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ONLINE ENGINEERING TOOLS FOR DESIGN AND FIELD ENGINEERS

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SHORT SUMMARY
The Plastics Pipe Institute has developed several online calculators to aide designers and engineers in pipe material selection for different applications. These users often have little time to search out new piping material physical properties and capabilities when bidding a project. This paper will give a pipe manufacturers perspective on educating engineers and designers by demonstrating these calculators and will discuss general capabilities of these online tools along with giving one in depth demonstration of a calculation.

KEYWORDS
DESIGN TOOLS, PPI, ENGINEERING CALCULATORS, PRESSURE, BURIAL

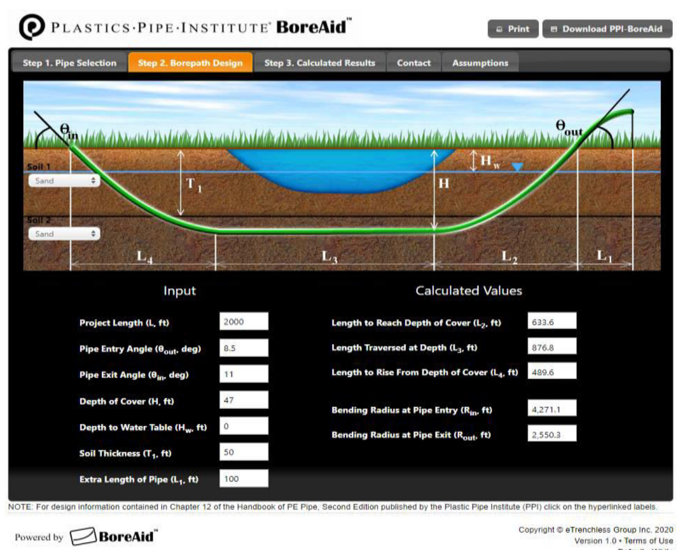
ABSTRACT
The design and installation of polyethylene systems can be complex, specifically due to the many applications and environmental conditions that surround those systems. Online design tools have been developed to address this complexity and the various factors that must be considered. These online tools used widely in North America, aide engineers with planning installation using horizontal directional drilling (HDD), surge and service life analysis and pressure ratings for polyethylene pipe systems. For HDD installation, the online tool accounts for key factors such as deflection, unconstrained collapse, compressive wall stress, pull back force (which includes consideration of capstan effect), and maximum tensile stress. These are calculated based on the input by the user which in turn tailors the scenario to a specific installation path and soil strata. For surge and service life analysis, the tool calculations are based on the American Water Works Association (AWWA) methodology for C901 (1/2 tubing – 3" OD) and C906 (4" – 63") polyethylene pipe used in water distribution and transmission systems. The user can evaluate the effects of design velocities of recurring and occasional surge, working pressure, service temperature and minimum design life requirements. For the polyethylene pipe design tool, a new feature is added for design of polyethylene systems utilizing chlorine or chloramine as a disinfectant. The oxidative resistance methodology, for potable water systems, was introduced into key ASTM standards in 2014. Key

considerations comprise the water pH, disinfectant type and residual level, working pressure and the oxidative resistance category. This tool can also be used to calculate pressure ratings, burial stresses, supported span distance and much more. All tools have aided design engineers and have also expanded the growth of plastic pipe systems in many markets. This paper highlights their development and the key aspects of each tool. In addition. a case study on the utilization of these online tools will be presented demonstrating the ease and relevance to the engineering community. This case study will be presented from the perspective of a user of these tools, not a software developer. As a pipe manufacturing engineer, I regularly use these tools to educate and inform pipeline designers, field personnel and utility staff on polyethylene pipe.

INTRODUCTION

The Plastics Pipe Institute garners more than 3,000 unique website traffic hits per month on their design calculators. With more calculators being created, the number of site visitors will continue to rise. As a pipe manufacturer I am often called on to educate the users on functionality and results generated by these calculators. The users vary widely from the most humble projects of cattle ranches figuring out flow capabilities of irrigation lines and minimum slope for field drainage, to energy engineers designing produced water lines, to highly complex projects such as a municipal engineer trying to get a better understanding of HDPE pipe burial forces under a taxiway at LaGuardia International Airport. Here are some examples of available calculators used today:

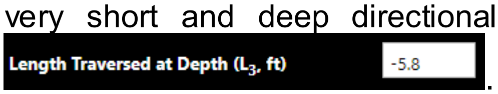
S-1 PPI BoreAid™ Calculator



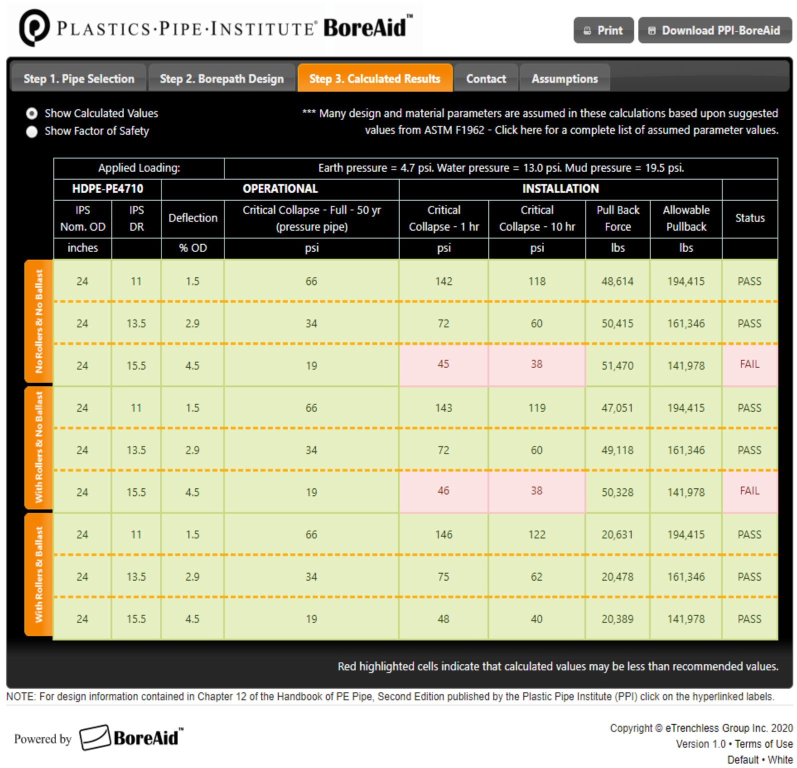
The most common users of PPI's BoreAid calculator are directional drill companies planning routes for polyethylene pressure pipe, conduits, and gas distribution lines. This calculator can give accurate values of expected forces and also gives general guidelines for acceptable entry/exit angles, bend radii, DR selection, pull back forces, pipe deflection and critical collapse pressures. The following is a real-life request from a customer on use of this calculator for their project.

Customer Question – "I have a 400ft directional drill of 24" IPS DR13.5, my entry angle is 18 degrees, and my exit angle is 16 degrees with a general depth of cover of 30 feet. Will DR17 work?"

Response – We have a few red flags that are being thrown by the calculator. First, these entry and exit angles are steeper than industry standards recommend. Next this is a very short and deep directional drill, resulting in a negative "Length Traversed"



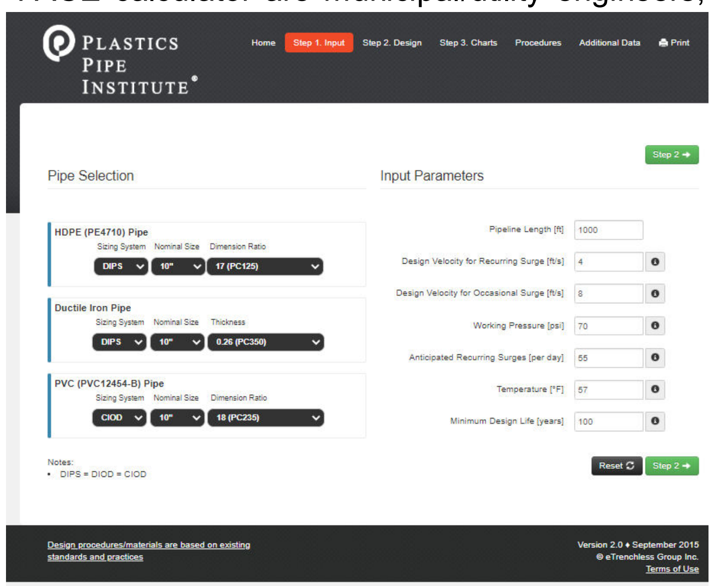
. Now we are understanding why the contractor was attempting such steep entry and exit angles. They were trying to get deep fast to have a better chance at making the bend. The recommendation back to the customer is to move the drill rig further back, reduce your entry and exit angles and put a few more feet of pipe in the ground. By doing this we get positive values where we need them and an easy to read PASS or FAIL with side by side DR comparisons. We are also given calculated results for three different installation details. Pipe installed using "No Rollers & No Ballast", "With Rollers & No Ballast", and "With Rollers & Ballast". DR13.5 will work in all three installation scenarios.



	Applied Loading:		Earth pressure = 4.7 psi. Water pressure = 13.0 psi. Mud pressure = 19.5 psi.						
	HDPE-PE4710		OPERATIONAL		INSTALLATION				
	IPS Nom. OD	IPS DR	Deflection	Critical Collapse - Full - 50 yr (pressure pipe)	Critical Collapse - 1 hr	Critical Collapse - 10 hr	Pull Back Force	Allowable Pullback	Status
	inches		% OD	psi	psi	psi	lbs	lbs	
No Rollers & No Ballast	24	11	1.5	66	142	118	48,614	194,415	PASS
	24	13.5	2.9	34	72	60	50,415	161,346	PASS
	24	15.5	4.5	19	45	38	51,470	141,978	FAIL
With Rollers & No Ballast	24	11	1.5	66	143	119	47,051	194,415	PASS
	24	13.5	2.9	34	72	60	49,118	161,346	PASS
	24	15.5	4.5	19	46	38	50,328	141,978	FAIL
With Rollers & Ballast	24	11	1.5	66	146	122	20,631	194,415	PASS
	24	13.5	2.9	34	75	62	20,478	161,346	PASS
	24	15.5	4.5	19	48	40	20,389	141,978	PASS

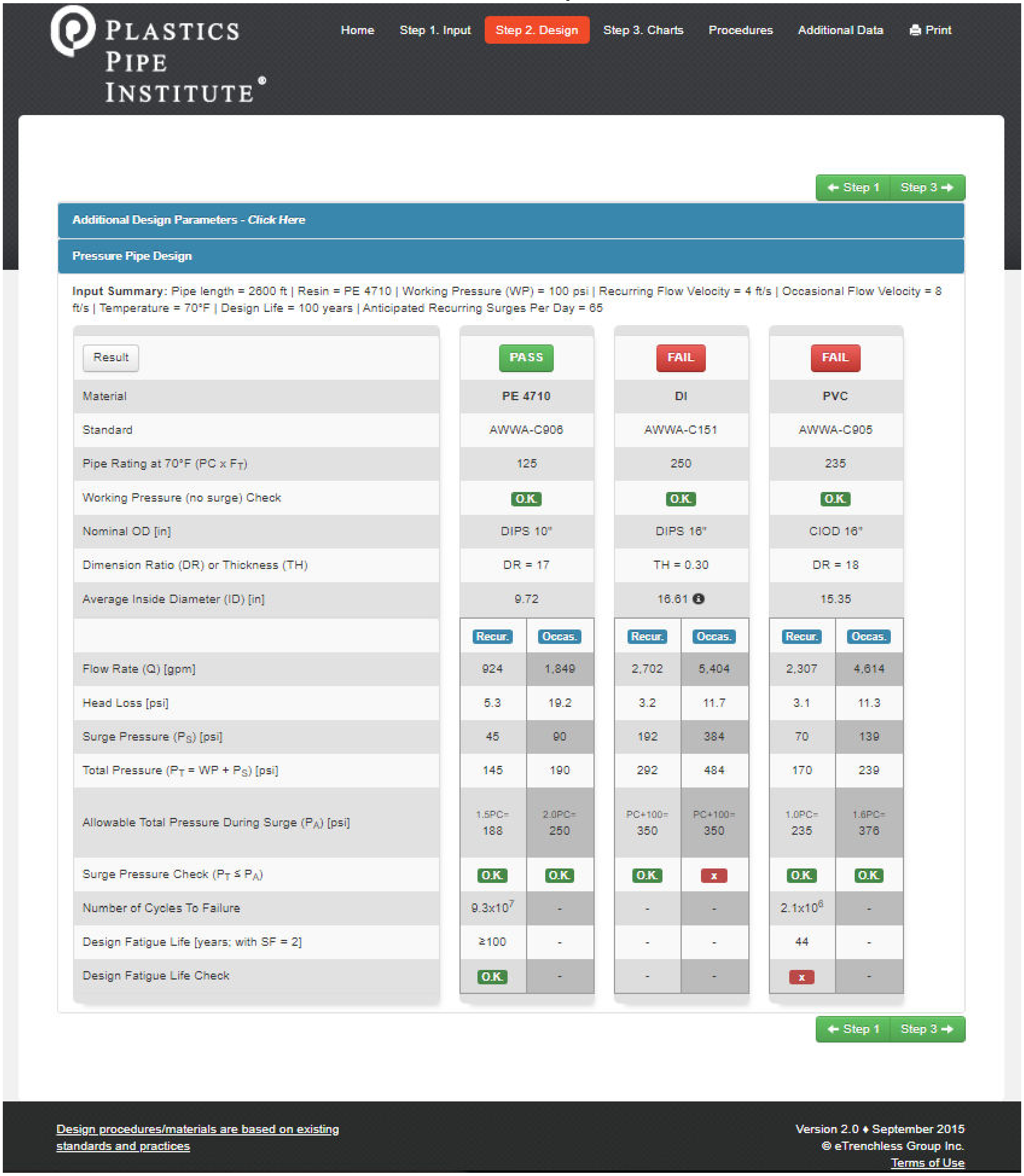
S-3 PPI PACE Calculator

The most common users of the PPI's PACE calculator are municipal/utility engineers, looking to get a side by side comparison of pipe materials in surge events for a designated fatigue design life.



Customer Question – "I am designing a half mile sewer force main and am looking for the best pipe material for the job. This will be a large force main with a multi pump manifold. Working pressure will be 100 psi but we will have flow velocities at peak hours of up to 8 feet per second. We are also looking for a 100-year life on the pipe.

Response – We will start by selecting pipe dimensions and DR based off of required flow for a general inside diameter (can be calculated in S-5 HDPEapp). Next we will enter pipeline length, flow velocities, anticipated recurring surge events, fluid temperatures, working pressures and design life. Next we can move on to results. In keeping with the simplicity theme, we are given a simple PASS or FAIL at the top of the results. But let's take a closer look at the data. First PE-4710 HDPE pipe has a pass for both recurring and occasional surge and meets the 100-year design life. Next on the list is ductile iron with a pass on recurring surge but a fail on occasional surge. Ductile irons high elastic modulus creates too high of a pressure spike in occasional surge events which exceeds its allowed surge pressure. Last on the list we have PVC pipe which passes both the occasional and recurring surge requirements but fails on the 100-year fatigue service life coming in at 44 years. These results are also available in the calculator graphically under "Step-3". As a result, HDPE PE-4710 is the material of choice for their sewer force main application.



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Home | Step 1. Input | Step 2. Design | Step 3. Charts | Procedures | Additional Data | Print

← Step 1 | Step 3 →

Additional Design Parameters - *Click Here*

Pressure Pipe Design

Input Summary: Pipe length = 2600 ft | Resin = PE 4710 | Working Pressure (WP) = 100 psi | Recurring Flow Velocity = 4 ft/s | Occasional Flow Velocity = 8 ft/s | Temperature = 70°F | Design Life = 100 years | Anticipated Recurring Surges Per Day = 65

Result	PASS		FAIL		FAIL	
Material	PE 4710		DI		PVC	
Standard	AWWA-C906		AWWA-C151		AWWA-C905	
Pipe Rating at 70°F (PC x F_T)	125		250		235	
Working Pressure (no surge) Check	O.K.		O.K.		O.K.	
Nominal OD [in]	DIPS 10"		DIPS 16"		CIOD 16"	
Dimension Ratio (DR) or Thickness (TH)	DR = 17		TH = 0.30		DR = 18	
Average Inside Diameter (ID) [in]	9.72		16.61		15.35	
	Recur.	Occas.	Recur.	Occas.	Recur.	Occas.
Flow Rate (Q) [gpm]	924	1,849	2,702	5,404	2,307	4,614
Head Loss [psi]	5.3	19.2	3.2	11.7	3.1	11.3
Surge Pressure (P_S) [psi]	45	90	192	384	70	139
Total Pressure (P_T = WP + P_S) [psi]	145	190	292	484	170	239
Allowable Total Pressure During Surge (P_A) [psi]	1.5PC= 188	2.0PC= 250	PC+100= 350	PC+100= 350	1.0PC= 235	1.6PC= 376
Surge Pressure Check ($P_T \le P_A$)	O.K.	O.K.	O.K.	x	O.K.	O.K.
Number of Cycles To Failure	$9.3x10^7$	-	-	-	$2.1x10^6$	-
Design Fatigue Life [years; with SF = 2]	≥100	-	-	-	44	-
Design Fatigue Life Check	O.K.	-	-	-	x	-

← Step 1 | Step 3 →

Design procedures/materials are based on existing standards and practices

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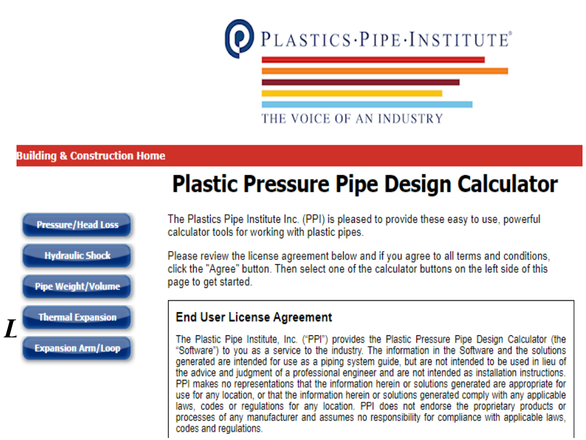
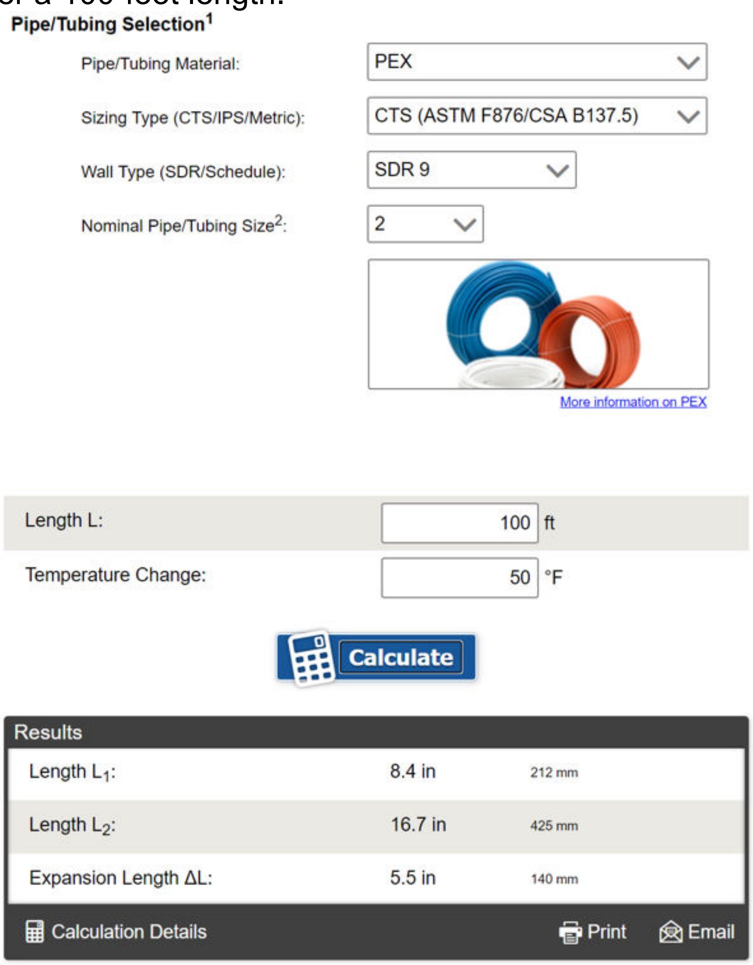
S-4 PPI Building Construction Plastic Pipe Design Calculator v2.0

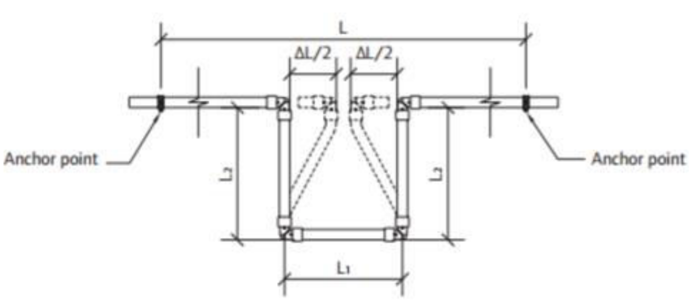
The most common users of PPI's Building Construction calculator are plumbing contractors and mechanical system designers



for water, fire protection and geothermal for residential, commercial, and industrial buildings. The newly updated v2.0 performs these calculations for CPVC, HDPE, PE-RT, PEX, PP-R, & PP-RCT. The most common uses of this calculator are for figuring pressure and head loss in a system allowing designers to select a variety of fluid types and temperatures. This calculator is also used to design for thermal expansion/contraction, hydraulic shock/surge for fast closing valves, pipe dimensions and volumes, and expansion loops to accommodate expansion/contraction.

Customer Question – I am designing a system where I will need an expansion loop. I need to know my expansion loop dimensions with a 50°F temperature change in 2" CTS DR9 PEX pipe over a 100-foot length.

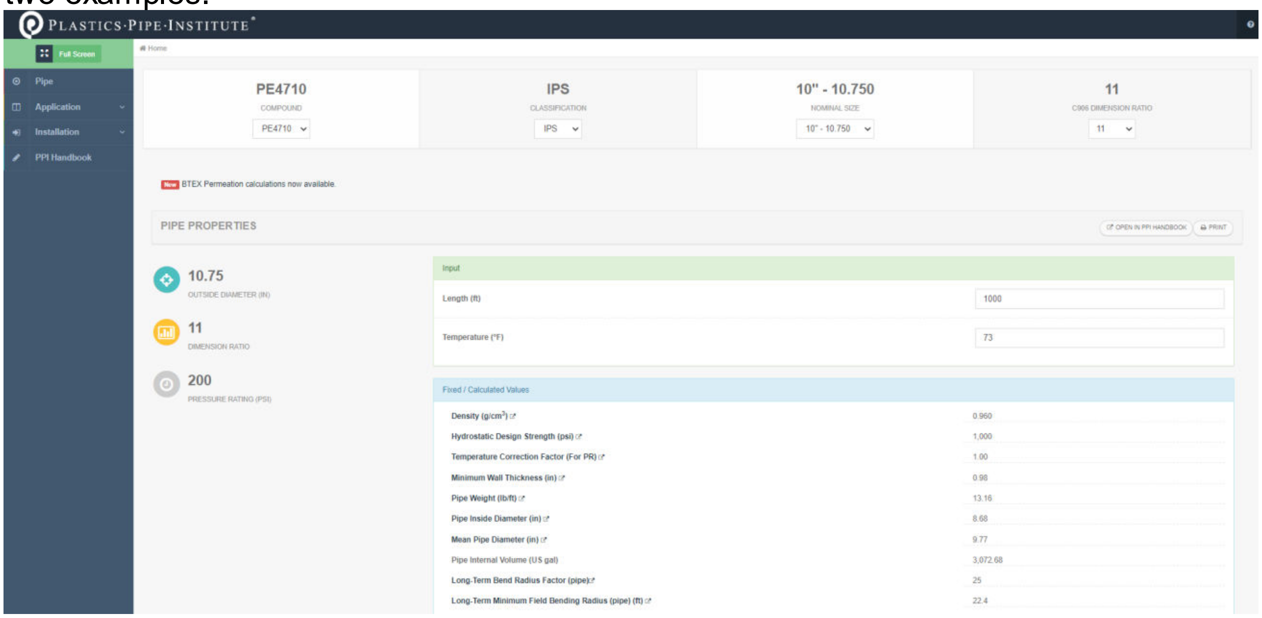




Response – The S-4 calculator makes it easy to select materials and enter required values. For a 100 foot length of PEX, we find that we will have an expansion length ΔL of 5.5 in. The loop dimensions required to take this length change is 8.4 in X 16.7 in.

S-5 PPI HDPEapp Calculator v2.0

The users of the HDPEapp calculator vary widely. There is so much functionality built into this calculator that it can be used for dozens of applications. Some of those functions include general pipe properties such as bend radius, tensile strength, pipe dimensions, pressure rating at designated temperature, pipe volume, and much more. But the real benefit of the calculator is the more in depth functions such as pressure and gravity flow, surge pressure, unrestrained dimensional change with temperature fluctuation, pipe span distances between supports, end anchor load due to temperature change, safe pull force, thrust block sizing, buckling pressure, burial loads/pipe deflection and the newly added oxidative resistance. For this calculator we will calculate two examples.



Customer Question – "I am designing an above ground produced water transfer line in West Texas. I need to transfer 5,000 barrels per day over a distance of one mile. We have no hydrocarbons in this fluid stream and the line has very little elevation change. What is the smallest diameter of pipe I can use, and do you have a DR suggestion?"
Response – Often, question on pipe size will come before pumps are selected, so we may need to calculate a few difference scenarios for frictional pressure loss. First we will need to figure out the pressure rating of a recommended DR. Because this pipe is being installed above ground in Texas, pipe temperatures can easily reach 140F. We will start with a DR11, which will give us a pressure rating of 125 psi at 140F. 5,000 barrels per day is roughly 110 gallons per minute. We can now start playing with possible pipe diameters to see what results we get. You have the option of solving for "Frictional Pressure Loss", "Length of Pipe", or "Flow Rate". Let's start with solving for flow rate. An 85 psi frictional loss gives us 110 gallons per minute flow, with a fluid velocity of 5.6 feet per second and a surge pressure of 80 psi. Checking on a 2" diameter for comparison there is no way we can get the 110 gallons per minute required flow through it. It is often the case that when the bare minimum is discussed the decision is then made at a later

time to increase wall thickness to protect the pipe against third party damage as this pipeline is installed above ground. If a lower DR is selected or a pump design comes back and the originally designed frictional pressure loss is too high, a new flow velocity can easily be calculated for a new pipe size or DR.

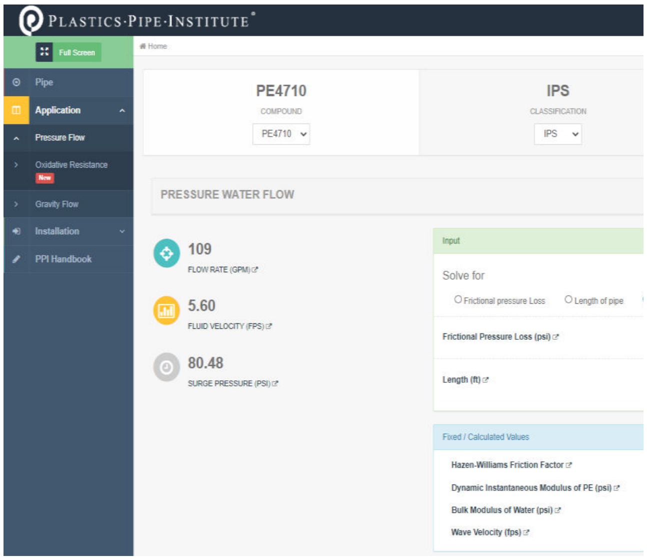


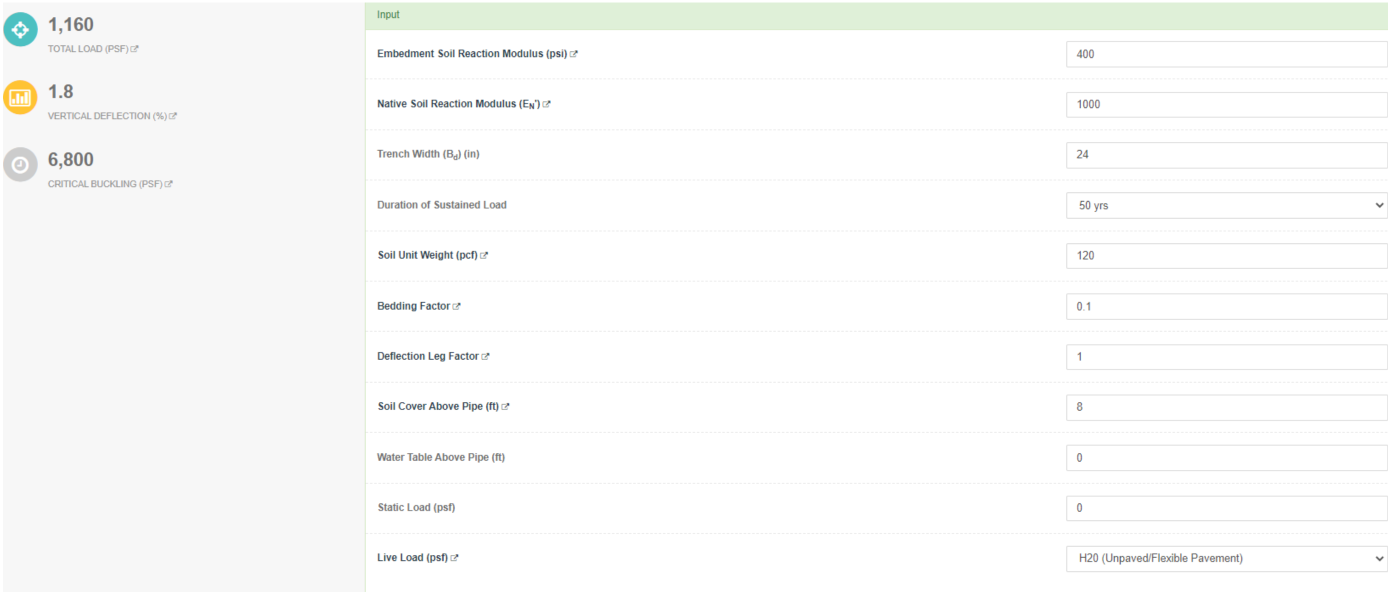
TABLE 3-7
Values of E' for Pipe Embedment (See Howard [8])

Soil Type-pipe Embedment Material (Unified Classification System)[1]	E' for Degree of Embedment Compaction, lb/in²			
	Dumped	Slight, <85% Proctor, <40% Relative Density	Moderate, 85%-95% Proctor, 40%-70% Relative Density	High, >95% Proctor, >70% Relative Density
Fine-grained Soils (LL > 50)[2] Soils with medium to high plasticity; CH, MH, CH-MH	No data available: consult a competent soils engineer, otherwise, use E' = 0.			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse grained particles.	50	200	400	1000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse grained particles; Coarse-grained Soils with Fines, GM, GC, SM, SC[3] containing more than 12% fines.	100	400	1000	2000
Coarse-grained soils with Little or No Fines GW, GP, SW, SP[3] containing less than 12% fines	200	1000	2000	3000
Crushed Rock	1000	3000	3000	3000
Accuracy in Terms of Percentage Deflection[4]	±2%	±2%	±1%	±0.5%

[1] ASTM D-2487, USBR Designation E-3
[2] LL = Liquid Limit
[3] Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).
[4] For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Customer Question – "I have a 12" IPS DR17 pipe that I am wanting to bury at a 8ft depth in clay with some sand in it. The pipe will have sections that will see H20 loads on dirt/gravel roads. The pipe will have fair to moderate compaction. Will a DR17 be able to stand up to these forces? What kind of deflection can we expect?"

Response – Under the "Below Ground Earthloading" section of the calculator we can design for burial loads. To run these calculations, we will need a soil modulus. If you are needing to find information on the S-5 calculator, you will notice these icons ↗. By clicking these it will take you to a page in PPI's Handbook of Polyethylene Pipe where you can find information or values you will need for these calculations. A clay soil with some sand in it would fall into a Class IV soil type. With moderate compaction that will give us a soil modulus of 400 psi for the embedment materials. We will assume a 1000 psi soil modulus for the native soil (trench walls).



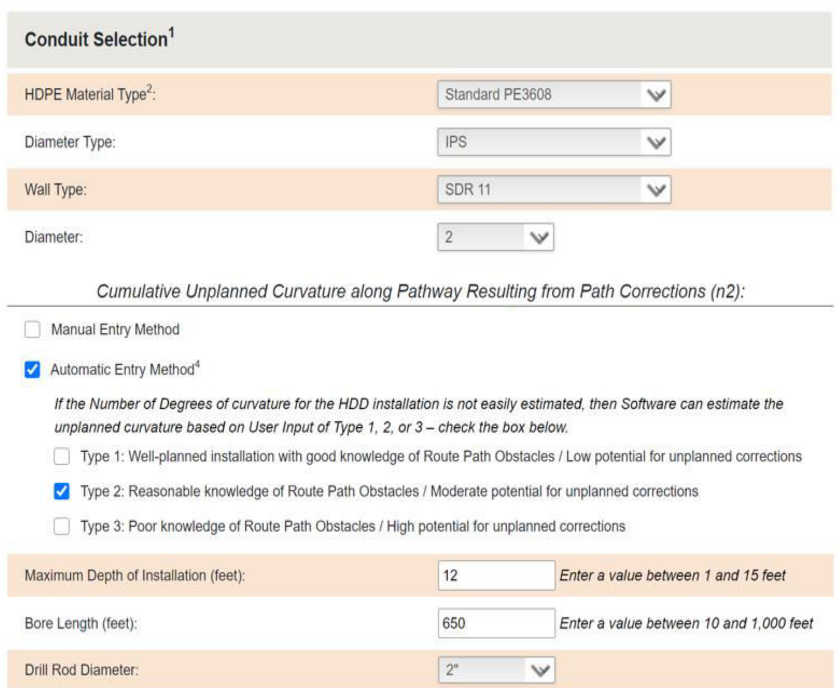
After entering these values, we can see what the critical buckling pressure is and what the resultant total load is for this installation. We are given an allowed 6,800 psi with an applied load of 1,160 psi. The final burial results in a vertical deflection of 1.8% which is well within specification.

S-6 PPI Conduit Design Calculator

The users of PPI's conduit design calculator are conduit contractors and sometimes gas/water service line installers. This calculator automates PPI's Technical Report TR-46 for mini HDD equipment and proper pipe size and wall thickness selection.

Customer Question – "I was supposed to be drilling in some 2" IPS DR11 PE3608 conduit, but I just called my supplier and they don't have any DR11 in stock. What other DR's would work for this drill?"

Response – After inputting pipe size and material into the calculator, we can select between the manual entry method and the automatic entry method, we will use the automatic entry for this example. You can then select how comfortable you are with the chosen route and possible obstacles, along with maximum burial depth, bore length and drill rod diameter. The result will give us acceptable DR's and Schedules for this



application of conduit pipe.

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	1501	0.91	Fail	Use a Thicker Wall
Schedule 80	1867	1393	1.34	Pass	This Wall Type is OK
SDR 9	2211	1318	1.68	Pass	This Wall Type is OK
SDR 11	1852	1396	1.33	Pass	This Wall Type is OK
SDR 13.5	1535	1465	1.05	Pass	This Wall Type is OK
DR 15.5	1359	1503	0.90	Fail	Use a Thicker Wall
SDR 17	1258	1524	0.83	Fail	Use a Thicker Wall

CONCLUSIONS

It is important for trade organizations and their membership to develop these online tools in order to continue driving customers to plastic piping materials. Engineers and designers will continue to use these calculators as “quick glance” comparisons to see if a pipe material is viable for their application. These calculators benefit the plastic pipe industry as a whole. It is important for all involved in plastic piping to understand these calculators and aid those around you in learning how to use them.

ACKNOWLEDGMENTS

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PPI PE Handbook, Ch 6 - Design of PE Piping Systems
PPI PE Handbook, Ch 12 - Horizontal Direction Drilling
PPI PE Handbook, Ch 13 – HVAC Applications for Plastic Pipe
PPI PE Handbook, Ch 14 – Duct and Conduit
PPI Technical Report TR-46 Mini-HDD
ASTM F1962 Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings