PERFORMANCE PIPE
A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP

PERFORMANCE PIPE DRISCOPLEX® 4000/4100 Pipe

Water and Wastewater Piping Systems

- Corrosion Resistant
- Leak Proof Fused Joints
- Ideal for Trenchless Applications
- Flexible
- Hydraulically Efficient ID
- Will Not Tuberculate
- Reduces Surge Pressure
- Outstanding Resistance to Fatigue
- Excellent Impact Strength
- Thrust Blocks Not Needed
- Resistant to Sewer Gas
- Less Maintenance
- Mechanical Fittings Available for Transitions and Repairs
- Environmentally Friendly

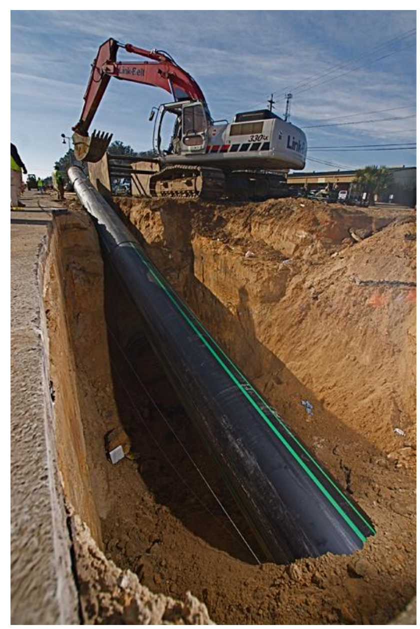
When Performance Matters
Rely on Us!

ASCE Report Card

The American Society for Civil Engineers (ASCE) issues a “report card” on the condition of America’s infrastructure about once every five years. In the 2009 report they gave water and wastewater infrastructure a grade of D minus. EPA has identified the two biggest problems facing America’s infrastructure as corrosion and leakage. DriscoPlex® 4000 and 4100 High Density Polyethylene (HDPE) pipes offer a solution. HDPE pipes do not undergo galvanic corrosion and are suited for “aggressive soils.” They do not rust, rot, corrode, tuberculate, or support biological growth. DriscoPlex® 4000 and 4100 pipes are joined by heat fusion which means the pipes are essentially a continuous pipe without gasket joints to leak. The heat-fused joint is as strong as the pipe itself and fully restrained requiring no thrust blocks.

The Future for Water and Wastewater Piping

Polyethylene pipe’s wide acceptance and use for natural gas distribution is the strongest statement that can be made about polyethylene pipe’s corrosion resistance and leak-tight nature. Polyethylene pipe has been used for gas distribution pipe since the early 1960’s. More than 95% of new gas distribution piping is polyethylene. By 2008, over 577,000 miles of polyethylene natural gas pipe and 39.6 million polyethylene pipe services were installed in the United States. Natural gas service is the most safety critical usage of piping in a municipality. Leakage cannot be tolerated. In addition to the excellent record in gas distribution, polyethylene pipe has been used for water in Europe and North America for 50 years. Recognizing these successes, more and more water and wastewater utilities are turning to polyethylene pipe for both trenchless construction and open-cut applications. For municipal usage, DriscoPlex® pipe is manufactured to ASTM F714, AWWA C901 and AWWA C906 standards. It meets the requirements of NSF/ANSI-61 (NSF/ANSI-14 where noted) and comes in either Iron Pipe Sizes or Ductile Iron Pipe Sizes, i.e. the outside diameter (OD) matches the OD of iron pipe or ductile iron pipe, respectively. In addition to pipe, standard products such as heat-fusion and electrofusion saddles, flanges, mechanical-joint adapters are available for hot tapping and connecting to pumps, hydrants or valves. Mechanical connections and hot taps requiring no fusion are available as well.



Performance Pipe Means the Highest Quality

Performance Pipe is a name you can trust in water and sewer piping. Performance Pipe has produced quality polyethylene piping products for fifty years. Our internal QA/QC requirements meet or exceed those required by industry standards. Each production line is continuously monitored throughout the manufacturing cycle to ensure that the product adheres to all internal quality control specifications and the manufacturing standard.

All nine of Performance Pipe’s manufacturing facilities and our headquarters are certified in accordance with the latest edition of ISO 9001:2000. Certificates of Conformance are available through our website. Performance Pipe produces all pipe and molded fittings products in the United States. These products are compliant with the Buy American requirement of the 2009 American Recovery and Reinvestment Act.

When you select Performance Pipe DriscoPlex® 4000 and 4100 pipe and fittings, in addition to receiving quality products, you also gain access to our team of experts for technical support, sales and assistance. Our territory sales teams are dedicated to the municipal piping industry and are active

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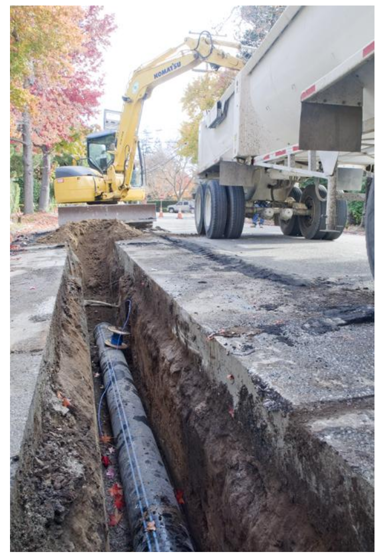
members of the ASTM International, Plastics Pipe Institute, American Water Works Association (AWWA) and many other industry associations. As a company we provide technical expertise and service to these organizations on an ongoing basis.

The unmatched quality and performance of Performance Pipe's polyethylene piping products is further enhanced and strengthened by more than five decades of quality polyolefin plastic resin production from our parent company Chevron Phillips Chemical Company LP.

Polyethylene Resin Continues to Improve



DriscoPlex® pipe and fittings for M&I applications are made from polyethylene materials that are engineered for high density, extra high molecular weight, and broad molecular weight distribution. These characteristics give DriscoPlex® products strength, flexibility, toughness and durability. Since the introduction of polyethylene piping materials in the 1950's, polyethylene resin manufacturers have worked continually to improve their resins. In 2005 "High Performance" polyethylene pipe materials were adopted in U.S. ASTM standards. The most improved of the new materials has a designation code of PE4710. Compared to PE3408 (now PE3608) materials, PE4710 resins have increased density, higher tensile strength and higher resistance to slow crack growth. These increased properties allow the pipe to meet higher performance requirements.

Performance Pipe manufactures pipe and fittings of high performance PE4710. Performance Pipe's PE4710 materials are listed in PPI TR-4 with a Hydrostatic Design Stress of 1000 psi at 73°F. Where specifications and standards permit, PE4710 materials can be operated at higher pressures than PE3408 materials due to the higher Hydrostatic Design Stress rating at 73°F. PE4710 materials meet or exceed all of the requirements of the former PE3408 resin.

For a more detailed explanation of PE4710 materials and information regarding temperature, design factors and calculation of pressure rating, see PP 816-TN *PE3608 and PE4710 Materials Designation Codes and Pipe Pressure Ratings.* All Performance Pipe documents may be found at www.performancepipe.com.

Cell Classification for PE4710 Material

ASTM D3350, *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials,* identifies polyethylene materials for pipe and fittings according to a cell classification system. Performance Pipe's DriscoPlex® 4000 and 4100 series pipe cell classification is listed in Table 1. For specific material properties see PP101, *"DriscoPlex® 4000 (DIPS)/4100 (IPS) Water, Wastewater and Industrial".*

Table 1: Cell Classifications

Performance Pipe Product Series	Material Designation Code (MDC)		ASTM D3350 Cell Classification
	Present	Past	
DRISCOPLEX® 4000/4100 Pipe	PE4710	PE3408	445574C

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PE Durability and Disinfectants in Potable Water Applications

HDPE pipes are used extensively in municipal water applications throughout Europe and the United Kingdom – boasting the lowest failure rates of any piping material. HDPE pipes contain additives which protect the pipe from the oxidizing effects of disinfectants. At Performance Pipe, our HDPE water pipes meet AWWA requirements and are evaluated to the toxicological requirements of NSF/ANSI 61. A recent study by Jana Laboratories examined the projected lifespan of polyethylene pipe under typical operating conditions at utilities in Indiana, Florida, North Carolina, and California. Their findings indicate a life expectancy greater than 100 years. Read Jana Laboratories' report, *Impact of Potable Water Disinfectants on PE Pipe*.

DriscoPlex® Piping Products for Municipal Applications

Performance Pipe offers pipe for municipal applications that are manufactured to both ASTM and AWWA standards simultaneously. Performance Pipe standard products are generally stocked by distributors and, for many sizes and DR's, are readily available. Specialty products are available but generally not stocked and thus have to be produced at Performance Pipe manufacturing plants. Table 2 lists the various products, applicable standards, and the pipe material designation code. DriscoPlex® pipes series are identified by a four digit number code. For example, DriscoPlex® 4000 pipe.

Table 2. DriscoPlex® Pipes

DriscoPlex® Municipal Water and Wastewater Pipe				
DriscoPlex® Pipe Series	**Features**	**Size Range**	**Applicable Standards**	**Pipe Materials Designation Codes Available (PPI TR-4)**
4000 (DIPS) Municipal potable water, raw water, process water, sewer	Black w/ blue stripes	4" through 42" DIPS	AWWA C906 & ASTM F714 (4" to 42") NSF/ANSI 61	**PE4710**
4100 (IPS) Municipal potable water, raw water, process water, sewer	Black pipe is standard	1-1/2" through 54" IPS	AWWA C901 & ASTM D3035 (3" & smaller) ASTM F714 & AWWA C906 (4" to 54") and NSF/ANSI 61	**PE4710**

For ¾" through 2" SIDR and CTS and for ¾" through 3" IPS for municipal potable water service lines consider 5100 Ultraline®. See PP410,"DriscoPlex® 5100 Series Ultraline® HDPE Water Service Pipe & Tubing".

DriscoPlex® Pipe is Manufactured to Both ASTM F714 and AWWA C906

DriscoPlex® 4000/4100 pipe meets or exceeds the requirements of ASTM F714 and AWWA C906. ASTM F714 designates a "Pressure Rating (PR)" whereas AWWA C906 designates a "Pressure Class, PC." Currently these are not calculated the same way and therefore are not equal. ASTM F714 recognizes PE4710 material, whereas AWWA C906 is being updated but currently treats PE4710 material as having the same PC as the former PE3408 material. For AWWA C906 ratings, see Appendix 1.

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The pressure rating of PE pipe varies with the pipe's Dimension Ratio (DR). The DR is equal to the average pipe outside diameter (OD) divided by the minimum wall thickness. The Plastics Pipe Institute's *Handbook of Polyethylene Pipe* gives the method for calculating the pressure rating. The pressure ratings for DriscoPlex® 4000/4100 pipe allowed by ASTM F714 are given in Table 3.

Water and force main sewer lines have frequent and recurring surges. The designer will consider both the pipe's working or pumping pressure and the total pressure (pumping pressure plus surge pressure) when determining an application's DR. Rating for both are given in Table 3 for easy comparison with design flow conditions.

Table 3 DriscoPlex® 4000 and 4100 Pipe Pressure Ratings per ASTM F714 at 80°F

PE4710 Pipe Pressure Ratings Per ASTM F714[1]			
Dimension Ratio	Working Pressure Rating (psi)	Allowable Total Pressure During Recurring Surge (psi)	Allowable Total Pressure During Occasional Surge (psi)
9	250	375	500
11	200	300	400
13.5	160	240	320
14.3	150	225	300
17	125	185	250
21	100	150	200
26	80	120	160

[1]For Pressure Class and Working Pressure Ratings per AWWA C906, see Appendix 1. Ratings are for water and can vary for other fluids and temperature. Table 3 Working Pressure Ratings may be used with AWWA C901 pipe.

The temperature range for polyethylene pipe is -40°F to 140°F for pressure pipe and -40°F to 180°F for non-pressurized pipe, e.g. gravity flow. When DriscoPlex® pipe operates at a temperature above 80°F the Pressure Rating and Pressure Class of the pipe are decreased. The PR/PC for temperatures above 80°F may be determined by multiplying the PC in Table 3 by the temperature factor from Table 4.

Table 4: Service Temperature Design Factor

Service Temperature Design Factor, F_T[1]							
Service Temperature, °F (°C)	≤80 (27) (1)	≤90 (32)	≤100 (38)	≤110 (43)	≤120 (49)	≤130 (54)	≤140 (60)
	1.0	0.9	0.8	0.71	0.63	0.57	0.50

[1]Use 80°F (27°C) service factor for service temperatures below 80°F (27°C). F_T for temperatures below 100°F are from AWWA M-55. F_T for temperatures above 100°F found by interpolation.

***PPI Design & Engineering Calculator for PE Pipe* is available on the Performance Pipe website.**

DriscoPlex®4000/4100 Pipe Common Sizes

Tables 5 and 6 give dimensions and weights for commonly used DR's in the water and wastewater industry. For other available DR's, see PP152 and PP153, *Size and Dimension Sheets*. All pipes of a given nominal size are made to the same OD regardless of DR. Therefore, the average inside diameter (ID) varies with the pipe wall thickness. DriscoPlex® 4000/4100 pipe is available in 40 or 50 foot lengths and is also available in coils through 6" DIPS. *Packaging and Loading* information is available on our website.

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Table 5 DriscoPlex® 4000 DIPS Pipe Sizing System

Common Dimension Ratio's for DriscoPlex® 4000 DIPS Pipe (Custom DR's available. Contact Performance Pipe)														
DIPS		DR 21			DR 14.3			DR 11			DR 9			
ASTM F714 PR		PR = 100 psi			PR = 150 psi			PR = 200 psi			PR = 250 psi			
AWWA C906 PC		PC = 80 psi			PC = 120 psi			PC = 160 psi			PC = 200 psi			
Pipe Size, in.	OD, in.	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	
4	4.80	0.229	4.315	1.45	0.336	4.088	2.07	0.436	3.876	2.62	0.533	3.670	3.13	
6	6.90	0.329	6.203	2.99	0.483	5.877	4.27	0.627	5.571	5.42	0.767	5.274	6.47	
8	9.05	0.431	8.136	5.13	0.633	7.708	7.35	0.823	7.305	9.33	1.006	6.917	11.13	
10	11.10	0.529	9.979	7.73	0.776	9.454	11.06	1.009	8.961	14.03	1.233	8.486	16.74	
12	13.20	0.629	11.867	10.93	0.923	11.243	15.64	1.200	10.656	19.84	1.467	10.090	23.67	
14	15.30	0.729	13.755	14.68	1.070	13.032	21.01	1.391	12.351	26.65	1.700	11.696	31.80	
16	17.40	0.829	15.643	18.98	1.217	14.820	27.17	1.582	14.046	34.47	1.933	13.302	41.13	
18	19.50	0.929	17.531	23.84	1.364	16.609	34.12	1.773	15.741	43.30	2.167	14.906	51.66	
20	21.60	1.029	19.419	29.25	1.510	18.398	41.87	1.964	17.436	53.13	2.400	16.512	63.38	
24	25.80	1.229	23.195	41.73	1.804	21.975	59.73	2.345	20.829	75.77	2.867	19.722	90.43	
30	32.00	1.524	28.769	64.18	2.238	27.256	91.89	2.909	25.833	116.58				
†36	38.30	1.824	34.433	91.93	2.678	32.622	131.63	3.482	30.918	167.02				
†42	44.50	2.119	40.008	124.09	3.112	37.903	177.70							

Average inside diameter is calculated using Nominal OD and Minimum Wall plus 6% for use in estimating fluid flow. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimensions and tolerances in the applicable pipe manufacturing specification. †OD available upon special request.

Table 6 DriscoPlex® 4100 IPS Pipe Sizing System

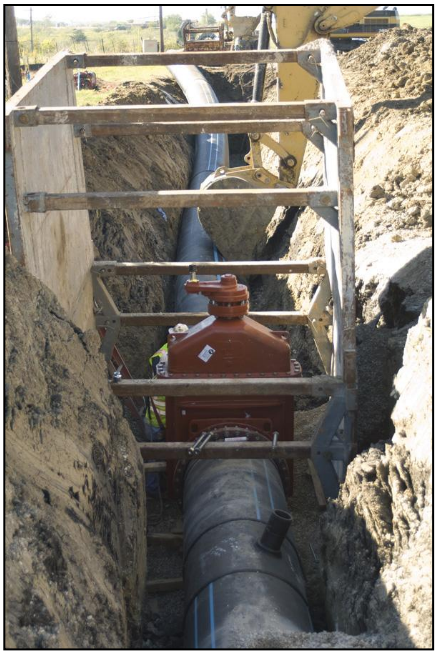
Common Dimension Ratio's for DriscoPlex® 4100 IPS Pipe (Custom DR's available. Contact Performance Pipe)																
IPS		DR 21			DR 17			DR 13.5			DR 11			DR 9		
ASTM F714 PR		PR = 100 psi			PR = 125 psi			PR = 160 psi			PR = 200 psi			PR = 250 psi		
AWWA C906 PC		PC = 80 psi			PC = 100 psi			PC = 130 psi			PC = 160 psi			PC = 200 psi		
Pipe Size in.	OD, in.	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. lbs/ft	Min. Wall, in.	Avg. ID, in.	Wgt. Lbs/ft
2	2.375				0.140	2.078	0.43	0.176	2.002	0.53	0.216	1.917	0.64	0.264	1.815	0.77
3	3.500				0.206	3.063	0.94	0.259	2.951	1.16	0.318	2.826	1.39	0.389	2.675	1.66
4	4.500	0.214	4.046	1.27	0.265	3.938	1.55	0.333	3.794	1.92	0.409	3.633	2.31	0.500	3.440	2.75
6	6.625	0.315	5.957	2.75	0.390	5.798	3.36	0.491	5.584	4.15	0.602	5.349	5.00	0.736	5.065	5.96
8	8.625	0.411	7.754	4.66	0.507	7.550	5.69	0.639	7.270	7.04	0.784	6.963	8.47	0.958	6.594	10.11
10	10.750	0.512	9.665	7.24	0.632	9.410	8.83	0.796	9.062	10.93	0.977	8.679	13.16	1.194	8.219	15.70
12	12.750	0.607	11.463	10.19	0.750	11.160	12.43	0.944	10.749	15.38	1.159	10.293	18.51	1.417	9.746	22.08
14	14.000	0.667	12.586	12.28	0.824	12.253	14.98	1.037	11.802	18.54	1.273	11.301	22.32	1.556	10.701	26.63
16	16.000	0.762	14.385	16.04	0.941	14.005	19.57	1.185	13.488	24.22	1.455	12.915	29.15	1.778	12.231	34.78
18	18.000	0.857	16.183	20.30	1.059	15.755	24.77	1.333	15.174	30.65	1.636	14.532	36.89	2.000	13.760	44.02
20	20.000	0.952	17.982	25.07	1.176	17.507	30.58	1.481	16.860	37.84	1.818	16.146	45.54	2.222	15.289	54.34
22	22.000	1.048	19.778	30.33	1.294	19.257	37.00	1.630	18.544	45.79	2.000	17.760	55.10	2.444	16.819	65.75
24	24.000	1.143	21.577	36.10	1.412	21.007	44.03	1.778	20.231	54.49	2.182	19.374	65.58	2.667	18.346	78.25
26	26.000	1.238	23.375	42.36	1.529	22.759	51.67	1.926	21.917	63.95	2.364	20.988	76.96	2.889	19.875	91.84
28	28.000	1.333	25.174	49.13	1.647	24.508	59.93	2.074	23.603	74.17	2.545	22.605	89.26	3.111	21.405	106.51
30	30.000	1.429	26.971	56.40	1.765	26.258	68.80	2.222	25.289	85.14	2.727	24.219	102.47	3.333	22.934	122.27
32	32.000	1.524	28.769	64.17	1.882	28.010	78.28	2.370	26.976	96.87	2.909	25.833	116.58	3.333	22.934	122.27
34	34.000	1.619	30.568	72.44	2.000	29.760	88.37	2.519	28.660	109.36	3.091	27.447	131.61			
36	36.000	1.714	32.366	81.21	2.118	31.510	99.07	2.667	30.346	122.60	3.273	29.061	147.55			
42	42.000	2.000	37.760	110.54	2.471	36.761	134.84	3.111	35.405	166.88						
48	48.000	2.286	43.154	144.38	2.824	42.013	176.12									
54	54.000	2.571	48.549	182.73	3.176	47.266	222.90									

For pipe smaller than 2" see PP415, DriscoPlex® 5100 Water Service Pipe and Tubing.
Average inside diameter is calculated using Nominal OD and Minimum Wall plus 6% for use in estimating fluid flow. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimensions and tolerances in the applicable pipe manufacturing specification.

PERFORMANCE ADVANTAGES OF DRISCOPLEX® 4000/4100 PIPE

Stripes
Stripes allow easy field identification of pipe. DriscoPlex® 4000 (DIPS) pipe comes standard with three pairs of blue stripe, but lavender, green, and no stripes is optional. The standard DriscoPlex® 4100 (IPS) is black, but blue, lavender and green striping is optional with 4 single stripes at 90 degrees apart.

Flow
DriscoPlex® 4000/4100 pipes are characterized as hydraulically smooth and typically have an absolute surface roughness (ε) of 0.000005 ft. The Hazen-Williams Friction Factor (C) equals 150 to 155 for polyethylene pipes. Even though the inside diameter of polyethylene pipe may be smaller for the same nominal size as metallic or concrete pipes, flow is often equal or greater through polyethylene pipe. For example, an 8" DR17 DriscoPlex® 4000 pipe has a lower pressure drop per given flow rate than an 8" CL350 concrete lined DI pipe (C equals 120). For gravity flow, the n-factor in the Manning equation is typically taken as 0.009 for clear water and 0.010 for sanitary sewer. For design information, see the *Handbook of Polyethylene Pipe*, Chapter 6.



Surge Pressure
When it comes to surges, polyethylene has two advantages over most piping materials. 1) As Table 3 shows, it has the capacity to handle surge pressures significantly in excess of its pressure rating. 2) It also has the lowest surge pressure of all common water pipes. For example, a 5 ft/sec velocity change in a DR17 Polyethylene pipe will produce a 56 psi surge, in a DR18 PVC pipe the surge is 88 psi, and in a Class 50 DI pipe the surge is 268 psi. Thus, with polyethylene pipe there are lower surge pressures and less wear and tear on valves, hydrants, and other system components and, when surges occur, HDPE pipes may be quite capable of handling them with a lower Pressure Class (PC) than required for other materials.

Fatigue
Repeated surges will cause fatigue stress in pipelines. This is particularly significant in certain thermoplastic pipes, excluding polyethylene. Fortunately, polyethylene has an excellent resistance to fatigue. The projected design life for DriscoPlex® 4000/4100 pipes exceeds 100 years for pipe operating at a velocity of 4 fps with a surge frequency of 4 times per hour continuously. See Bulletin PP-402, *Working Pressure Rating and Fatigue Life*.

Comparison with Other Piping Products
Polyethylene's superior performance is due to its fused joint, toughness, and flexibility. Comparisons of polyethylene to other piping materials based on PC alone can lead to costly over-designs, since the definition of "Pressure Class" varies from material to material (see AWWA C906, C905, etc). When correctly incorporating HDPE's lower surge magnitudes, higher surge allowances, and greater fatigue strength into the design, the PC required for HDPE may be much lower than the PC required for other pipe materials.

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Impact Resistance

Polyethylene pipe is routinely used in mining applications above the Arctic Circle and can withstand water freezing internally. A product that can be handled in these extreme conditions has to have excellent impact resistance. The Izod Impact Strength of high density polyethylene using ASTM D256 Method A is 4 to 5 ft-lbs/in at 73^{o}F, again a value significantly greater than other plastic pipe materials.

Rapid Crack Propagation

Impact damage, fatigue, or joint failure in metal or thermoplastic pipes under certain operating conditions can lead to long, running cracks that will propagate through fused joints and can travel hundreds of feet. This cracking is referred to as Rapid Crack Propagation (RCP). One published report cites an 1100 ft long crack that occurred in a fusion joined PVC pipeline. Polyethylene pipe has excellent resistance to RCP. In fact, laboratory testing has shown that RCP cannot occur in a water filled polyethylene pipe. PP838, *Preventing RCP in Fused Water Pipelines* indicates that the best way to avoid this type of cracking is to specify polyethylene pipe as opposed to other thermoplastic pipes.

INSTALLATION ADVANTAGES OF DRISCOPLEX® 4000/4100 PIPE

Heat Fusion of Polyethylene Pipe

Heat fusion of polyethylene pipe is proven, reliable, and time-tested, with over 50 years of success. The procedure is standardized, published in ASTM F2620, and there are thousands of trained operators around the nation. Compared to fusing other types of thermoplastic pipes, the process for polyethylene pipe is easier to learn, more forgiving, and results in higher productivity rates. Joints have the same tensile strength as the pipe and no thrust blocks or restraints are required at fittings and bends. Polyethylene pipe can be fused and installed in subfreezing weather. See PP750, *Heat Fusion Joining Procedures and Qualification Guide*.

Exceptional for Trenchless Installations

DriscoPlex® pipe is flexible and tough. As a result, polyethylene pipes are well-suited for horizontal directional drilling, plowing, river and water crossings, pipe bursting and sliplining. Installers like the fact that polyethylene pipe is tough enough to stand up to rigors of field handling with higher impact resistance, greater ductility, more flexibility, and higher resistance to RCP than its closest thermoplastic competitor. There is a wealth of technical publications for trenchless usage of polyethylene pipe including the *Handbook of Polyethylene Pipe*. See Chapter 11 “Pipeline Rehabilitation by Sliplining with PE Pipe,” Chapter 12, “Horizontal Directional Drilling,” and Chapter 16, “Pipe Bursting.”

Small Bend Radius; Big Installation Advantage

Installers often choose DriscoPlex® 4000/4100 pipe because of its flexibility and tight bend radius. The bend radius is the smallest radius to which a pipe can be bent without causing permanent damage. In open-cut and above-grade applications pipe may be strung around corners or over swales often eliminating fittings. Polyethylene water mains can typically be laid around a cul-de-sac without the use of fittings. In trenchless applications, a more flexible pipe results in shorter insertions pits and reduced costs.

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For horizontal directional drilling, a tight bend radius greatly reduces laydown space, the area where pipe is placed prior to pullback. In tight suburban right-of-ways, it is often necessary to string pipe around corners or bends while awaiting pullback. Flexibility facilitates this and polyethylene pipe can be curved to a radius 1/10th of that of its closest thermoplastic pipe competitor. Thus, it is more convenient for the installer and less disruptive to the public by eliminating inconvenient street closures. In addition, this extra flexibility provides a safety factor against damage during pullback as the polyethylene pipe will almost always have a tighter bending radius than the drill rod used to install it. Thus, polyethylene pipe is protected from over-bending unlike other fused thermoplastic pipes.

Bend radius should not be confused with the length of the pipe required to make a specific turn. Table 7 gives both the bend radius and the length required to make a 90^{o} bend. For additional information on bending see PP407, "*Small Bend Radius Big Installation Advantage"* and PP819, "*Field Bending of PE Pipe".*

Table 7. DriscoPlex® 4000/4100 Minimum Bend Radius

DriscoPlex® 4000/4100 Minimum Bend Radius													
4100 IPS Size (in)	Minimum Bend Radius (ft)			Length of Pipe Required to Make a 90^{o} Bend (ft)			4000 DIPS Size (in)	Minimum Bend Radius (ft)			Length of Pipe Required to Make a 90^{o} Bend (ft)		
	DR 9	DR 11 DR 13.5	DR 17 DR 21	DR 9	DR 11 DR 13.5	DR 17 DR 21		DR 9	DR 11 DR 14.3	DR 21	DR 9	DR 11 DR 14.3	DR 21
2	4.0	4.9	5.3	6.2	7.8	8.4	---		---	---		---	---
3	5.8	7.3	7.9	9.2	11.5	12.4	---		---	---		---	---
4	7.5	9.4	10.1	11.8	14.7	15.9	**4**	8.0	10.0	10.8	12.6	15.7	17.0
6	11.0	13.8	14.9	17.3	21.7	23.4	**6**	11.5	14.4	15.5	18.1	22.6	24.4
8	14.4	18.0	19.4	22.6	28.2	30.5	**8**	15.1	18.9	20.4	23.7	29.6	32.0
10	17.9	22.4	24.2	28.1	35.2	38.0	**10**	18.5	23.1	25.0	29.1	36.3	39.2
12	21.3	26.6	28.7	33.4	41.7	45.1	**12**	22.0	27.5	29.7	34.6	43.2	46.7
14	23.3	29.2	31.5	36.7	45.8	49.5	**14**	25.5	31.9	34.4	40.1	50.1	54.1
16	26.7	33.3	36.0	41.9	52.4	56.5	**16**	29.0	36.3	39.2	45.6	56.9	61.5
18	30.0	37.5	40.5	47.1	58.9	63.6	**18**	32.5	40.6	43.9	51.1	63.8	68.9
20	33.3	41.7	45.0	52.4	65.5	70.7	**20**	36.0	45.0	48.6	56.5	70.7	76.3
22	36.7	45.8	49.5	57.6	72.0	77.8	---		---	---		---	---
24	40.0	50.0	54.0	62.8	78.5	84.8	**24**	43.0	53.8	58.1	67.5	84.4	91.2
28	46.7	58.3	63.0	73.3	91.6	99.0	---		---	---		---	---
30	50.0	62.5	67.5	78.5	98.2	106.0	**30**		66.7	72.0		104.7	113.1
32		66.7	72.0		104.7	113.1	---		---	---		---	---
34		70.8	76.5		111.3	120.2	---		---	---		---	---
36		75.0	81.0		117.8	127.2	**36**		79.8	86.2		125.3	135.4
42		87.5	94.5		137.4	148.4	**42**		92.7	100.1		145.6	157.3
48			108.0			169.6	---		---	---		---	---
54			121.5			190.9	---		---	---		---	---
When fittings or flanges are present the bend radius is normally taken as 100 times the pipe diameter.													

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Safe Pull Strength

Most all trenchless methods using polyethylene pipe are pull-in or pullback techniques. Pull-in distance is often proportional to the pipe's safe pull strength, which is the maximum tensile force that can be applied to the pipe with adequate assurance that the pipe will not be damaged or changed in any way that could affect its long term performance. The maximum safe tensile stress in DriscoPlex® PE4710 pipe for a 10 hour pull is 1300 psi. Table 8 lists the safe pull strength for DriscoPlex® 4000/4100 pipe.

Table 8. Safe Pull Strength for DriscoPlex® 4000/4100

Safe Pull Strength for DriscoPlex® 4000/4100 (PE4710)										
4100 IPS Nom. Size (in)	Safe Pull Strength (lbs)					4000 DIPS Nom. Size (in)	Safe Pull Strength (lbs)			
	DR 9	DR 11	DR 13.5	DR 17	DR 21		DR 9	DR 11	DR 14.3	DR 21
2	2,275	1,904	1,580	1,275	1,045	--	--	--	--	--
3	4,941	4,135	3,431	2,770	2,269	--	--	--	--	-
4	8,168	6,835	5,672	4,579	3,751	**4**	9,294	7,777	6,120	4,267
6	17,704	14,814	12,294	9,924	8,129	**6**	19,204	16,070	12,647	8,818
8	30,007	25,109	20,838	16,820	13,779	**8**	33,037	27,644	21,756	15,170
10	46,614	39,005	32,371	26,130	21,404	**10**	49,699	41,587	32,728	22,821
12	65,572	54,869	45,536	36,757	30,110	**12**	70,282	58,811	46,283	32,273
14	79,060	66,155	54,903	44,317	36,303	**14**	94,424	79,012	62,181	43,358
16	103,262	86,407	71,709	57,884	47,416	**16**	122,123	102,190	80,422	56,077
18	130,691	109,359	90,757	73,259	60,011	**18**	153,380	128,345	101,005	70,430
20	161,346	135,011	112,046	90,443	74,088	**20**	188,194	157,477	123,931	86,416
22	195,229	163,363	135,576	109,436	89,646	--	--	--	--	--
24	232,339	194,416	161,346	130,238	106,686	**24**	268,496	224,672	176,813	123,289
28	316,239	264,621	219,610	177,269	145,212	--	--	--	--	--
30	363,029	303,775	252,104	203,497	166,697	**30**	--	345,628	272,003	189,664
32	--	345,628	286,838	231,535	189,664	--	--	--	--	--
34	--	390,182	323,813	261,381	214,113	--	--	--	--	--
36	--	437,435	363,029	293,036	240,044	**36**	--	410,898	389,647	271,696
42	--	--	494,123	398,855	326,726	**42**	--	--	526,010	366,780
48	--	--	--	520,953	426,745	--	--	--	--	--
54	--	--	--	--	540,099	--	--	--	--	--

Horizontal Directional Drilling Resources

In developing plans for a directional drilling project, the designer must determine what DR to use. In addition to working-pressure considerations, DR selection depends on how much force will be required to pull the pipe back into the bore and on how much external force will be applied to the pipe during and afterward from the drilling slurry, soil and groundwater. Several resources are available to help the designer select an appropriate DR. Some of these resources offer additional and important information for planning a crossing. Resources include the following: ASTM F1962, a standard guide for the design of a directional drilled crossing with polyethylene pipe; the PPI *Handbook of Polyethylene Pipe*, Chapter 12; ASCE MOP 108, *Pipeline Design for Installation by Horizontal Directional Drilling*; and the Plastics Pipe Institute's Technical Report 46, *Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of Polyethylene Pipe*. In addition, the PPI ***BoreAid*** program is useful for making a preliminary evaluation of the DR requirements and the anticipated pullback force. A link to PPI BoreAid can be found on the Performance Pipe website on the Engineering Information page.

Burial in Open-Cut Trenching

The PPI *Handbook of Polyethylene Pipe*, Chapter 6, gives design guidance for open-cut trench installations of polyethylene pipes. HDPE pipe has been placed in landfills with cover depths well in excess of 100 ft. However, most municipal applications are significantly shallower. For the convenience of the designer, AWWA M-55, *PE Pipe—Design and Installation*, offers a safe design window. Pipe within the window meets the design deflection limits of M-55 and provide at least a 2:1 Safety Factor against buckling. For deeper depths or heavier loading, calculations are required.

Table 9. AWWA M-55 Minimum and Maximum Depths without doing calculations

AWWA M-55 Design Window	
DriscoPlex® 4000/4100 Pipe DR7.3 through DR21	
Minimum Cover Depth with no surface load	2 feet
Minimum Cover Depth with H20 truck load	3 feet
Maximum Cover Depth	25 feet
Requirements Minimum E' of native soil of 1000 psi. Maximum backfill weight of 120 pcf. No water above ground surface. Granular embedment soil around pipe with a minimum density of 85% Standard Proctor. Pipe installed per ASTM D2774 and PP-901.	

Like all piping materials, HDPE piping must be properly installed. DriscoPlex® 4000/4100 pipe should be installed in accordance with ASTM D 2774 *Standard Practice for Underground Installation of Thermoplastic Pressure Piping* and Performance Pipe's PP-901, *Field Handbook*. HDPE is a flexible piping material that works together with its soil embedment to sustain the earth and live loads above it. Suitable embedment is required to provide support around the pipe, and embedment materials must be placed so that the pipe is properly surrounded. Under roadways, compacted coarse sands and gravels are preferred, but other materials may be used under the direction of the design engineer. For more information on installation of 12" and smaller diameter DriscoPlex® pipe see the Plastics Pipe Institute's *Polyethylene Piping Systems Field Manual for Municipal Water Applications*. For installation by plowing and planting see the special underground installation techniques section of PP-901.

Ground Movement and Seismic Resistance

A large number of water main breaks occur every year due to soil settlement, freeze/thaw cycles, and shrinking or swelling of expansive soils, not to mention the occasional widespread damage that accompanies earthquakes. Polyethylene's flexibility and its fusion joints make it considerably less susceptible to damage from ground movement. California gas utilities recognize polyethylene's excellent record in enduring seismic events without damage.

Poisson Effect

When polyethylene pipe connects to a gasket jointed pipeline, the polyethylene pipe must be anchored or the gasket joints upstream (or downstream) from the transition must be restrained to prevent pullout of the gasket joints. See PP813, *Poisson Effect*.

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Above Grade and Aerial Installation

Performance Pipe black polyethylene pipe contains carbon black allowing indefinite above grade storage and use. For details on above grade applications see PP814, *Thermal Effects* and PP815, *Above Grade Pipe Supports*.

Vacuum Resistance (External Pressure)

Many pipelines operate under full or partial vacuum or experience negative internal pressures when subject to pressure surges. External pressure exceeding the internal pressure (external differential pressure) creates the same effect. Pipelines may be subject to external pressure during installation, submergence, grouting of sliplined pipe, or directional drilling. All pipes have a limit to the amount of external differential pressure (or vacuum) they can withstand. Exceeding that limit will cause the pipe to collapse. Table 10 gives the allowable external differential pressure based on Equation 3-39 in Chapter 6 of the *Handbook of Polyethylene Pipe* with a safety factor of two against collapse and with 3% ovality in the pipe. Higher resistance to collapse can be achieved by embedding the pipe in soil, flowable fill, grout, or concrete. For additional temperatures, see PP-901, *Field Handbook*.

Table 10. DriscoPlex® 4000/4100 Collapse Resistance (Vacuum Resistance)

DriscoPlex® 4000/4100 External Pressure Resistance PE4710									
Service Temperature	Pipe DR	External Differential Pressure or Vacuum Resistance 3% ovality with 2:1 safety factor[1] (psi)							
		50 yr	10 yr	1 yr	1000 hr	100 hr	10 hr	0.5 hr	Short-Term
Modulus Value (psi)		*29000*	*34000*	*40000*	*46000*	*55000*	*65000*	*82000*	*130000*
73°F	9	54.0	63.3	74.5	85.6	102.4	121.0	152.6	242.0
	11	27.6	32.4	38.1	43.8	52.4	61.9	78.1	123.9
	13.5	14.1	16.6	19.5	22.4	26.8	31.7	40.0	63.4
	14.3	11.7	13.8	16.2	18.6	22.3	26.3	33.2	52.7
	17	6.7	7.9	9.3	10.7	12.8	15.1	19.1	30.2
	21	3.5	4.1	4.8	5.5	6.6	7.7	9.8	15.5
120°F	9	31.3	36.7	43.2	49.7	59.4	70.2	88.5	140.3
	11	16.0	18.8	22.1	25.4	30.4	35.9	45.3	71.9
	13.5	8.2	9.6	11.3	13.0	15.6	18.4	23.2	36.8
	14.3	6.8	8.0	9.4	10.8	12.9	15.3	19.3	30.5
	17	3.9	4.6	5.4	6.2	7.4	8.8	11.1	17.5
	21	2.0	2.3	2.8	3.2	3.8	4.5	5.7	9.0

[1]Gray shading indicates value equals or exceeds full vacuum of 14.7 psi.

Fittings

Performance Pipe manufactures HDPE molded *Fittings* including tees and elbows in sizes through 8” diameter. Flange adapters for flange connections are available through 24” diameter. MJ Adapters for both DriscoPlex® 4000 and 4100 pipe are available through 12” diameter. Larger fittings are available through third party fabricators.

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Transition to Non-Polyethylene Pipes

Polyethylene pipe can be conveniently connected to metallic valves, pumps and even pipe. Normally the connection is made using a polyethylene Van Stone style Flange Adapter with a metallic backup ring which mates to a metallic flange or using a polyethylene Mechanical Joint (MJ) Adapter which mates to a DI mechanical joint bell. The MJ Adapter works with both IPS and DIPS polyethylene pipe. Acceptable methods also include metallic transition couplings that slide on, seal, and grip the polyethylene pipe or metallic transition couplings that slide on and seal but require additional external restraint rings. These types of couplings may require the use of an insert stiffener in the polyethylene pipe. DriscoPlex® 4000 pipe may be inserted directly into an MJ Bell. This requires placing an insert stiffener inside the end of the DriscoPlex® pipe and restraining the connection with an external ring or clamp on the DriscoPlex® pipe. When selecting mechanical couplings or components for use with DriscoPlex® pipe, make sure the mechanical coupling manufacturer recommends the particular part for HDPE pipe. For additional information on HDPE to non-HDPE pipe transitions, see the Plastics Pipe Institute's TN-36, *General Guidelines for Connecting Potable Water HDPE Pressure Pipes to DI and PVC Piping Systems* and *Polyethylene Piping Systems Field Manual for Municipal Water Applications*.

Tapping

A variety of heat fusion and mechanical fittings make hot or cold tapping a straightforward process. Heat fusion jointed products include saddle fusion tapping tees, electrofusion tapping tees, and branch-saddles. A number of manufacturers produce metallic full body tapping saddles and sleeves for polyethylene pipe. Performance Pipe recommends that the manufacturer be contacted to make sure their saddles work with polyethylene pipes. Service saddles are available as well. These may come with double or extra wide straps, with spring washers, or with both.

Repair

Polyethylene pipe has an excellent field record. However, circumstances may arise where repair is necessary. The most likely form of damage is impact or an underground strike which is usually localized. A variety of repair clamps (both mechanical and electrofusion) and tapping saddles are available. If a section of pipe has to be removed, a new pup piece can be inserted using mechanical couplings, polyethylene flange adapters, or electrofusion couplings.

Leak Testing

Polyethylene pipe may be hydrostatically tested to determine system integrity for leaks. When testing is required, observe all safety measures. See Performance Pipe PP 802, *Leak Testing of Polyethylene Pipe*. Typically, HDPE pipe is leak tested to 1.5 times its Pressure Rating (PR). See Tables 5 and 6.

Water Quality

Water utilities aim to maintain a high standard of water quality and to protect public drinking water from any internal and external contaminates. All piping systems have some potential for contamination from external agents through permeation of gaskets, jointed connections, or permeation through the pipe wall. Literature suggests that permeation of organic chemicals and hydrocarbons through polyethylene pipe is possible, while actual cases of soil contaminated hydrocarbon permeation are extremely rare.

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Hydrocarbons do not degrade polyethylene but can diffuse through the wall of the pipe in areas of gross contamination. The exterior contact may affect sidewall fusions and or butt fusions; thus, after polyethylene pipes have been exposed to grossly contaminated soils, mechanical connections may be preferred.

There are several ways to address gross hydrocarbon contamination of soil surrounding the pipe including removal and replacement of the contaminated soil with good clean soil of Class I or Class II materials, sleeving the pipe, and rerouting the pipe around the contaminated area.

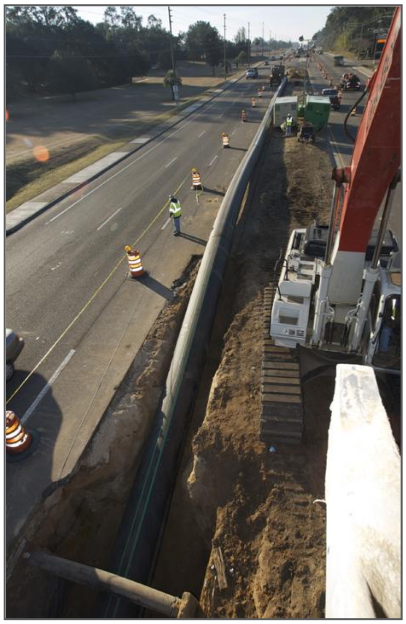
Safety
Polyethylene piping has been safely used in thousands of applications. However, there are general precautions that should be observed when using any product. In this respect, polyethylene piping is no different. Performance Pipe's recommends the following reading for a more detailed list of cautions and safety features.

1. The Plastic Pipe Institute Handbook of Polyethylene Pipe, Chapter 2. *Inspections, Tests and Safety Features*.

2. *The Performance Pipe Field Handbook*.

3. *Pipe Loading/Unloading-Truck Driver Safety Video*

Technical Information
A large body of technical information related to the design and installation of polyethylene pipe is available at the Plastics Pipe Institute's website, www.plasticpipe.org and on Performance Pipe's website, www.performancepipe.com. Additional information on polyethylene pipe including case history information is available at the PE Alliance site, www.pepipe.org.



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APPENDIX A. PRESSURE CLASS SELECTION PER AWWA C906

Selecting the right Pressure Class for High Density Polyethylene pipe in accordance with AWWA C906 is easy. Just two steps! AWWA C906 takes into account the continuous pumping and transient (surge) pressures that occur in municipal water pipes.

Step 1. Compare the pipeline working pressure with the pipe's Pressure Class.

AWWA C906 defines working pressure as "the maximum anticipated, sustained **operating pressure applied to the pipe exclusive of transient pressures".** The maximum working pressure for a pipe must be less than or equal to the pipe's Pressure Class. Table A-1 gives Pressure Class for standard Dimension Ratio's (DR) HDPE pipe made from PE3608 material.

Table A-1: Maximum Allowable Pressures for HDPE Pipe (PE3608) at 80°F[1]
(Per AWWA C906)

Pipe DR	Pressure Class/ Maximum Working Pressure (psi)	Maximum Total Pressure[2] Allowed During Recurring Surge (psi)	Maximum Total Pressure[2] Allowed During Occasional Surge (psi)	Maximum Test Pressure Allowed per AWWA Manual M55 (psi)
7.3	254	380	510	380
9	200	300	400	300
11	160	240	320	240
13.5	128	185	250	185
17	100	150	200	150
21	80	120	160	120

[1]Pressures above 80°F require derating. See Table 4.
[2]Total pressure equals the combined pumping (working) pressure plus surge pressure. Recurring surges are frequently occurring surges inherent to the design and operation of the system. Occasional surges are caused by emergency operations such as fire flows.

Step 2. Compare the peak pipeline pressure during surge with the pipe's allowable Maximum Total Pressure.

Peak pressure during a surge is equal to the sum of the pumping pressure and the transient surge pressure. Transient surge pressure depends on the instantaneous change in flow velocity. Maximum transient pressure due to an instantaneous change in flow velocity is given in Table A-2. Peak pressure may be obtained by adding the surge pressure at the design velocity from Table A-2 to the pumping pressure. Peak pressure is compared with the Maximum Total Pressure Allowed During Surge in Table A-1. The Maximum Total Pressure Allowed equals 1.5 times the pipe's Pressure Class for recurring surge and 2.0 times the pipe's Pressure Class for occasional surge.

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Note: *The surge pressure occurring in HDPE pipe is significantly lower than surge pressures occurring in cast or ductile iron pipe and is lower than that in PVC pipe of the same DR. For example, a 4 fps instantaneous velocity change in HDPE DR17 pipe results in a 45.0 psi surge whereas for DI pipe the surge is 200 psi and for PVC DR18 pipe the surge is 69.6 psi. When HDPE pipe is connected to DI pipe the surge pressure is dampened by the HDPE pipe.*

Table A-2. Surge Pressure at 80°F for Sudden Velocity Change, psi (Per AWWA M-55)

		Surge Pressure, psi							
		1 fps	2 fps	3 fps	4 fps	5 fps	6 fps	7 fps	8 fps
Pipe DR	7.3	18.4	36.8	55.2	73.6	92.0	110.4	128.8	147.2
	9	16.2	32.4	48.5	64.7	80.9	97.1	113.2	129.4
	11	14.4	28.7	43.1	57.5	71.9	86.2	100.6	115.0
	13.5	12.8	25.6	38.4	51.2	63.9	76.7	89.5	102.3
	17	11.3	22.5	33.8	45.0	56.3	67.5	78.8	90.0
	21	10.0	20.1	30.1	40.1	50.2	60.2	70.2	80.3

Working Pressure and Surge Pressure Example:

An engineer is designing a water system that operates at 85 psi and has some runs in it where the flow velocity is 4 fps. In addition, his/her state requires a 150 psi test for the pipeline. What DR pipe does the engineer use?

Step 1. Compare the pumping pressure, 85 psi, with the available Pressure Classes in Table A-1. DR17 has a PC of 100 psi>85 psi. The test pressure of DR17 is also 150 psi, which meets the specified test pressure.

Step 2. The anticipated peak pressure in the pipeline is found by adding the pumping pressure of 85 psi to the surge pressure of 45.0 psi (given in Table A-2 for a 4 fps velocity). The sum equals 130.2 psi and is less than the Maximum Total Pressure Allowed for Recurring Surge for DR17 pipe of 150 psi. DR17 pipe is O.K. A similar comparison can be made for peak pressure during fire flow where velocity may reach 8 fps. In this case add 90.0 psi (from Table A-2) to 85 psi to obtain a peak pressure during occasional surge of 175 psi. Compare with the Maximum Total Pressure Allowed for Occasional Surge for DR17 of 200 psi. DR17 pipe is O.K.

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