Technical Note 803 - Pull In Applications

Pull-In Applications

When Performance Pipe OD controlled polyethylene pipe or conduit is installed using pull-in techniques such as sliplining, insertion renewal, horizontal directional drilling, pipe bursting, plowing and planting, the installation applies temporary stresses to the pipe. If installation-applied stresses are too great, the polyethylene pipe may be damaged beyond use, or its potential service life may be compromised.

Polyethylene Tensile Properties

Unlike metals that break almost immediately after yielding, polyethylene 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, 1 foot of pipe will stretch an additional 4 feet, but while stretching after yield, the pulling load stays about the same until it drops to zero when the pipe breaks.

Polyethylene 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 known as 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. The ATL is the allowable safe pulling load that can be applied to a polyethylene pipe.

Lastly, as with all thermoplastic materials, the strength of polyethylene 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.

Pull-In Installation

Weak-Link Devices

A "weak-link" or breakaway device should always be used at the leading end of the PE pipe to protect the pipe from damage if the pulling load gets too high. The breakaway strength for the weak-link device should be set so that the allowable tensile load (ATL) of the pipe cannot be exceeded. Indicators such as drilling rig hydraulic pressure or winch rope pulling force do not show the load at the connection to the PE pipe and do not provide reliable protection against pull-in damage. A weak-link device is not necessary only when the pulling equipment is incapable of exceeding the ATL for the pipe being installed.

Allowable tensile loads for setting weak-link devices for polyethylene pipe can be determined from ASTM F 1804 *Standard Practice for Determining Allowable Tensile Load for Polyethylene (PE) Gas Pipe During Pull-In Installation.* From ASTM F 1804,

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

where ATL = allowable tensile load, lb (N)
f_Y = tensile yield design (safety) factor
f_T = time under tension design (safety) factor
T_Y = PE material tensile yield strength, psi (MPa)
D = pipe outside diameter, in (m)
R = pipe dimension ratio (DR or SDR).

In Equation (1), Performance Pipe recommends the following values:

Table 1 Recommended Design Factors for Equation (1)

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 h*	*0.95 for up to 12 h*	*0.91 for up to 24 h or less*
† In Equation (1), multiplying by a 0.40 design factor is the same as dividing by a 2.5 safety factor.				

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

Material	*73°F (23°C)*	*100°F (38°C)*	*120°F (49°)*	*140°F (60°C)*
MDPE	2,600 psi (17.9 MPa)	2,365 psi (16.3 MPa)	1,920 psi (15.4 MPa)	1,640 psi (14.3 MPa)
HDPE	3,200 psi (22.1 MPa)	2,910 psi (17.4 MPa)	2,365 psi (13.7 MPa)	2,015 psi (11.0 MPa)

Certain installation methods such as horizontal directional drilling may impose additional bending stresses while the pipe is under pull-in tension. Allowable tensile load values may need to be reduced to accordingly. Horizontal Directional Drilling (HDD) applications are to be performed as specified by the project engineer or/and in accordance with ASTM F1962 *Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit under Obstacle, Including river Crossings*[1], Plastic Pipe Institute (PPI) *Polyethylene Pipe for Horizontal Directional Drilling*[2] and the *Mini Horizontal Directional Drilling Manual* published by the North American Society of Trenchless Technology (NASTT)[3].

Pull-In Installation Practices

When pull-in tensile loads are at or below the ATL, polyethylene pipe has elastic properties. That is, the pull-in load causes the pipe to elongate a small amount, but the material is not permanently damaged, and 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. Relaxation periods typically range from 8 to 24 hours. Normal installation practice is to pull 3-5% past the exit point, and 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, but afterwards the pipe ends will still be exposed for tie-in connections.

As explained above, the tensile load that causes pipe yielding is about the same as the load that causes elongation and breakage. Thus, monitoring just the pulling load at the pulling equipment does not protect against pipe damage. A good practice is to observe the pipe or conduit at the entry point as it is pulled-in. It should continue to move at a steady pace. If pipe movement stops or it's pace is interrupted, pipe yielding may be indicated. It is important to observe allowable tensile load requirements, to use a weak link device, to monitor pipe movement at the entry location and pulling equipment movement at the exit point, and to monitor pulling load, especially for smaller pipes and conduits that have low allowable tensile loads.

1 Available from ASTM at www.ASTM.org
2 Available from PPI at www.plasticpipe.org
3 Available from NASTT at www.nastt.org

Allowable Tensile Load (ATL) Tables

Tables 3, 4, and 5 give approximate allowable tensile load (ATL) values for selected MDPE and HDPE tubing and pipe sizes. For other sizes or materials, use Equation (1) 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 1 Hour or Less ∇

Size	Nominal OD	Minimum Wall	ATL*∇	
			MDPE†	HDPE‡
1/2” CTS	0.625”	0.090”	157 lb	194 lb
3/4” CTS	0.875”	0.090”	231 lb	284 lb
1” CTS	1.125”	0.090”	304 lb	375 lb
1-1/4” CTS	1.375”	0.090”	378 lb	465 lb

* At elevated temperature, multiply ATL by the appropriate Table 6 multiplier. ∇ For pull duration between 1 and 12 hours, multiply table value by 0.95; for pull duration between 12 and 24 hours, multiply table values by 0.91. † 2600 psi nominal tensile yield strength. ‡ 3200 psi nominal tensile yield strength.

Table 4 Allowable Tensile Loads for MDPE† IPS Pipe Sizes at 73°F (23°C)* & Pull Duration of 1 Hour or Less ∇

IPS Size	ATL*∇, lb					
	SDR 17	SDR 13.5	DR 11.5	SDR 11	DR 10	SDR 9
1/2”				191		228
3/4”				307		367
1”				467		558
1-1/4”				744	811	889
2”				1,524		1,821
3”	2,216	2,746	3,179	3,309		3,954
4”	3,664	4,539	5,254	5,470		6,563
6”	7,941	9,838	11,389	11,855		14,167
8”	13,460	16,675	19,303	20,093		24,012
10”	20,910	25,904	29,986	31,213		37,302
12”	29,414	36,439	42,182	43,908		52,473
14”	35,464	43,935	50,858	52,939		63,266
16”	46,320	57,384	66,427	69,145		82,633
18”	58,624	72,627	84,071	87,512		104,582
20”	72,375	89,663	103,792	108,040		129,114
22”	87,574	108,492	125,588	130,728		156,228
24”	104,221	129,114	148,460	155,577		185,924

† 2600 psi nominal tensile yield strength. * At elevated temperature, multiply ATL by the appropriate Table 3 multiplier. ∇ For pull duration between 1 and 12 hours, multiply table value by 0.95; for pull duration between 12 and 24 hours, multiply table values by 0.91.

Table 5 Allowable Tensile Loads for HDPE‡ IPS Pipe Sizes at 73°F (23°C)* & Pull Duration of 1 Hour or Less ∇

IPS Size	ATL*∇, lb			
	SDR 17	SDR 13.5	SDR 11	SDR 9
1/2”			235	280
3/4”			378	451
1”			575	687
1-1/4”			916	1,095
1-1/2”			1,200	1,434
2”			1,875	2,241
3”	2,728	3,380	4,072	4,867
4”	4,510	5,587	6,732	8,045
6”	9,774	12,109	14,591	17,437
8”	16,566	20,523	24,730	29,553
10”	25,735	31,882	38,416	45,910
12”	36,202	44,849	54,041	64,582
14”	43,648	54,073	65,156	77,866
16”	57,010	70,627	85,102	101,702
18”	72,153	89,387	107,707	128,717
20”	89,077	110,354	132,972	158,910
22”	107,784	133,528	160,896	192,281
24”	128,271	158,910	191,480	225,530

‡ 3200 psi nominal tensile yield strength. * At elevated temperature, multiply ATL by the appropriate Table 6 multiplier. ∇ For pull duration between 1 and 12 hours, multiply table value by 0.95; for pull duration between 12 and 24 hours, multiply table values by 0.91.

Table 6 Elevated Temperature Multipliers for ATL

Material	73°F (23°C)	100°F (38°C)	120°F (49°)	140°F (60°C)
PE 2406	1.00	0.91	0.74	0.63
PE 3408	1.00	0.91	0.74	0.63

These elevated temperature multipliers are used only to adjust Table 3, 4, or 5 ATL values for elevated temperature. That is, multiplying the 73° F (23° C) ATL value by the Table 6 elevated temperature multiplier gives the same result as determining ATL with Equation (1) and the appropriate Table 2 elevated temperature yield strength value. When Equation (1) is used to determine ATL, the Table 6 elevated temperature multiplier is not used.

PERFORMANCE PIPE, a division of
Chevron Phillips Chemical Company LP
PO Box 269006
Plano, TX 75026-9006
Phone: 1-800-527-0662
Fax: 972-599-7348

Web:
www.performancepipe.com

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