, and conduit diameter of 2”.
3. Input 2-45 degree planned bends.
4. Use the Automatic Entry Method and choose Type 2 (Reasonable knowledge of bore path.)
5. Depth of 10’ and bore length of 800’.
6. Drill rod diameter of 2”.
7. See **Figure 7** for results.
8. The result shows Schedule 80, SDR 9, 11 and 13.5 pass the required tensile load. But note the safety factor of SDR 13.5 is only 1.09, and perhaps a thicker wall should be considered.

4.2. Scenario 2

1. From Scenario 1 - change the planned bends to 2-45 degree and 2-30 degree.
2. As shown in **Figure 8**, the result eliminates SDR 13.5. SDR 11 now has a safety factor of only 1.0. SDR 9 would be a more practical choice.

Results

Conduit Wall Type for selected Diameter Type and Diameter	Safe Pull Strength (lbs)	Calculated Tensile Load (lbs)	Safety Factor (if <1.0, do not use)	Status Pass / Fail	Message
Schedule 40	1367	1982	0.69	Fail	Use a Thicker Wall
Schedule 80	1867	1839	1.02	Pass	This Wall Type is OK
SDR 9	2211	1740	1.27	Pass	This Wall Type is OK
SDR 11	1852	1843	1.00	Pass	This Wall Type is OK
SDR 13.5	1535	1934	0.79	Fail	Use a Thicker Wall
DR 15.5	1359	1984	0.68	Fail	Use a Thicker Wall
SDR 17	1258	2013	0.62	Fail	Use a Thicker Wall

Figure 8 - Scenario 2 Results

4.3. Scenario 3

1. From Scenario 1 - change the Automatic Method of unplanned curvature to Type 3, poor knowledge of route path.
2. As shown in **Figure 9**, only SDR 9 now passes with a safety factor.

Results

Conduit Wall Type for selected Diameter Type and Diameter	Safe Pull Strength (lbs)	Calculated Tensile Load (lbs)	Safety Factor (if <1.0, do not use)	Status Pass / Fail	Message
Schedule 40	1367	2110	0.65	Fail	Use a Thicker Wall
Schedule 80	1867	1958	0.95	Fail	Use a Thicker Wall
SDR 9	2211	1853	1.19	Pass	This Wall Type is OK
SDR 11	1852	1962	0.94	Fail	Use a Thicker Wall
SDR 13.5	1535	2059	0.75	Fail	Use a Thicker Wall
DR 15.5	1359	2113	0.64	Fail	Use a Thicker Wall
SDR 17	1258	2144	0.59	Fail	Use a Thicker Wall

Figure 9 - Scenario 3 Results

4.4. Scenario 4

1. From Scenario 1 - change the drill rod diameter to 1½ inch.
2. As shown in Figure 10, the result changes from Scenario 1, in that SDR 13.5 is no longer passing. Only Schedule 80, SDR 9 and 11 have acceptable safety factors.

Results

Conduit Wall Type for selected Diameter Type and Diameter	Safe Pull Strength (lbs)	Calculated Tensile Load (lbs)	Safety Factor (if <1.0, do not use)	Status Pass / Fail	Message
Schedule 40	1367	1642	0.83	Fail	Use a Thicker Wall
Schedule 80	1867	1524	1.23	Pass	This Wall Type is OK
SDR 9	2211	1442	1.53	Pass	This Wall Type is OK
SDR 11	1852	1527	1.21	Pass	This Wall Type is OK
SDR 13.5	1535	1603	0.96	Fail	Use a Thicker Wall
DR 15.5	1359	1644	0.83	Fail	Use a Thicker Wall
SDR 17	1258	1668	0.75	Fail	Use a Thicker Wall

Figure 10 - Scenario 4 Results

APPENDIX A – CALCULATIONS

This appendix details the calculations performed by the CDC to provide guidance on the selection of conduit wall thickness. The variables considered and formulas used are from the former TR-46 (now MAB-7). (The reader is encouraged to review the entire MAB-7 as it discusses site considerations, safety, conduit/pipe design considerations and other important facets of the overall design.)

Note that the CDC utilizes a novel method for estimating unintended curvature that is not included in MAB-7. This method is used in the section below described as Automatic Method and was developed in conjunction with Dr. Larry Slavin to simplify the unintended curvature input process using the user's project knowledge. *The PPI Power & Communications Division would like to thank Dr. Larry Slavin of Outside Plant Consulting Services, Inc. for assistance in developing the original PPI TR-46 (2009).*

Variables and formulas as used in the CDC[4]:

1. Safe Pull (Strength) Tension of Conduit:

   a. For Industry Standard Conduit Material[5,6]:

   $$Safe\ Pull\ Strength\ (Tension)(lbs) = Area\ of\ Conduit\ \times 1{,}200\ psi$$

or

   b. For Higher Strength Conduit Material[5,6,7]:

   $$Safe\ Pull\ Strength\ (Tension)(lbs) = Area\ of\ Conduit\ \times 1{,}400\ psi$$

2. Tensile Load (i.e., Peak Tension) is calculated as:

Notes:

- It is normal, and assumed, the conduit is empty during the installation and pre-operational phase. Some more complex HDD applications pressure the pipe to offset external pressure due to drilling fluids.
- A larger diameter drill rod will have less potential to bend, meaning it will result in a lower total amount of directional change. Conversely, a small diameter rod can bend more, and could accommodate more severe directional changes.

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[4] Calculations from PPI TR-46 modified with input from Dr. Larry Slavin.

[5] Industry standards for HDPE conduit, such as ASTM F2160, NEMA TC 7, and UL 651A, require a standard minimum material cell classification of PE334480C or PE334480E, when evaluated according to ASTM Specification D3350.

[6] PPI Handbook of PE Pipe, 2nd Edition, Chapter 12, Table 1. Safe pull stress at 73 °F - 1 hour (Errata Sheet published 06/06/12).

[7] Higher strength materials that exceed industry minimum requirements, e.g tensile strength cell class ≥ 5, may be available but are not commonly used for HDPE conduit.

a. Tensile Load is

$$Tensile\ Load\ (lbs) = \left[\frac{Bore\ Length\ (ft) \times Buoyant\ Weight\ (\frac{lbs}{ft})}{3}\right] \times 1.6^{n}$$

Where

$$Buoyant\ Weight\ \left(\frac{lbs}{ft}\right) = \frac{[Pipe\ Diameter\ (inch)]^2}{2} - Pipe\ Weight\ (\frac{lbs}{ft})$$

$$n = n_1 + n_2$$

and where

1. n is the total curvature as reported as the number or fraction of 90 degrees route bends due to cumulative route curvature (deliberate and unplanned) (e.g. n =1.5 for 135 degrees)
2. n_1 is the effective number of deliberate/planned route bends (curvatures) in the bore path divided by 90 degrees.
3. There are two alternative methods for calculating n_2:

   n_2 (Manual Entry) is the effective unplanned curvatures (estimation), due to typical path corrections. Degrees are inputted manually by user and converted to an integer by dividing by 90 degrees.

or

n_2 (Automatic Entry) is calculated as (see Appendix B):

$$n_{2\ (Automatic)} = \frac{[Bore\ Length\ (ft) \div 500] \times [2 \div Drill\ Rod\ Diameter\ (inch)]}{Reduction\ Factor\ Based\ on\ Type} \div 90°$$

Where the user chooses between 3 scenarios:

a. Type 1: Well-planned installation with good knowledge of route path obstacles / Low potential for unplanned corrections: *Reduction Factor* = 4.0
b. Type 2: Reasonable knowledge of route path obstacles / Moderate potential for unplanned Obstacles: *Reduction Factor* = 2.0
c. Type 3: Poor knowledge of route path obstacles / High potential for unplanned corrections: *Reduction Factor* = 1.0

3. The resulting tensile load is then compared to the safe pull tension:

$$Safety\ Factor = \frac{Safe\ Pull\ Strength\ (lbs)}{Tensile\ Load\ (lbs)}$$

4. The calculator reports a PASS result where the $Safety\ Factor$ is above 1.0 and FAIL when below 1.0. Note other installation related factors (e.g., soil type, etc.), not addressed here, may suggest that heavier wall conduit should be used.

To illustrate the n_2 calculation the following 3 examples are provided:

a) Example A1: 2" IPS PE3608; 2" Drill; 800 ft bore; n_2 (Auto-Type 1) = 36° / 90° = 0.40
b) Example A2: 2" IPS PE3608; 2" Drill; 800 ft bore; n_2 (Auto-Type 2) = 72° / 90° = 0.80
c) Example A3: 2" IPS PE3608; 2" Drill; 800 ft bore; n_2 (Auto-Type 3) = 144° / 90° = 1.6

For larger diameter installations and longer bore lengths, a more detailed design methodology can be found in ASTM F1962 or Chapter 12 of the PPI Handbook of Polyethylene Pipe.