Technical Note PP 803-TN
Pull-In Applications

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When DriscoPlex® polyethylene (PE) piping or conduit is installed using pull-in techniques such as sliplining, insertion renewal, horizontal directional drilling, pipe bursting, or plowing and planting, the installation applies temporary tensile stresses to the pipe. If installation-applied stresses are too high, the PE pipe may be damaged, or its potential service life may be compromised.

PE Tensile Properties

Unlike metals that break almost immediately after yielding, PE will elongate several hundred percent before breaking under tensile load. Once the material yields, it doesn't require greater pulling force to stretch it until it breaks. That is, the pulling load that causes the pipe to yield is about the same as the load that causes it to break, but between yield and break the pipe will stretch out several hundred percent. For example, 400% elongation means that when the pipe yields, one foot of pipe will stretch an additional four feet. However, while the pipe is stretching after yield, the pulling load will stay about the same until it drops to zero when the pipe breaks.

PE is sensitive to the length of time the pulling load is applied. That is, the pulling load that causes the pipe to yield and break in a few minutes is much higher than the load that causes failure in an hour or a day. This phenomenon is called creep. It means that the pipe's allowable tensile load (ATL) for a half-day pull is lower than the ATL for a 1-hour pull. Published tensile strength values are based on short-term tests that take only minutes to run. Because pull-in installations take longer, ATL values must be much lower than the published short-term tensile yield strength of the pipe. The ATL is the maximum tensile load that can be applied to a PE pipe that does not result in unrecoverable tensile elongation.

Lastly, as with all thermoplastic materials, the strength of PE decreases as the temperature increases. As a result, pipe that has been warmed by the sun before pull-in has a lower allowable tensile load.

Allowable Tensile Load (ATL)

Allowable tensile loads for setting weak-link devices for PE pipe can be determined by using Equation 1 from ASTM F1804 “Standard Practice for Determining Allowable Tensile Load for Polyethylene (PE) Gas Pipe During Pull-In Installation”.

Equation 1:

$$ATL = f_Y f_T T_Y \pi (OD)^2 \left(\frac{1}{DR} - \frac{1}{(DR)^2}\right)$$

ATL = allowable tensile load, lbs.
f_Y = tensile yield design factor
f_T = time under tension design factor
T_Y = PE material tensile yield strength, psi
OD = pipe outside diameter, in
DR = pipe dimension ratio (SDR)

For Equation 1, Performance Pipe recommends the following values:

Table 1 Recommended Design Factors for Equation 1

Recommended Design Factors				
Factor	**Parameter**	**Recommended Value**		
f_Y	Tensile yield design factor	0.40*		
f_T	Time under tension design factor	1.00 for up to 1 hour	0.95 for up to 12 hours	0.91 for up to 24 hours
*To prevent 'plastic' deformation and allow for full strain recovery, tensile stress in PE should not exceed 40% of yield strength.				

Table 2 Approximate Tensile Yield Strength Values, T_Y, for Equation 1

Tensile Yield Strength Values				
Material	**73°F (23°C)**	**100°F (38°C)**	**120°F (49°C)**	**140°F (60°C)**
PE2708	2,600 psi (17.9 MPa)	2,300 psi (15.9 MPa)	1,900 psi (13.1 MPa)	1,500 psi (10.3 MPa)
PE4710	3,500 psi (24.1 MPa)	2,900 psi (20.0 MPa)	2,400 psi (15.9 MPa)	2,000 psi (13.8 MPa)

Certain installation methods such as horizontal directional drilling may impose additional bending stresses while the pipe is under pull-in tension. When installing pipe in tight bends, allowable tensile load values may need to be reduced accordingly. The PPI Handbook of PE Pipe gives a method for accounting for the additional bending stress in Chapter 12.

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Weak-Link Devices

During pull-in installation, it is essential to ensure the pipe's ATL is not exceeded. A weak link is a device or method used that ensures the ATL is not exceeded when pulling PE pipe. For PE gas piping installations that are jurisdictional to 49 CFR 192, §192.329 requires the use of a weak link. Indicators such as drilling rig hydraulic pressure or winch rope pulling force do not show the load at the connection to the PE pipe. For directional drilling, the pulling force at the drill rig will include the force required to pull the reamer and drill-string and will therefore typically exceed the force acting on the pipe. Thus, a conservative approach is to limit the force at the rig to the pipe's ATL, though this may not always be practical. The more typical approach is to utilize a connector that uncouples the pipe from the rig at a preset tensile force.

A mechanical weak-link device, such as a breakaway swivel, is recommended. The use of smaller and/or thinner PE pipe is discouraged since it is difficult to determine a PE pipe's ultimate break strength. The value is a function of many factors including the rate and duration the load is applied. Due to the variation, the break strength of a smaller or thinner PE pipe may actually surpass the ATL of the PE pipe being installed. A properly selected break-away swivel does not have this limitation. A weak-link device is not necessary when the pulling equipment is incapable of exceeding the ATL for the pipe being installed.

Over-Pull and Relaxation After Pullback

When tensile loads are at or below the ATL, PE pipe has elastic properties. When a tensile load is applied to a PE pipe, the load causes the pipe to elongate a small amount, but the pipe material is not permanently damaged. After the tensile load is removed, the pipe shrinks back to its original length. To recover from temporary pull-in installation tensile stress effects, a relaxation period is required before tie-ins are made. The required relaxation period depends on the amount of tensile force applied and the duration the tensile load was applied. Relaxation periods typically range from 8 to 24 hours. Normal installation practice is to pull 3-5% past the exit point and to leave 3-5% extra pipe length at the entry point. This allows the pipe to shrink back to its original length during the relaxation period, while still keeping the pipe ends exposed for tie-in connections.

Allowable Tensile Load (ATL) Tables

Tables 3, 4, and 5 give approximate ATL values for selected PE2708 and PE4710 tubing and pipe sizes. The ATL values in Tables 3, 4, and 5 are calculated for pipe at 73°F (23°C) and for pull durations of up to 12 hours. Bending stress from pipe bent to a tight radius is not accounted for in the values. ATL values are rounded to the nearest 50 psi per ASTM F1804. For other sizes, materials, pull durations, and elevated temperatures, use Equation 1 and the information in Tables 1 and 2 to determine the ATL for the pipe size, material, and application.

Table 3 Allowable Tensile Loads for CTS Tubing Sizes at 73°F* (23°C) & Pull Duration of Up to 12 Hours[a]

Allowable Tensile Load^ (ATL), lbs.				
Size	**Nominal OD**	**Minimum Wall**	**PE2708**	**PE4710**
1/2" CTS	0.625"	0.090"	150	200
3/4" CTS	0.875"	0.090"	200	300
1" CTS	1.125"	0.090"	300	400
1-1/4" CTS	1.375"	0.090"	350	500

*Values assume pipe is 73°F or cooler. For pipe at elevated temperatures, utilize Equation 1.
^ATL calculation utilizes a tensile yield design factor of 0.4 and a time under tension design factor of 0.95 for pulls up to 12 hours.
[a]For pull durations of less than 1 hour or between 12 and 24 hours, utilize Equation 1.

Table 4 Allowable Tensile Loads for PE2708 IPS Pipe Sizes at 73°F* (23°C) & Pull Duration of Up to 12 Hours[a]

Allowable Tensile Load^ (ATL), lbs.						
IPS Size	**SDR 17**	**SDR 13.5**	**DR 11.5**	**SDR 11**	**SDR 10**	**SDR 9**
1/2"				200		200
3/4"				300		350
1"				450		550
1-1/4"				700	750	850
2"				1,450		1,750
3"	2,100	2,600	3,000	3,150		3,750
4"	3,500	4,300	5,000	5,200		6,200
6"	7,550	9,350	10,800	11,250		13,450
8"	12,800	15,850	18,350	19,100		22,800
10"	19,850	24,600	28,500	29,650		35,450
12"	27,950	34,600	40,050	41,700		49,850
14"	33,700	41,750	48,300	50,300		60,100
16"	44,000	54,500	63,100	65,650		78,500
18"	55,700	69,000	79,850	83,100		99,300
20"	68,750	85,150	98,550	102,600		122,600
22"	83,150	103,050	119,250	124,150		148,350
24"	99,000	122,600	141,950	147,750		176,600

*Values assume pipe is 73°F or cooler. For pipe at elevated temperatures, utilize Equation 1.
^ATL calculation utilizes a tensile yield design factor of 0.4 and a time under tension design factor of 0.95 for pulls up to 12 hours.
[a]For pull durations of less than 1 hour or between 12 and 24 hours, utilize Equation 1.

Table 5 Allowable Tensile Loads for PE4710 IPS Pipe Sizes at 73°F* (23°C) & Pull Duration of Up to 12 Hours[a]

Allowable Tensile Load^ (ATL), lbs.				
IPS Size	**SDR 17**	**SDR 13.5**	**SDR 11**	**SDR 9**
1/2”			250	300
3/4”			400	450
1”			600	700
1-1/4”			950	1,150
1-1/2”			1,250	1,500
2”			1,950	2,350
3”	2,850	3,500	4,250	5,050
4”	4,700	5,800	7,000	8,350
6”	10,150	12,600	15,150	18,100
8”	17,200	21,300	25,700	30,700
10”	26,750	33,100	39,900	47,700
12”	37,600	46,600	56,150	67,100
14”	45,350	56,150	67,700	80,900
16”	59,200	73,350	88,400	105,650
18”	74,950	92,850	111,900	133,700
20”	92,550	114,650	138,150	165,050
22”	111,950	138,700	167,150	199,750
24”	133,250	165,050	198,900	237,700

*Values assume pipe is 73°F or cooler. For pipe at elevated temperatures, utilize Equation 1.
^ATL calculation utilizes a tensile yield design factor of 0.4 and a time under tension design factor of 0.95 for pulls up to 12 hours.
[a]For pull durations of less than 1 hour or between 12 and 24 hours, utilize Equation 1.