GF Piping Systems

Technical Manual

Industrial Polyethylene Piping System

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Section 1: Overview

Overview

General Information

Polymers which consist only of carbon and hydrogen (hydrocarbons) are called polyolefins. Polyethylene (PE) belongs to this group. It is a semi-crystalline thermoplastic. Polyethylene is the best known standard polymer. The chemical formula is: $(CH_2\text{-}CH_2)_n$. It is an environmentally friendly hydrocarbon product.

PE is considered a non-polar material, meaning it does not dissolve in common solvents and hardly swells. As a result, PE pipes cannot be solvent cemented. The appropriate joining method for this material is heat fusion. For piping installations, GF offers three joining techniques in our product range: Electrofusion, Contact Butt Fusion and Infrared Butt Fusion.

The advantages of Polyethylene include

- Lower installed cost*
- Low weight
- Excellent impact resistance
- Outstanding flexibility
- Superior abrasion resistance
- Corrosion resistant
- Wide range of chemical compatibility
- Safe and easy joining by heat fusion

*When compared to Stainless Steel and Large Diameter PVC

Mechanical Properties

Modern PE100 grades show a bimodal molecular weight distribution, i.e.: they consist of two different kinds of molecular chains (short and long). These polyethylenes combine a high tensile strength with a high resistance against fast and slow crack propagation.

PE also shows a very high impact resistance throughout its entire temperature range. For this test (Izod), a specimen is weakened with a sharp notch and then struck. In doing this, the impact energy absorbed by the material is measured. This test proves that with subsequent impact stress, polyethylene is not as susceptible to surface damage. A robust behavior like this, combined with an acute resistance to fracture, is a significant advantage in applications where lower temperatures (down to -58°F) cause other thermoplastic piping systems to become brittle.

Chemical, Weathering and Abrasion Resistance

Due to its non-polar nature as a hydrocarbon of high molecular weight, polyethylene shows a high resistance against chemical attack. PE is resistant to acids, alkaline solutions, solvents, alcohol and water. Fat and oil swell PE slightly. PE is not resistant against oxidizing acids, ketones, aromatic hydrocarbons and chlorinated hydrocarbons.

Experience has shown that PE offers considerable advantages over metal and other plastics, such as, low temperature applications and excellent resistance against abrasion. As a result, PE piping systems are used in numerous applications for transporting brine solutions, dissolved solids and slurries.

If Natural Polyethylene (not including additives) is exposed to direct sunlight over a long period of time, it will, like most natural and plastic materials, be damaged by the combination of short wave UV and oxygen, causing photo-oxidation. To effectively address this degradation phenomenon, carbon black additive is blended with resins to stabilize the material against UV exposure.

Thermal Properties

Pressurized polyethylene pipes can be used at temperatures ranging from -58°F to +140°F.

The thermal conductivity of PE100 is 2.7 BTU-in/ft^2/hr/°F. Because of its inherent insulating properties, a PE piping system is notably more economical due to not requiring secondary insulation when compared to a system made of metals such as Stainless Steel and Copper. This makes PE100/4710 pipe an excellent choice for chilled water systems.

Like all thermoplastics, PE shows a higher thermal expansion than metal. Our PE100/4710 has a coefficient of linear thermal expansion of 1.10×10^{-4} in/in°F. As long as this is taken into account during the planning of the installation, there should be no problems with expansion or contraction requirements. Thermal strain management is important.

At higher temperatures, the tensile strength and stiffness of the material are reduced. Therefore, please consult the pressure-temperature diagram (Figure 4) for further information.

Combustion Behavior

Polyethylene is considered a flammable plastic with oxygen index amounts to 17%. (Materials that burn with less than 21% of oxygen in the air are considered to be flammable). Below 17% O_2 concentration, HDPE self-extinguishes.

PE drips and continues to burn without soot after the ignition source is removed. When PE burns, toxic substances; primarily carbon dioxide and carbon monoxide, are released. Carbon monoxide is generally the combustion product most dangerous to humans.

The following classifications in accordance with different combustion standards are used: According to UL94, PE is classified as HB (Horizontal Burning). The self-ignition temperature is 662°F. Suitable fire-fighting agents are water, foam, carbon dioxide or powder.

Electrical Properties

Because of the low water absorption of PE, its electrical properties are hardly affected by continuous water contact.

PE is a non-polar hydrocarbon polymer that exhibits outstanding insulating qualities. These insulating properties can be reduced considerably as a result of weathering, pollution or the effects of oxidizing media. The specific volume resistance is $>10^{13}$ Ωcm; the dielectric strength is 500 V/mil.

Because of the possible development of electrostatic charges, caution is recommended when using PE in applications where the danger of fires or explosion is magnified.

Resin

Updates and additions to ASTM D3350 caused the EHMW-HDPE resins designated as PE3408 in 2006, to become PE3608 in 2007. The HDPE material did not change, but the ASTM D3350 cell classification that described the material did change, necessitating the upgrade to PE3608. Those same changes encompassed the addition of PE4710 High Performance Polyethylene (HPPE) into the arsenal of pipe grade resins. A PE4710 HPPE piping system can result in a 15% savings when compared to current costs of PE3408 piping systems. By virtue of its higher pressure rating enabling the use of the next lower DR, wall thickness becomes less, the pipe I.D. increases and the weight per foot of pipe is reduced.

- PE3608 (prev. PE3408) Material Designation

  Materials designated as PE3608 have a hydrostatic design basis of 1600 psi for water at 73°F. After applying the 0.5 Design Factor, the design working stress for 73°F is 800 psi.

- PE4710 (prev. PE3408) Material Designation

  Materials designated as PE4710 have a hydrostatic design basis of 1600 psi for water at 73o F. After applying the 0.63 Design Factor, the design working stress for 73o F is 1000 psi. PE4710 has higher performance as described in PPI's TN41.

- PE100 Material Designation (ISO Pipe Material Designation Code)

  The ISO pipe material designation code uses similar letters for the type of material as the ASTM code. Examples are PE for polyethylene, PA for polyamide or PVC for poly vinyl chloride. These letters are followed by numbers that are simply the MRS (from ISO 9080 and ISO 12162) times ten. For example, PE 100 is a PE material with an MRS of 10 MPa. Note that there are no physical property or performance requirements in the ISO pipe material designation code, or information about the design coefficient. The ISO pipe material designation code is simply the material and the MRS.

Complete System of Pipe, Valves and Fittings

GF Piping Systems' Polyethylene piping system easily transitions between PP and PVC and is available with pipes, fittings and valves in IPS sizes from 2" to 42".

(For technical data on PP and PVC, please see GF's online technical data)

Ball valves (PP/PE) are available in sizes 2" to 4". Diaphragm valves (PP/PE) are available in sizes 2" to 4" and butterfly valves in sizes up to 24" (metal external bodies with elastomer seals). Other valves, including check valves and metering valves are also available for this system.

This system includes all commonly required pressure pipe fittings, including threaded adaptors and flanges for ease of mating to equipment or other piping materials.

See product guide for details on full line of available products.

Reliable Fusion Joining

Assembly and joining of this system is performed by heat fusion. Fusion joints are made by heating and melting the pipe and fitting together. This type of joint gives a homogeneous transition between the two components without the lowering of chemical resistance associated with solvent cement joining and without the loss of integrity and loss of pressure handling ability of a threaded joint.

Three different fusion methods for GF Piping Systems' PE100/4710 are available and commonly used in today's demanding applications. These include socket, electrofusion, CNC controlled (conventional) contact butt fusion, and Infrared (IR) non-contact butt fusion.

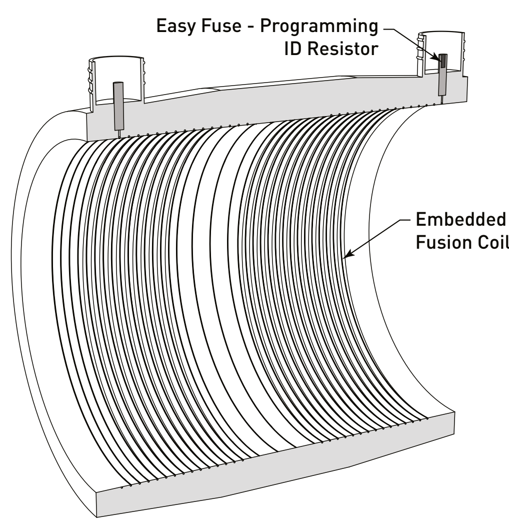
Electrofusion Joining

GF's advanced electrofusion technology uses the resistance of the coil as well as ambient conditions to ensure a quality joint every time. The design of our electrofusion fittings eliminates the potential of the fluid media contacting the coil, while insuring no change in pressure rating for your piping system.
These features as well as the fully automated welding process makes this one of the safest and easiest fusion technologies on the market.

Advantages

- Fast fusion times
- Completely controlled process
- Easiest fusion method
- Corrosion resistant

Figure 1 - Electrofusion Coupling



CNC Controlled (Conventional) Contact Butt Fusion Joining

GF's Contact Butt Fusion joining is an industry standard for sizes 2" to 24".

Butt fusion pipe and fittings both have the same nominal inside and outside diameters. To make a butt fusion joint, the pipe and fitting are clamped so that the ends to be joined are facing each other. The ends are then "faced" flat and parallel. A flat heating plate is used to simultaneously heat both faces to be joined. When each end is molten, the heating plate is removed and the pipe and fitting are brought together, joining the molten materials by fusion.

Advantages

- Repeatable weld parameters
- Controlled facing and joining pressure
- Automated fusion records
- Ease of operation due to CNC controller
- Eliminates operator dependant decisions

For information on Infrared Butt Fusion please contact your local GF distributor.

Conventional contact butt fusion

GF's Contact Butt Fusion joining is an industry standard for sizes 2" to 42".

Butt fusion pipe and fittings both have the same nominal inside and outside diameters. To make a butt fusion joint, the pipe and fitting are clamped so that the ends to be joined are facing each other. The ends are then "faced" flat and parallel. A flat heating plate is used to simultaneously heat both faces to be joined. When each end is molten, the heating plate is removed and the pipe and fitting are brought together, joining the molten materials by fusion.

General Properties

Material Data

The following table lists typical physical properties of Polyethylene thermoplastic materials. Variations may exist depending on specific compounds and product.

Mechanical

Properties	IPS/DIPS/FM/Metric		
	Unit	PE100/4710	ASTM Test
Density	lb/in^3	0.0345	ASTM D792
Tensile Strength @ 73°F (Yield)	PSI	3,600	ASTM D638
Tensile Strength @ 73°F (Break)	PSI	4,500	ASTM D638
Modules of Elasticity Tensile @ 73°F	PSI	130,000	ASTM D638
Compressive Strength @ 73°F	PSI	3,200	ASTM D695
Flexural Strength @ 73°F	PSI	150,000	ASTM D790
Izod Impact @ 73°F	Ft-Lbs/In of Notch	8	ASTM D256
Relative Hardness @ 73°F	Durometer "D"	64	ASTM D2240
Abrasion info		1–5 mg/1000 rev	ASTM D1044
MDB (Micro Design Basics)	PSI	1,600	ASTM D2837

Thermodynamics

Properties	Unit	PE100/4710	ASTM Test
Brittleness Temperature	°F	≤180	ASTM D746
Melt Index	gm/10min	0.08	ASTM D1238
Melting Point	°F	261	ASTM D789
Coefficient of Thermal Linear Expansion per °F	in/in/°F	1.10×10^{-4}	ASTM D696
Thermal Conductivity	$BTU\text{-}in/ft^2/hr/°F$	2.7	ASTM D177
Specific Heat	CAL/g/°C	1.7	
Maximum Operating Temperature	°F	140	
Heat Distortion Temperature @ 264 PSI	°F	160	ASTM D648
Decomposition Point	°F	255	ASTM D1525

Other

Properties	Unit	PE100/4710	ASTM Test
Volume Resistivity	Ohm-cm	2.6 × 1016	ASTM D991
Water Absorption	%	<1%	
Poisson's Ratio @ 73°F		0.45	
ASTM Cell Classification		445574C	ASTM D3350
Industry Standard Color		Solid black	RAL 9005
NSF Potable Water Approved		Yes	NSF-61
Flame & Smoke Info	Red oak; smoke density: 350		ASTM D635; ASTM E84

Note: This data is based on information supplied by the raw material manufacturers.

Mechanical Connections

Mechanical Joining of Piping Systems

Flange Connections	Flange adapters for butt fusion Coated Metal Flanges Backing Rings Mechanical joint adapters
Transition Pipe Fittings	Stainless Weld × PE Butt Fusion Transition Fittings Stainless Thread × PE Butt Fusion Transition Fittings
Threaded Fittings	Stainless Thread × PE Butt Fusion Transition Fittings

Threaded Connections

The Following Different Types of Threads Are Used

Designation of the thread	According to standard	Typical use	Description
NPT = National (American Standard) Pipe Taper	ASTM F1498	Transition and threaded fittings	Taper internal or external pipe thread for plastic pipes and fittings, where pressure-tight joints are made on the threads

Flanged Connections

Creating Flange Joints

When making a flange connection, the following points have to be taken into consideration:

There is a general difference between the connection of plastic pipes and so-called adapter joints, which represent the transition from a plastic pipe to a metal pipe or a metal valve. Seals and flanges should be selected accordingly.

Flanges with sufficient thermal and mechanical stability should be used. GF flange types fulfil these requirements.

A robust and effective seal can only be achieved if sufficient compressive forces are transmitted to the polyethylene stub end via the ductile iron backup ring. These compressive forces must be of sufficient magnitude to overcome fluctuating hydrostatic and temperature generated forces encountered during the lifetime of the joint. It is possible to achieve a good seal between polyethylene stub ends without the use of a gasket, but in some circumstances a gasket may be used. In assembling the stub ends, gasket and backup rings it is extremely important to ensure cleanliness and true alignment of all mating surfaces. The correct bolt tightening procedure must also be followed and allowance made for the stress relaxation characteristics of the polyethylene stub ends.

Alignment

- Full parallel contact of the sealing faces is essential.
- The backup ring must contact the stub end evenly around the circumference.
- Misalignment can lead to excessive and damaging stresses in either the stub

When to Use a Flange?
Flanges may be used when:

- The piping system may need to be dismantled
- The installation is temporary or mobile
- Transitioning between dissimilar materials that can not be bonded together

Note: Visually inspect flanges for cracks, deformities or other obstructions on the sealing surfaces.

Gaskets

A rubber gasket may be used between the flange faces in order to ensure a good seal. GF recommends a 0.125" thick, full-face gasket with Shore A scale hardness of 70±5, and the bolt torque values (Table 12) are based on this specification. For other hardness requirements, contact GF Technical Services. Select the gasket material based on the chemical resistance requirements of your system. A full-face gasket should cover the entire flange-to-flange interface without extending into the flow path.

Ref: www.plasticpipe.org/pdf/tn-38_bolt_torque_flanged_joints.pdf

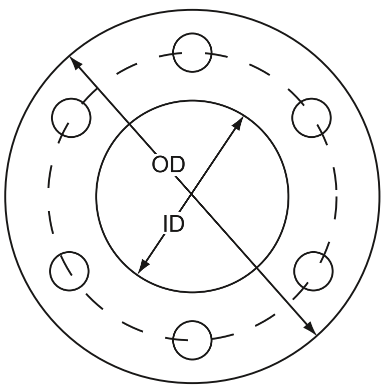


Figure 2 - Gasket Dimensions

Table 1 - Flange Size

Size (in)	O.D. (in)	I.D. (in)	Size (in)	O.D. (in)	I.D. (in)
½" - 20mm	3.74	1.10	12"	19.00	13.13
¾" - 25mm	4.13	1.34	14"	21.00	14.18
1" - 32mm	4.53	1.65	16"	23.50	16.19
1¼" - 40mm	5.51	2.01	18"	25.00	18.38
1½" - 50mm	5.91	2.44	20"	27.50	20.38
2" - 63mm	6.50	3.07	22"	29.50	22.38
2½" - 75mm	7.28	3.62	24"	32.00	24.38
3" - 90mm	7.87	4.25	26"	34.25	26.38
4" - 110mm	9.02	5.04	28"	36.50	28.38
6" - 160mm	11.22	7.01	30"	38.75	30.38
8" - 200mm	13.39	9.25	32"	41.75	32.38
10" - 250mm	15.98	11.34	36"	46.00	36.38

Fasteners

It is critical to avoid excessive compression stress on a vinyl flange. Therefore, only low-friction fastener materials should be used. Low-friction materials allow torque to be applied easily and gradually, ensuring that the flange is not subjected to sudden, uneven stress during installation, which can lead to cracking.

Either the bolt or the nut, and preferably both, should be zinc-plated to ensure minimal friction. If using stainless steel bolt and nut, lubricant must be used to prevent high friction and seizing. In summary, the following fastener combinations are acceptable:

- zinc-on-zinc, with or without lube
- zinc-on-stainless steel, with or without lube
- stainless-on-stainless, with lube only

Cadmium-plated fasteners, while becoming more difficult to obtain due to environmental concerns, are also acceptable with or without lubrication. Galvanized and carbon-steel fasteners are not recommended. Use a copper-graphite anti seize lubricant to ensure smooth engagement and the ability to disassemble and reassemble the system easily.

Bolts must be long enough that two complete threads are exposed when the nut is tightened by hand. Using a longer bolt does not compromise the integrity of the flange connection, although it wastes material and may make tightening more difficult due to interference with nearby system components.

Table 2 - Fastener Specifications

Flange Size (in)	No. of Bolts	Bolt Size (in) and Type	Washer Size (in) and Type[2]
½ - 20mm	4	½" SAE GRD 5	½" SAE
¾ - 25mm	4	½" SAE GRD 5	½" SAE
1 - 32mm	4	½" SAE GRD 5	½" SAE
1¼ - 40mm	4	½" SAE GRD 5	½" SAE
1½ - 50mm	4	½" SAE GRD 5	½" SAE
2 - 63mm	4	⅝" SAE GRD 5	⅝" SAE
2½ - 75mm	4	⅝" SAE GRD 5	⅝" SAE
3 - 90mm	4	⅝" SAE GRD 5	⅝" SAE
4 - 110mm	8	⅝" SAE GRD 5	⅝" SAE
6 - 160mm	8	¾" SAE GRD 5	¾" SAE
8 - 200mm	8	¾" SAE GRD 5	¾" SAE
10 - 250mm	12	¾" SAE GRD 5	¾" SAE
12	12	⅞" SAE GRD 5	⅞" SAE
14	12	1" SAE GRD 5	1" SAE
16	16	1" SAE GRD 5	1" SAE
18	16	1⅛" SAE GRD 5	1⅛" SAE
20	20	1⅛" SAE GRD 5	1⅛" SAE
22	20	1¼" SAE GRD 5	1¼" SAE
24	20	1¼" SAE GRD 5	1¼" SAE
26	24	1¼" SAE GRD 5	1¼" SAE
28	28	1¼" SAE GRD 5	1¼" SAE
30	28	1¼" SAE GRD 5	1¼" SAE
32	28	1½" SAE GRD 5	1½" SAE
36	32	1½" SAE GRD 5	1½" SAE

2. Minimum spec. Use of a stronger or thicker washer is always acceptable as long as published torque limits are observed.

3. Also known as Type A Plain Washers, Narrow Series.

4. ASTM F436 required for larger sizes to prevent warping at high torque.

A washer must be used under each bolt head and nut. The purpose of the washer is to distribute pressure over a wider area, reducing the compression stress under the bolt head and nut. Failure to use washers voids the GF warranty.

Torque Wrench

Compared to metals, vinyls are relatively flexible and deform slightly under stress. Therefore, not only must bolt torque be controlled in order to avoid cracking the flange, but continuing to tighten the bolts beyond the recommended torque levels may actually make the seal worse, not better.

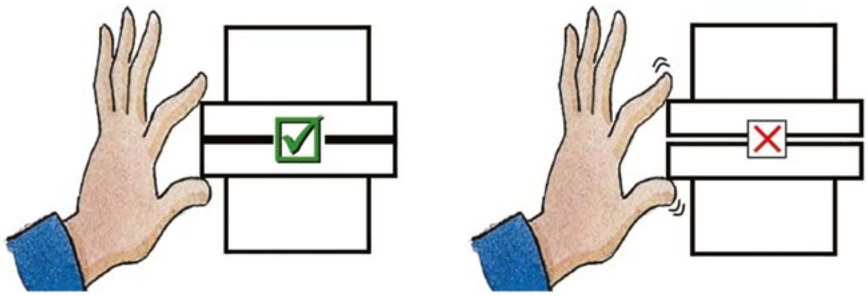
Because bolt torque is critical to the proper function of a vinyl flange, a current, calibrated torque wrench accurate to within ±1 ft-lb must be used when installing vinyl flanges.

Experienced installers may be tempted to forgo the use of a torque wrench, relying instead on "feel." GF does not endorse this practice. Job-site studies have shown that experienced installers are only slightly better than new trainees at estimating bolt torque by feel. A torque wrench is always recommended.

Checking System Alignment

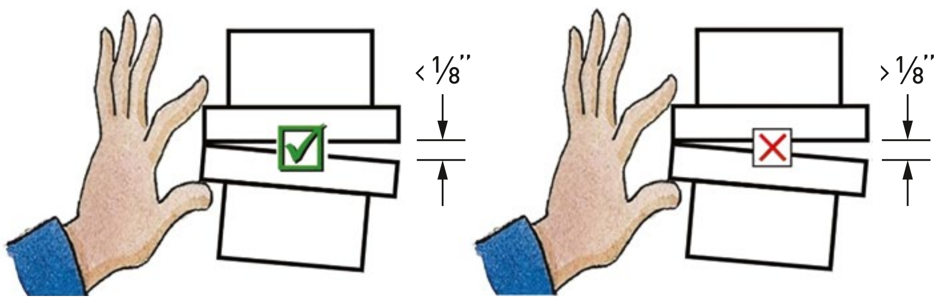
Before assembling the flange, be sure that the two parts of the system being joined are properly aligned. GF has developed a "pinch test" that allows the installer to assess system alignment quickly and easily with minimal tools. First check the gap between the flange faces by pinching the two mating components toward each other with one hand as shown below. If the faces can be made to touch, then the gap between them is acceptable.

Figure 3 - Pinch Test



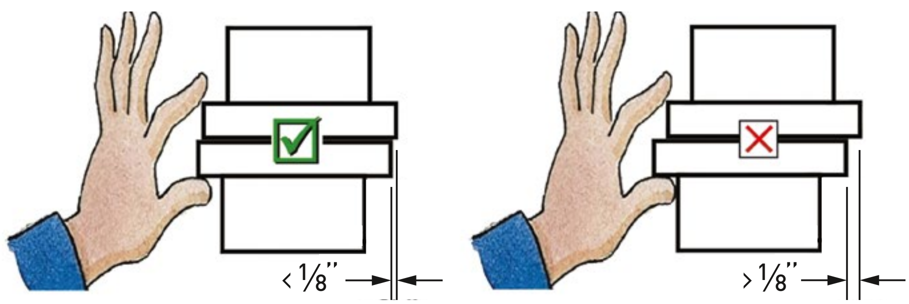
Next check the angle between the flange faces. If the faces are completely flush when pinched together, as shown above, then the alignment is perfect, and you may continue installation. Otherwise, pinch the faces together so that one side is touching, then measure the gap between the faces on the opposite side. The gap should be no more than 1/8".

Figure 4 - Gap Test



To assess high-low misalignment, pull the flange faces flush together. If the faces are concentric within 1/8", then the high-low misalignment is acceptable.

Figure 5 - Alignment Test



If the gap between the mating components can not be closed by pinching them with one hand, or if the angle or high-low misalignment between them is too large, then using the bolts to force the components together will result in excessive stress and possible failure during or after installation. In this case, inspect the system to find the greatest source of misalignment and refit the system with proper alignment before bolting.

Bolt Hole Alignment

Orientation of bolts should be outside of main axis. Horizontal pipelines should have the shown orientation of the bolts. This will avoid medium drops on the bolts in case of a leak.

To align the bolt holes of a fixed flange, use standard two-holing procedure.

Figure 6 - Flange Orientation

Placing the Gasket

Center the gasket between the flange adapter faces, with the bolt holes at the outer edge of the gasket. A gasket cut to the specified dimensions (see Tables 1 and 2) should come just to the inner edge of the flange adapter face near the flow path, or overlap the edge slightly.

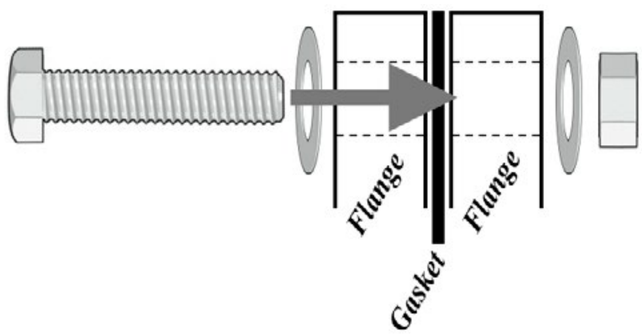
Inserting the Bolts

If using copper-graphite anti-seize lubricant as recommended, apply the lubricant evenly with a brush directly to the bolt threads, and to the nut if desired. Cover the bolt from its tip to the maximum extent to which the nut will be threaded. No lubricants can be used for high purity applications, only zinc-on-zinc or zinc-on-stainless steel fastener combinations are acceptable.

Insert bolts through washers and bolts holes as shown:

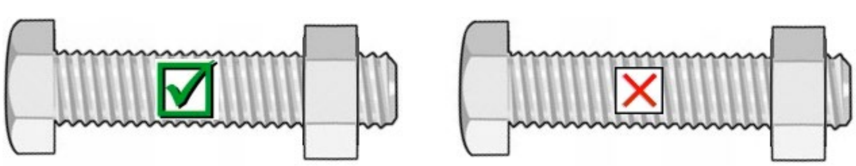
Tighten all nuts by hand. As you tighten each nut, the nuts on the other bolts will loosen slightly. Continue to hand-tighten all of the nuts until none remain loose. Now the flange assembly will remain in place as you prepare to fully tighten it.

Figure 7 - Flange Assembly



Again, when hand-tightened, at least two threads beyond the nut should be exposed in order to ensure permanent engagement. If less than two threads are exposed, disassemble the flange and use longer bolts.

Figure 8 - Proper Thread Engagement



Tightening the Bolts

Tightening one bolt to the maximum recommended torque while other bolts are only hand-tight, or tightening bolts in the wrong order, produces uneven stresses that may result in poor sealing. To ensure even distribution of stresses in the fully-installed flange, tighten the bolts in a star pattern as described in ANSI B16.5.

To ensure even distribution of stresses and a uniform seal, tighten the bolts to the first torque value in the sequence, using a star pattern, then repeat the star pattern while tightening to the next torque value, and so on up to the maximum torque value.
Vinyls, like all polymers, deform slightly under stress. A final tightening after 24 hours is recommended, when practical, to ensure that any bolts that have loosened due to relaxation of the polymer are fully engaged.

If a flange leaks when pressure-tested, retighten the bolts to the full recommended torque and retest. Do not exceed the recommended torque before consulting an engineer or GF representative.

Figure 9 - Recommended Bolt Tightening Sequence

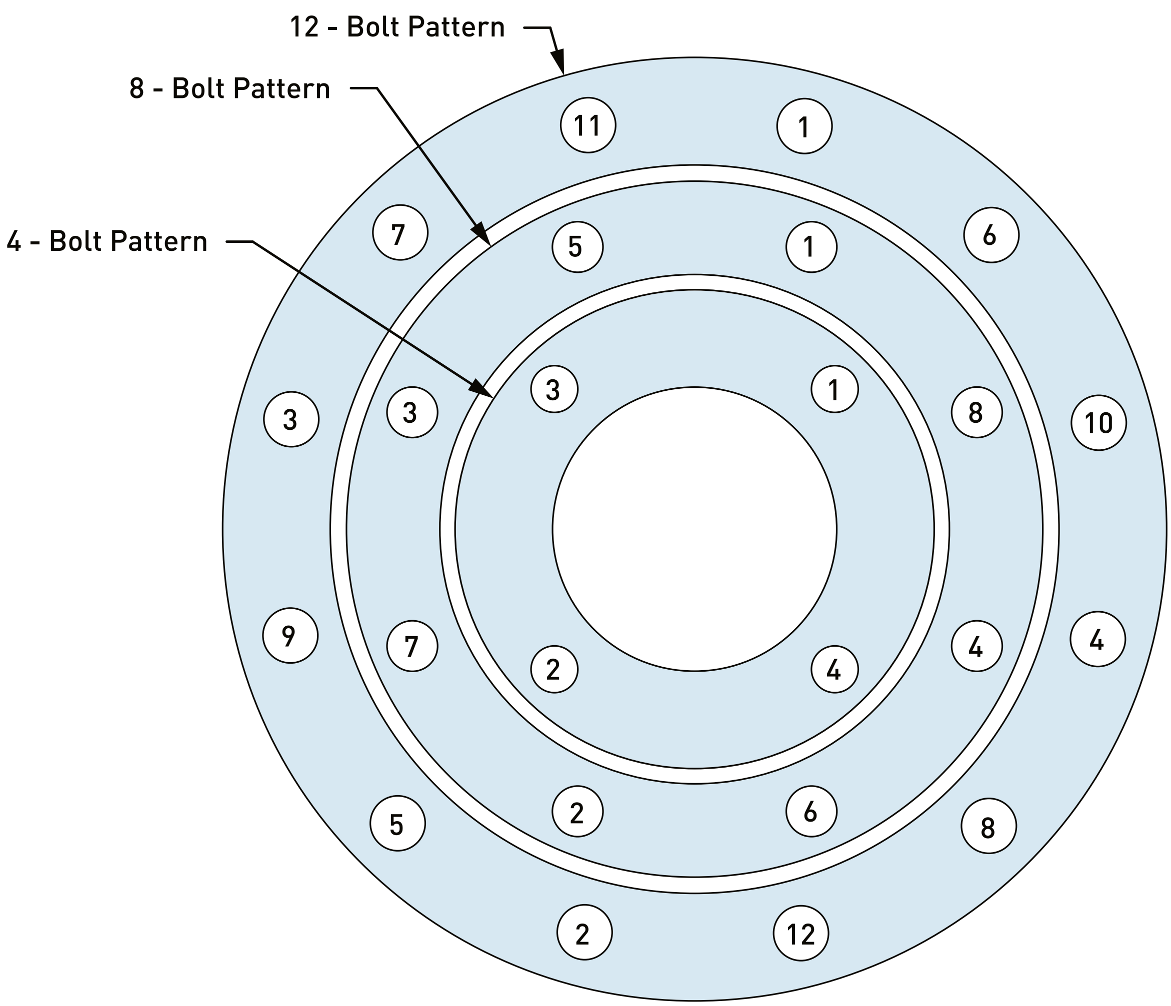


Table 3 - Flat Gasket Multiple Pass Bolt Torque

Size (in)	Torque Sequence (ft-lb, lubed*)				Torque Sequence (ft-lb, unlubed**)			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
½" - 20mm	4	7	--	--	5	9	--	--
¾" - 25mm	5	9	--	--	6	12	--	--
1" - 32mm	5	11	--	--	7	14	--	--
1¼" - 40mm	7	14	--	--	9	18	--	--
1½" - 50mm	7	16	--	--	7	14	21	--
2" - 63mm	7	14	28	--	12	25	36	--
2½" - 75mm	10	20	30	43	15	30	45	56
3" - 90mm	11	22	33	47	15	30	45	61
4" - 110mm	8	15	30	--	10	20	30	39
6" - 160mm	10	20	30	45	15	30	45	59
8" - 200mm	15	30	40	52	18	36	54	68
10" - 250mm	15	30	45	56	20	40	60	73
12	18	36	50	64	20	40	60	83
14	18	36	50	66	20	40	60	75
16	20	40	60	75	20	40	60	80
18	30	60	90	120	30	60	90	132
20	35	75	115	140	35	75	115	154
22	53	106	144	160	45	90	135	160
24	59	119	162	180	45	90	135	180
26	59	119	162	180	60	120	180	180
28	59	119	162	180	65	130	195	180
30	59	119	162	180	45	90	135	180
32	79	158	216	240	60	120	180	240
36	86	172	234	260	65	130	195	260

* Assumes the use of SS, zinc- or cadmium-plated bolt and/or nut along with copper-graphite anti seize lubricant brushed directly onto the bolt threads.

** Assumes the use of zinc- or cadmium-plated bolt, nut, or both. Never use unlubricated, uncoated bolts and nuts with vinyl flanges, as high friction and seizing lead to unpredictable torque and a high incidence of cracking and poor sealing.

Note: that the torques listed in Table 3 are recommended for flange-to-flange connections in which the full faces of the flanges are in contact.

For other types of connections, such as between a flange and a butterfly valve, where the full face of the flange is not in contact with the mating component, less torque will be required.
Do not apply the maximum listed torque to the bolts in such connections, which may cause deformation or cracking, since the flange is not fully supported by the mating component. Instead, start with approximately two-thirds of the listed maximum torque and increase as necessary to make the system leak-free after pressure testing.

Documentation for Flanged Connections

Keep Instructions Available

Provide a copy of these instructions to every installer on the job site prior to beginning installation. Installers who have worked primarily with metal flanges often make critical mistakes when installing vinyl flanges. Even experienced vinyl installers will benefit from a quick review of good installation practices before starting a new job.

Installation Tags (Figure 10)
Best practices include tagging each flange with

- Installer's initials
- Installation date
- Final torque value (e.g., "29.2-31.5")
- Confirmation of 24-hour torque check ("y" or "n")

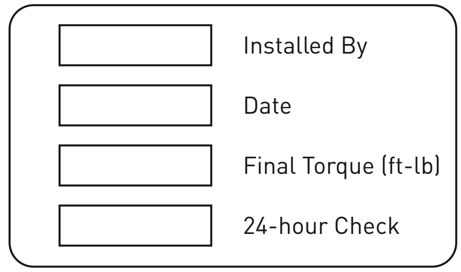


Figure 10 - Flange Installation

This information can be recorded on pre-printed stickers, as shown below, and placed on each flange immediately after installation. Experience has shown that installation tags speed up the process of resolving system leaks and product failures, improve communication between the contractor and distributor or manufacturer, highlight training opportunities, and promote worker diligence.

Creating Union Joints

Introduction

Because unions and ball valves have similar, threaded nut connectors, these instructions have been written with both of these components in mind. GF unions and ball valves are designed to provide many years of service when installed properly.

As with any piping system component, unions and valves have particular considerations that must be kept in mind during installation in order to ensure best performance. Even experienced installers will benefit from reviewing these instructions before each installation.

Valve Support

Ball valves must be well-supported. Refer to the GF Engineering Handbook for detailed instructions on support installation. (www.gfpiping.com) An unsupported or insufficiently-supported valve body will twist when opened and closed, subjecting the union connection to torque stress that may cause cracking or distortion and subsequent leakage.

System Alignment

The major contributor to union nut failures is misalignment. Uneven compression of the o-ring will cause leaks to occur. Union nuts can be damaged by the stress of holding a misaligned system together.

Sealing Mechanism

GF union connections use an o-ring as the sealing mechanism which is highly effective under relatively low tightening force.

Dirt and Debris

An often overlooked issue is the presence of dirt and debris on the o-ring or sealing surface. This will prevent proper o-ring sealing; if it is present on the nut or body threads, it will clog the threads and prevent proper tightening.

Installation

Understand and carefully follow these installation steps in order to ensure a seal that is sufficient to guard against leaks while avoiding excessive forces that can damage the union nut.

End Connectors

Always remove the union nut and end connectors from the ball valve for installation. Make sure that you slide the union nut onto the pipe, with the threads facing the proper direction, BEFORE installing the end connector.

Solvent Cementing

Solvent cementing of pipe into the union or ball valve sockets should be done before the union nut connections are engaged. Be careful not to get any cement on the sealing surfaces, which can disrupt the seal and cause leaks. For best results, allow the cemented joint to properly cure prior to assembling the union nut connection, in order to avoid damaging the uncured joint.

O-Ring Placement

Once the cement has cured, ensure that the o-ring is securely seated in its groove. The o-ring should rest securely in place without adhesive or other aids.

- Never use any foreign substance or object to hold the o-ring in place.

Union Connection

There should be no gap between the mating components, so that the threaded nut serves only to compress the o-ring, thus creating the seal. However, a small gap (less than 1/8") between the mating components is acceptable.

- Never use the union nuts to draw together any gaps between the mating faces of the components or to correct any system misalignment.

Hand-Tightening (all sizes) (see Table 4)

The next step is to hand-tighten the union nut. With the o-ring in place, engage the nut with its mating threads and turn clockwise with one hand. Continue turning with moderate force until the nut no longer turns.

Be careful to use reasonable force when tightening the nut. Your grip should be firm but not aggressive. The nut should turn easily until it bottoms out and brings the mating faces into direct contact.

It is recommended that you place an indexing mark with a permanent marker on the union nut and body to identify the hand tight position.

Do not use any form of lubricant on the threads of the union nut.
Union and ball valve sizes ½" through 1½" should be sufficiently sealed after hand-tightening, for the hydrostatic pressure test of the system.

Optional: Further Tightening (2")

Based on experience, or system requirements, the installer may choose to turn the nut an additional 1/8 turn (approximately 45°) in order to ensure a better seal before hydrostatically pressure testing the system. To do this, use a strap wrench to turn the nut 1/8 turn past the index mark applied after assembly.

Do not exceed 1/8 turn past the index mark.

Do not use any metallic tools. (Tool marks on the union nut will void manufacturer's warranty.)
At this point, the system should be hydrostatically pressure tested before turning the union nut any farther.

Table 4 - Tightening Guide for Union and Ball Valve Nuts

Nominal Size (inch)	Initial	Additional Pre-Test	Additional Post-Test
½	Hand-Tight	None	1/8 Turn (max)
¾	Hand-Tight	None	1/8 Turn (max)
1	Hand-Tight	None	1/8 Turn (max)
1½	Hand-Tight	None	1/8 Turn (max)
2	Hand-Tight	1/8 Turn (max)	1/8 Turn (max)

Post-Test Tightening (Sizes ½" to 1½" only)

It is highly unlikely that any union nut connection; when tightened as instructed above, will leak under normal operating conditions.

In the unlikely event that a leak occurs, the union nut at the leaking joint may be tightened an additional 1/8 turn, as described above. The system should then be re-tested. If the joint still leaks after post-test tightening, do not continue to tighten the nut at the leaking joint. Disassemble the leaking joint, re-check system alignment, and check for obstructions in the sealing area. If the cause of a leak can not be determined, or if you suspect that the union or valve is defective, contact your GF representative at (800) 854-4090 for further instructions.

Quality Check After Assembly

To check if the union connections are installed in a stress-free manner, GF recommends that a random check of alignment be done by removing the nut on selected union connection one at a time. A properly installed system will not have any movement of the piping as the nut is loosened. If any springing action is noticed, steps should be taken to remove the stress prior to re-installing the union nut.

Documentation for Union Joints

Keep Instructions Available

Provide a copy of these instructions to every installer on the job site prior to beginning installation.

Installation Tags

Best practices include tagging each union with:

- Installer's initials
- Installation date

This information can be recorded on pre-printed stickers, as shown below, and placed on each union nut immediately after installation.

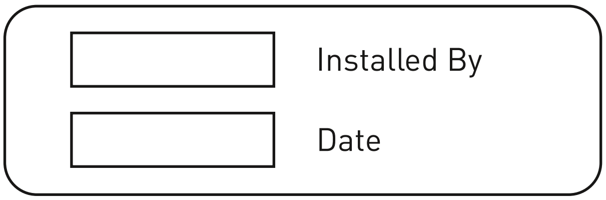


Figure 11 - Union Installation

Experience has shown that installation tags speed up the process of resolving system leaks and product failures, improve communication between the contractor and distributor or manufacturer, highlight training opportunities, and promote worker diligence. See the GF vinyl technical manual for information on guides, support spacing, and allowance for thermal expansion.

Creating Threaded Joints

Introduction

NPT threaded connections are not recommended for high pressure systems or those greater than two inches. They also should be avoided in systems where leaks would be dangerous or costly.

When properly installed, threaded connections offer the benefit of an easy and inexpensive transition to metal systems. They can also be used for joining plastic where the installation is expected to be modified or moved later.

Design Considerations

Due to the difference in stiffness between plastic and metal, a metal male-to-plastic female joint must be installed with care and should be avoided if possible. Only Schedule 80 pipe may be threaded. Threading reduces the rated pressure of the pipe by one-half.

Preparation - Thread Sealant

A thread sealant (or "pipe dope") approved for use with plastic or PTFE ("Teflon®") tape must be used to seal threads.

Installation - Thread Sealant

Use a thin, even coat of sealant. PTFE tape must be installed in a clockwise direction, starting at the bottom of the thread and overlapping each pass.

Making the Connection

Start the threaded connection carefully by hand to avoid cross threading or damaging threads. Turn until hand tight. Mark the location with a marker. With a strap wrench on the plastic part, turn an additional half turn. If leakage occurs during pressure testing, consult the chart for next steps.

Table 5 - Threaded Connection Guide

Connection Type	Next Step
Plastic to Plastic	Tighten up to ½ turn
Plastic Male to Metal Female	Tighten up to ½ turn
Metal Male to Plastic Female	Consult Factory

Alignment

Threaded connections are susceptible to fracture or leaking due to misalignment. Pipe should be installed without bending. See the GF vinyl technical manual for information on guides, support spacing, and allowance for thermal expansion.

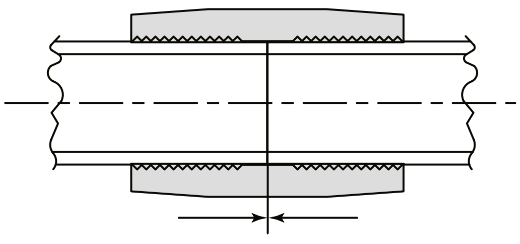
Electrofusion - Overview

Electrofusion Joining Method

The fusion area of the pipes and socket fittings are heated to fusion temperature and joined by means of an interference fit, without using additional materials. A homogeneous joint between socket and spigot is accomplished. Electrofusion must only be carried out with fusion joining machines by Georg Fischer that tightly control the fusion parameters. Details of the requirements for machines and equipment used for electrofusion joining of GF PE100 is included in the GF training manual and can be made available upon request.

General Requirements

The basic rule is that only similar materials can be fusion joined, i.e. PE with PE. For best results, only components which have a melt flow index in the range from MFR 190/5 0.3 to 1.7 g/10 min should be fusion joined. This requirement is met by PE butt fusion pipe and fittings and socket electrofusion from GF. The components must be joined with the fitting inserted to the full socket depth for the joint to be considered acceptable. Should this not be the case, failure to meet the depth requirement could result in joint failure, overheating and intrusion of the heating coil.



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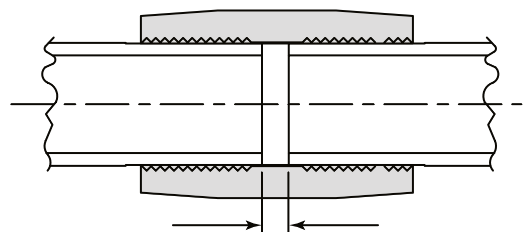

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Storage and Handling

The ecoFIT electrofusion fittings are packed separately in a polyethylene bag. If the fittings are protected from direct sunlight in the original packing and not stored above 50 °C, they can be stored for almost 10 years. The storage duration commences on the date that the fittings are produced.

To Avoid Pipe Damage and Ovaling

- Always store material in a safe, stable environment away from direct sunlight.
- Care must always be taken when handling PE pipe and fittings due to the softness of the materials to avoid unnecessary scratches and gouges.
- Pipe should be properly supported if stacked to prevent damage.
- Pipe should not be stacked more than 3 feet high without supports.

The pipe and fitting surfaces to be fused should be carefully protected from dust, grease, oil and lubricants. Use only cleaning agents that are suitable for PE.

Attention: There should be no grease (such as hand cream, oily rags, silicone etc.) in the fusion zone!

Fusion Equipment

Electrofusion socket fusion requires the GF MSA330/340 electrofusion machine in addition to the tools normally used for plastic piping construction. The fusion machine must meet the following minimum requirements.

Technical Information - MSA330/340

Input voltage and frequency	115 V (+/-20%) 50 – 60 Hz 230 V (+/-20%) 50 – 60 Hz
Suggested generator power requirements	6kVA All fittings including 26" IPS/660 mm couplings 3.5KVA Couplings up to 8"/225 mm, all reducers, and all saddles (service tapping tees, high volume tapping tees, & branch)
Input Waveform	AC (sine, square, or quasi-sine)
Fusion Type	Voltage controlled
Fusion voltage	8 – 48 V~
Operating temperature	-10°F – 120°F
Internal temperature	-10°F – 190°F
Power cable length	12 ft
Fusion cables length	25 ft
Fusion data input mode	Bar code, manual, CP mode
Capacity of internal memory	1000 fusions (MSA340 model) 500 fusions (MSA330 model)
USB Port	Type A
Barcode reader port	Dedicated inputs, DIN 5 connector
Protection factor	IP 54
Dimensions	11"×18.9"×12.6"
Weight	48.4 lbs
Revision/Calibration Interval	2 Years
Warranty	1 Year
Standards	ISO 12176-2; ISO 12176-3; ISO 12176-4; EN 60335-1 (Safety); EN 61000-6-2 (EMC); EN 61000-6-4 and others (EMC).

MSA 340

MSA 330

Pipe Preparation Equipment

- Pipe cutting tools
- Pipe scraping/peeling tools
- Pipe re-rounding tools
- Pipe cleaning materials (including 90% IPA Alcohol)
- Silver non-grease style marker

Scrape/Peel the area to be fused with an approved scraping tool. Make sure that the appropriate amount of material is removed.

Do not use abrasives, grinding wheels, or other devices that do not cleanly remove the surface material.

Note: Grease pencils are generally petroleum-based and therefore should not be used on PE pipe prior to electrofusion joining.

Recommended Marker

Approved Peeling Tools

Rotary Peeler - For pipe ends and saddles

RTC 160 / 315 - For pipe ends only

PT4 Peeling Tool - for pipe ends only

Pipe Restraint Equipment

- For sizes 20mm – 63mm, the provided screws are used. For saddles, use the provided under clamp.
- For sizes 75mm (2") and above, the use of GF approved clamping devices are required.

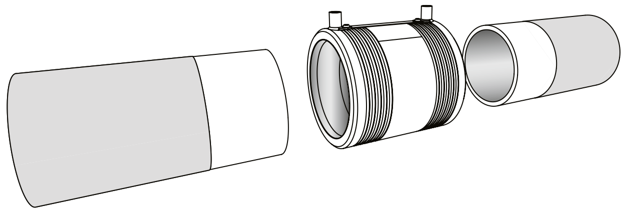
Note: Only remove fitting from bag when ready for fusion to prevent and contamination to the fitting.

Fusion Indicators (ecoFIT Metric only)

- When the fusion cycle has finished a visual check should be made to be sure the fusion indicators have functioned.
- This protrusion indicates that fusion pressure has developed but it does not necessarily guarantee any integrity for the joint. The height of the extended pin is dependant upon the fitting in use, component tolerances as well as pipe material.

Fusion Process

Pipe should be inserted parallel to the fitting, equal depth from each side.



Note: It is not possible to fuse fittings one side at a time.

Due to the amperage draw of the electrofusion fitting, use of extension cords is not encouraged. In the event it becomes necessary to use an extension cord, the following lengths and wire gages are recommended:

Cord Length	Wire Gauge
25 ft	#10 / 3 wire
50 ft	#8 / 3 wire

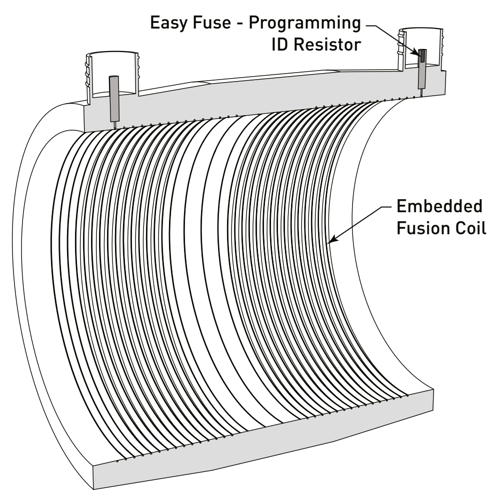
The proper applications of the electrode connectors requires that the red terminal be connected to ID resistor (easily visible on the fitting) side of the fitting. Should the terminals be connected opposite to this requirement, the machine will require the operator to continue in the barcode or manual mode. When this occurs, the machine can be reset and the terminals properly applied to resume auto mode.

Important note:
All electrofusion couplings require the pipe to be restrained or sufficiently supported on each side of the pipe to:

1. Restrict movement during the fusion and cooling process
2. Alleviate or eliminate source of stress and/or strain until both the fusion and cool-down cycle have been completed

Only GF approved restraint tools should be used.

A properly prepared and assembled joint that is kept stationary and free from stresses and strains during the fusion process and recommended cooling time should have good joint integrity.



GF Electrofusion fittings can be re-fused only in the event of an input power interruption, i.e. Fusion leads were detached during the fusion process, the generator runs out of gas, processor malfunction or other circumstances that result in processor input power interruption.

The recommended procedure for re-fusing fittings is:

1. Fitting should remain in clamped position and be allowed to cool to ambient temperature.
2. The fitting should be reconnected to the processor and fused for the entire fusion time.
3. This re-fusion procedure should be used for fusions that terminate due to input power reasons ONLY.

Fittings that fault for any other reason should be cut out and replaced!

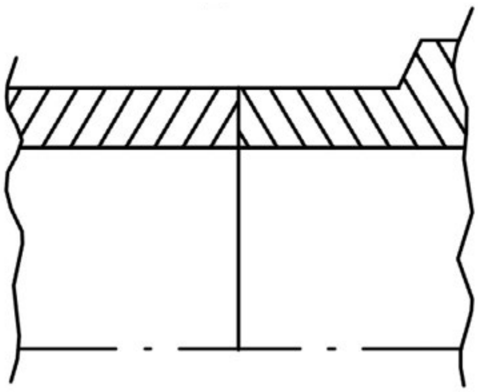
CNC Controlled (Conventional) Contact Butt Fusion - Overview

Butt Fusion Joining Method

The fusion areas of the pipes and fittings are heated to fusion temperature and joined by means of mechanical pressure, without using additional materials. A homogeneous joint results. Butt fusion must only be carried out with fusion joining machines which allow the joining pressure to be regulated. Details of the requirements for machines and equipment used for fusion joining thermoplastics are contained in DVS 2208 Part 1. The drawing to the right illustrates the principle of fusion joining.

General Requirements

The basic rule is that only similar materials can be fusion joined, i.e.: PE with PE. For best results, only components which have a melt flow index in the range from MFR 190/5 0.3 to 1.7 g/10 min should be fusion joined. This requirement is met by PE butt fusion fittings from GF. The components to be joined must have the same wall thicknesses in the fusion area.
Join only components with similar wall thicknesses



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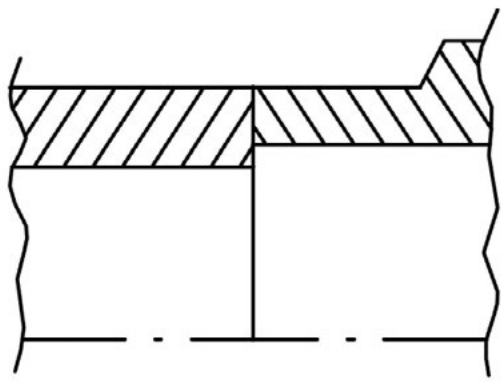


Incorrect

Heated tool butt fusion joining may only be performed by adequately trained personnel.

Storage and Handling

The ecoFIT butt fusion fittings, if protected from direct sunlight and not stored above 122°F (50°C), they can be stored for almost 10 years. The storage duration commences on the date that the fittings are produced.

To Avoid Pipe Damage and Ovaling

- Always store material in a safe, stable environment away from direct sunlight.
- Care must always be taken when handling PE pipe and fittings due to the softness of the materials to avoid unnecessary scratches and gouges.
- Pipe should be properly supported if stacked to prevent damage.
- Pipe should not be stacked more than 3 feet high without supports.

The pipe and fitting surfaces to be fused should be carefully protected from dust, grease, oil and lubricants. Use only cleaning agents that are suitable for PE.

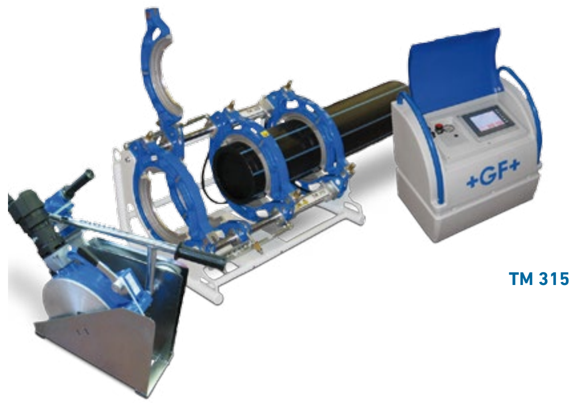
Attention: There should be no grease (such as hand cream, oily rags, silicone etc.) in the fusion zone!

Fusion Equipment

CNC Contact butt fusion requires the GF TM160/250/315/400/630 contact butt fusion machines in additional to the tools normally used for plastic piping construction. The fusion machines meet the following minimum requirements.

Technical Information - TM160/250/315/400/630

Input voltage and frequency	230V (±10%) 50Hz (TM160/TM250) 400V (±5%) 50Hz (TM315/TM400/TM630)
Suggested generator power requirements	1.9kVA (TM160) 3.3kVA (TM250) 3.9kVA (TM315) 5.7kVA (TM400) 11kVA (TM630)
Operating temperature	-10 °F – 120°F
Internal temperature	-10°F – 190°F
Power cable length	12 ft
Fusion data input mode	CNC Controller
Capacity of internal memory	100 Joints
USB Port	Type A
Barcode reader port	Optional
Dimensions	43.3“×26.8”×26.8“ (TM160) 51.2“×37.4“×29.5“ (TM250) 63.8“×37.4“×37.4“ (TM315) 56.3“×53.9“×41.7“ (TM400) 65.0“×55.1“×53.1“ (TM630)
Weight	154 lbs (TM160) 245 lbs (TM250) 280 lbs (TM315) 452 lbs (TM400) 1,356 lbs (TM630)
Revision/Calibration Interval	2 Years
Warranty	1 Year
Standards	ISO 12176-1; ISO 12176-3; ISO 12176-4; EN 60335-1 (Safety); EN 61000-6-2 (EMC); EN 61000-6-4 and others (EMC).



TM 315

620SC

Contact butt fusion requires the GF 620, 414, 28, 14, 1442, 824 contact butt fusion machines in additional to the tools normally used for plastic piping construction. The fusion machines meet the following minimum requirements.

Technical Information

	620SC	414HP	414SC	414EP	28HP	28EP	14M	28CQ*	1442EP	824EP*
Input voltage and frequency	240VAC, 16.7A	120VAC, 29.9A 240VAC, 15.0A	240VAC, 10.4A	240VAC, 23.1A	120VAC, 25.7A 240VAC, 12,9A	120VAC, 35.3A 240VAC, 9.75A	120VAC, 18A 240VAC, 9.75A	120VAC, 18A	208VAC 3-phase, 95.7A	240 VAC 3-phase 60Hz, 38A
Capacity	6”–20” (160mm–500mm)	4”–14” (110mm–355mm)	4“–14”	4”–14” (110mm–355mm)	2”–8” (63mm–225mm)	2”–8” (63mm–225mm)	¾”–4” (25mm–110mm)	2”–8” (63mm–225mm)	14”–42”	8”–24” (225mm–630mm)
Dimensions (carriage mounted on frame)	122.4“ L 61.5” W 50.75“ H	77.73” L 47.17“ W 46.81“ H	77.48“ L 55.92“ W 46.81“ H	77.72“ L 52.50“ W 46.82“ H	62.23“ L 34.25“ W 35.43“ H	62.25“ L 36.88“ W 42.56“ H	41.34“ L 24.68“ W 41.92“ H	24“ L 24“ W 17“ h	206“ L 93” W 91” H	104“ L 63” W 51” H
Weight	2,500 lbs	1,015 lbs	1,325 lbs	1,438 lbs	562 lbs	590 lbs	149 lbs	185 lbs	9,650 lbs	2,700 lbs

* Dimensions are carriage only

Pipe Preparation Equipment

Butt fusion joining requires a special joining machine in addition to the tools normally used for plastic piping construction (pipe cutters, saw with cutting guide). The fusion joining machine must meet the following minimum requirements:

The clamping equipment must hold the various parts securely without damaging the surfaces. Possible ovality can be largely compensated by centered clamping of the components to be joined. It must also be possible to hold all parts firmly in alignment.

The machine must also be capable of face planing the fusion surfaces of pipes and fittings.

The fusion joining machine must be sufficiently solid to be able to absorb the pressures arising during the fusion procedure without detrimentally deforming the joint.

The heating surfaces of the heating element must be flat and parallel. The temperature variation over the working area must not exceed 50°F (10°C). The machine should be set up and operated according to the manufacturer's instructions.

The fusion procedure detailed below including the preparation is based on DVS 2207-1 Welding of thermoplastics - Heated tool welding of pipes, pipeline, components and sheets made from PE.

Note:
Protect the area of the fusion joint from adverse weather conditions, such as rain, snow and wind. At temperatures below 41°F (5°C) or above 113°F (45°C), measures must be taken to ensure that the temperature in the working area is in the range required for satisfactory joining and does not hinder the necessary manual tasks.

IR Plus® Infrared Non-contact Butt Fusion

For further information please contact your local GF Distributor.

Section 2: IPS

System Specification - Design Flow™ Piping Systems in IPS/DIPS Polyethylene (PE)

1.0 Scope

This specification covers the requirements for the GF Piping Systems (PE) IPS/DIPS Piping Systems intended for a wide range of industrial applications including water, wastewater and effluent treatment as well as a wide range of chemical applications. The components of the ecoFIT IPS (PE) piping system are in accordance with the following standards.

2.0 Basic System Data

2.1 Material Specification for Design Flow (PE) IPS/DIPS Pipe & Fittings

A. All Design Flow (PE) IPS/DIPS pipe shall be manufactured from a PE100/4710 high density copolymer resin meeting the requirements of ASTM D3350 and D3035. Pipe shall be manufactured to SDR 11 or SDR 17 dimensions with a pressure rating of 200 psi or 130 psi respectively when measured at 68°F. The material shall achieve a minimum tensile strength of 3600 psi when tested at 73°F according to ASTM D 638. The material shall also comply with guidelines approved by the U.S. Food and Drug Administration (FDA) as specified in the Code of Federal Regulations (CFR), Title 21, Section 177.160 for basic polyethylene and Section 178.3297 "colorants for polymers" for pigments suitable for contact with foodstuff, pharmaceutical use and potable water. Piping materials shall conform to the requirements of ASTM D2837 for hydrostatic design basis. Industrial grade pipe shall be supplied capped off at the extruder and supplied in 20ft lengths.

B. All Design Flow (PE) IPS/DIPS fittings shall be manufactured from a PE100/4710 high density copolymer resin meeting the requirements of ASTM D3350. Fittings in sizes through 42" shall be butt fusion type, suitable for heat fusion joining. All fittings through 42" shall be compatible with manual and contact butt fusion machines. Fittings shall be manufactured to SDR 11 or SDR 17 dimensions with a pressure rating of 200 psi or 130 psi respectively when measured at 68°F. All flanges shall be manufactured to SDR 11 dimensions with a pressure rating of 150 psi when measured at 68°F.

C. All components of the pipe and fitting system shall conform to the following applicable ASTM Standards, D3035, D638, D2837, shall conform to NSF Standard 61 for potable water applications and shall conform to FDA CFR 21 177.160 and 178.3297. All pipes shall be marked with manufacturers name, pipe size, SDR rating, type, quality control mark and pressure rating information. Fittings shall be embossed with a permanent identification during the production process to ensure traceability. All flanged connections shall utilize flange rings with bolt patterns to accommodate ANSI bolt circles. All threaded connections shall have pipe threads designed in accordance with the requirements of ASTM D2464, which references ANSI B1.20.1 (formerly B2.1) for tapered pipe threads (NPT).

D. Pipe, valves, fittings and joining equipment shall be supplied by a single source provider to insure compatibility of system components and to assure proper joint integrity.

E. Acceptable material shall be GF Design Flow Industrial Polyethylene as manufactured by Georg Fischer Central Plastics.

F. Pipe and fittings shall be manufactured by an FM approved and listed facility.

3.0 Material Specification for Valves

3.1 Butterfly Valves

3.1.1 Plastic Butterfly Valves

A. Butterfly valves suitable for the Design Flow (PE) System of GF Piping Systems are made from PP-H, ABS, or PVC material.

B. All butterfly valves, sizes 2"–12", shall be GF Piping Systems Type 567/578 wafer/lug type with a double eccentric disc design manufactured by GF Piping Systems in accordance with EN ISO 16136. Seals shall be available in EPDM, FPM and PTFE/FPM. The lever handle shall be lockable in increments of 5 degrees. There shall always be six teeth engaged between the ratchet and the index plate to ensure accurate and safe positioning of the lever. There shall be the option of fine adjustment by use of a specific hand lever, allowing the disc to be exposed at any angle between 0° and 90°. As an option, the hand lever shall be lockable. The hand lever shall be manufactured of high strength PPGF (polypropylene glass fiber reinforced). The option of an integrated electric position indicator shall be available. As an option the valves can be actuated by gear box with hand wheel. The electric position indicator shall be integrated into the mounting flange. Butterfly valves shall have low actuation torque to enable easy operation. All butterfly valves Type 567/578 manufactured by GF Piping Systems are designed for a nominal pressure rate of 10 bar. All butterfly valves Type 563 are designed for a nominal pressure rate of 4 bar.

3.1.1.1 Electrically Actuated Butterfly Valves

A. Electric actuators shall be GF Piping Systems Types EA31 or EA42 dependent on valve size. They shall be manufactured by GF Piping Systems in accordance with EN 61010-1, as per the above specifications. Actuator housing shall be made of PPGF (polypropylene glass fiber reinforced), flame retardant and feature external stainless steel screws. All electric actuators shall have an integrated emergency manual override and integrated optical position indication.

B. All electric actuator types shall have the following accessories available:
- Fail-safe unit
- Heating element
- Cycle extension, monitoring, and counting
- Motor current monitoring
- Position signalization
- Positioner Type PE25
- Limit switch kits Ag-Ni, Au, NPN, PNP
- Manual override
- AS-Interface Plug Module

3.1.1.2 Pneumatically Actuated Butterfly Valves

A. Pneumatic actuators shall be GF Piping Systems Types PA 35 (sizes 2" and 2½"), PA40 (size 3" only), PA45 (size 4"), PA55 (size 6"), PA60, PA65. They shall be supplied by GF Piping Systems. Pneumatic actuators shall be available as fail safe close, fail safe open and double acting and have an integrated optical position indication. Actuator housing shall be made of hardened anodized aluminum. Actuators shall contain integrated Namur interfaces for the easy mounting of positioners, limit switches and accessories. All pneumatically actuated butterfly valves shall have the following accessories available:

- Solenoid pilot valve remote or direct mounted in voltages 24VDC/AC, 110VAC, 230VAC
- Positioner Type DSR 500-3
- Feedback with following limit switches Ag-Ni, Au, NPN, PNP, NAMUR
- Stroke limiter & emergency manual override
- ASI-controller

4.0 Material Specification for Design Flow (PE) IPS Ball Valves

A. Ball valves consist of a valve body out of PP-H, ABS, or PVC combined with connection parts in PE.

4.1.1 Manual Operated Ball Valves – Municipal

B. All manual ball valves shall be manufactured by Georg Fischer Central Plastics' from a high density polyethylene (PE100) material according to ASTM D3350 with a smooth, full bore design available in SDR 11 IPS sizes 1 ¼" through 6" as standard. The fused valve body and ends shall be constructed of bi-modal PE3408/PE4710 resin which also carries an MRS rating of 10 (PE100). The valve shall be suitable for operation in systems using a .63 design factor at pressures up to 200 psig and also meeting the requirements of ASTM D2513. The sealing element is an elastomer that is captured on the valve seat. The valve operation is 1/4 turn (clockwise open) using a 2" square drive and can be supplied with gear reduction actuation. The valve is compatible for heat fusion with like or similar PE materials including PE2406/PE2708. It is suitable for installation by butt fusion, electrofusion, mechanical jointing, and other methods. It can be supplied in various end configurations, such as flanged or pupped as needed.

4.1.2 Manual Operated Ball Valves – Industrial

A. All Design Flow (PE) ball valves with inch sizes 2" IPS to 4" IPS, shall be Polypropylene valve body and PE100 ends Type 546 and/or 543 with true double union design manufactured by GF Piping Systems in accordance with EN ISO 16135. Incorporated into its design shall be a safety stem with a predetermined breaking point above the bottom O-ring, preventing any media leaking in the event of damage. The valve nut threads shall be buttress type to allow fast and safe radial mounting and dismounting of the valve during installation or maintenance work. Seats shall be PTFE with backing rings creating self-adjusting seals and constant operating torque. Backing rings and seals shall be EPDM or FPM. The handle shall include in its design an integrated tool for removal of the union bush. Union bushes shall have left-hand threads to prevent possible unscrewing when threaded end connectors are removed from pipe.

4.1.3 Ball Valve Accessories – Industrial

A. A Multi-Functional Model (MFM) in PPGF equipped with internal limit switches for reliable electrical position feedback, is mounted directly between the valve body and the valve handle. This MFM is also the necessary interface for later mounting of actuators.

B. Mounting plate in PPGF with integrated inserts for mounting on any support

C. Lockable multi-functional handle

4.2 Material Specification for Design Flow (PE) IPS Diaphragm Valves

A. Diaphragm valves consist of a valve body out of PP-H, ABS, or PVC.
- Type 514 (2" true double union design with PE ends)
- Type 517 (3" and 4" flange design)

B. Diaphragm valves shall have EPDM or PTFE/EPDM backed diaphragm type seal configurations and EPDM backing or FPM O-ring seals.

C. Valves shall be Type 514 Diaphragm Valves as manufactured by GF Piping Systems.

D. Diaphragm valves and shall be rated for 150 psi when measured at 68°F. Top works must include integral lock out device on handle. Pneumatic valve actuators, if required shall be supplied by GF Piping Systems to ensure proper system operation.

5.0 Welding and Assembly

A. All electrofusion fittings shall be manufactured under strict quality requirements as stated by the manufacturer such as ISO9001 or equivalent. All electrofusion fittings must be packaged to ensure cleanliness and protection from contamination.

B. All butt fusion fittings and valves shall also be manufactured with laying lengths designed for use with electrofusion capabilities with and for butt fusion machines according to DVS 2207-11 including CNC control parameters from GF Piping Systems or conventional butt as per AWWA or ASTM.

C. Optional IR Plus fusion machines, IR63 Plus, IR225 Plus use non-contact radiant heating. The cooling time for is calculated on the basis of ambient temperature and the bead surface temperature. To increase the cooling capacity, an additional cooling fan is included in the IR-225 Plus.

D. Only authorized and certified welders by GF Piping Systems are allowed to perform fusion on GF approved equipment.

E. The welding and the installation should be in accordance with GF Piping Systems guidelines.

6.0 Quality

6.1 Production Conditions

Pipes, fittings, valves and accessories shall be manufactured in an environment equivalent to, or meeting the requirements of a Quality Assurance System such as ISO 9001.

6.2 Uniformity

Pipes, fittings, valves and welding machines shall be supplied from one manufacturer, GF Piping Systems to ensure correct and proper jointing between components and uniform chemical and physical properties of the piping system.

6.3 Handling of Material

A. Material shall be stored in original packaging and protected from environmental damage until installation.

B. Pipe shall be supported sufficiently to prevent sagging. Care shall be taken not to gouge or otherwise notch the pipe in excess of 10% of the wall thickness.

6.4 Training, Certification and Installation

A. Site personnel, permissible for PE piping installation, shall undergo training and certification according to manufacturer's published guidelines prior to performing any jointing operations on site.

6.5 Testing

A. The system shall be tested in accordance with the manufacturers' recommendations.

B. Following is a general test procedure for GF Piping Systems. It applies to most applications. Certain applications may require additional consideration. For further questions regarding your application, please contact your local GF representative.

1. All pressure tests should be conducted in accordance with the appropriate building, plumbing, mechanical and safety codes for the area where the piping is being installed.
2. When testing plastic piping systems, all tests should be conducted hydrostatically and should not exceed the pressure rating of the lowest rated component in the piping system (often a valve). Test the system at 150% of the designed operational pressure. (i.e.: If the system is designed to operate at 80PSI, then the test will be conducted at 120PSI.)
3. When hydrostatic pressure is introduced to the system, it should be done gradually through a low point in the piping system with care taken to eliminate any entrapped air by bleeding at high points within the system. This should be done in four stages, waiting ten minutes at each stage (adding ¼ the total desired pressure at each stage).
4. Allow one hour for system to stabilize after reaching desired pressure. After the hour, in case of pressure drop, increase pressure back to desired amount and hold for 30 minutes. If pressure drops by more than 6%, check system for leaks.

Note: If ambient temperature changes by more than 10°F during the test, a retest may be necessary.

Pressure/Temperature

Long-Term Stress

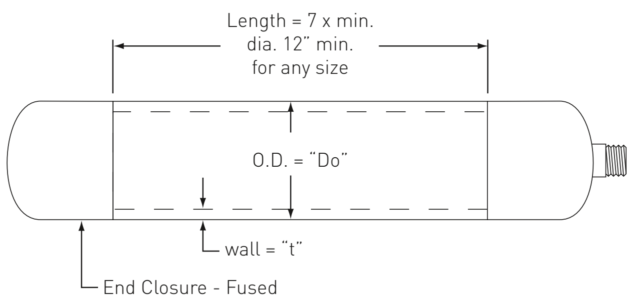
To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends (Figure 2) and subjected to various internal pressures, to produce circumferential stresses that will predict failure in from 10hrs to 50yrs. The test is run according to ASTM D1598 / EN ISO 15494:2003, “Standard Test for Time to Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure.”

The resulting failure points are used in a statistical analysis (outlined in ASTM D2837 / EN ISO 15494:2003) to determine the characteristic regression curve that represents the stress/time-to-failure relationship of the particular thermoplastic pipe compound. The curve is represented by the equation

$$\log T = a + b \log S$$

Where a and b are constants describing the slope and intercept of the curve, and T and S are time-to-failure and stress, respectively.

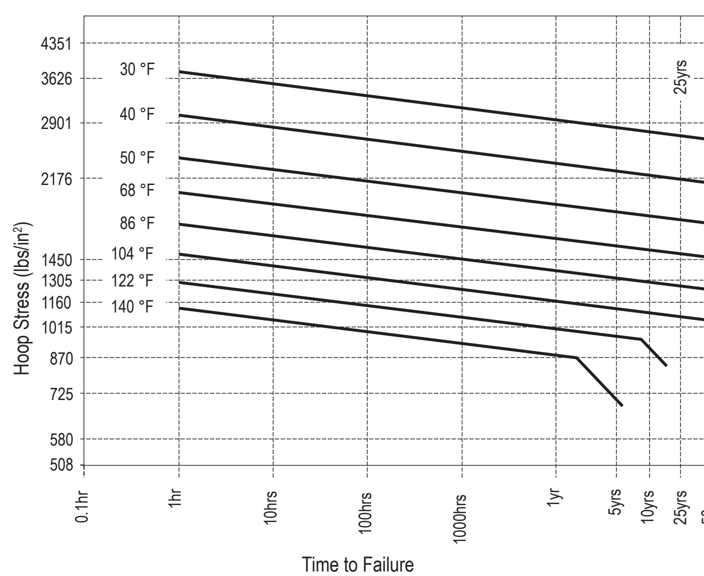
Figure 12 - Long-Term Stress



The regression curve may be plotted on log-log paper as shown in Figure 3 and extrapolated from 5 years to 25 years. The stress at 25 years is known as the hydrostatic design basis (HDB) for that particular thermoplastic compound. From this HDB the hydrostatic design stress (HDS) is determined by applying the service factor multiplier.

Figure 13 - Regression Curve

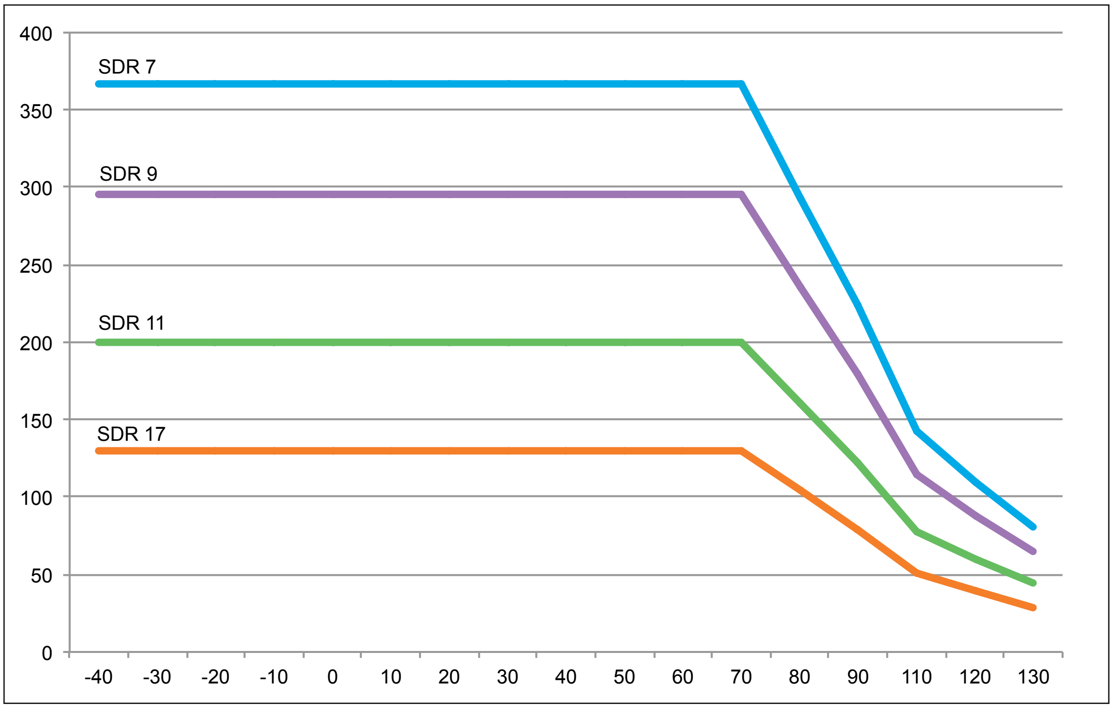
Regression Curve - Stress/Time to failure for PE100 Pipe



Working Pressures and Temperatures for PE100 Pipe and Fittings

Based on 25 yrs service life. (Hydrostatic Design Basis (HDB) per ASTM 2837)

Figure 14 - Pressure/Temperature Curve



Dimensional Pipe Size - SDR

Table 6 - Pipe Size Comparison

Nominal Diameter (inch)	Weight of PE Pipe (lbs/ft)				Outside Dimensions				Wall Thickness				Inside Dimensions			
	SDR 17	SDR 11	SDR 9	SDR 7	SDR 17	SDR 11	SDR 9	SDR 7	SDR 17	SDR 11	SDR 9	SDR 7	SDR 17	SDR 11	SDR 9	SDR 7
2	0.43	0.64	0.77	0.95	2.375	2.375	2.375	2.375	0.140	0.216	0.264	0.339	2.078	1.917	1.815	1.656
3	0.94	1.39	1.66	2.06	3.543	3.543	3.543	3.543	0.206	0.318	0.389	0.500	3.063	2.826	2.675	2.440
4	1.55	2.31	2.75	3.40	4.5	4.5	4.5	4.5	0.265	0.409	0.500	0.643	3.938	3.633	3.440	3.137s
6	3.36	5.00	5.96	7.37	6.625	6.625	6.625	6.625	0.390	0.602	0.736	0.946	5.798	5.349	5.065	4.619
8	5.69	8.47	10.11	12.50	8.625	8.625	8.625	8.625	0.507	0.784	0.958	1.232	7.550	6.963	6.594	6.013
10	8.83	13.16s	15.70	19.42	10.75	10.75	10.75	10.75	0.632	0.977	1.194	1.536	9.410	8.679	8.219	7.494
12	12.43	18.51	22.08	27.31	12.750	12.750	12.750	12.750	0.750	1.159	1.417	1.821	11.160	10.293	9.746	8.889
14	14.98	22.32	26.63	32.93	14.000	14.000	14.000	14.000	0.824	1.273	1.556	2.000	12.352	11.301	10.701	9.760
16	19.57	29.15	34.78	43.01	16.000	16.000	16.000	16.000	0.941	1.455	1.778	2.286	14.118	12.915	12.231	11.154
18	24.77	36.89	44.02	54.43	18.000	18.000	18.000	18.000	1.059	1.636	2.000	2.571	15.882	14.532	13.760	12.549
20	30.58	45.54	54.34	67.20	20.000	20.000	20.000	20.000	1.176	1.818	2.222	2.857	17.648	16.146	15.289	13.943
22	37.00	55.10	65.75	81.32	22.000	22.000	22.000	22.000	1.294	2.000	2.444	3.143	19.412	17.760	16.819	15.337
24	44.03	65.58	78.25	96.77	24.000	24.000	24.000	24.000	1.412	2.182	2.667	3.429	21.176	19.374	18.346	16.731
26	51.67	76.96	91.84		26.000	26.000	26.000	26.000	1.529	2.364	2.889		22.942	20.989	19.876	
28	59.93	89.26	106.51		28.000	28.000	28.000	28.000	1.647	2.545	3.111		24.706	22.604	21.404	
30	68.80	102.47	122.27		30.000	30.000	30.000	30.000	1.765	2.727	3.333		26.470	24.218	22.933	
32	78.28	116.58	139.12		32.000	32.000	32.000	32.000	1.882	2.909	3.556		28.236	25.833	24.462	
36	99.07	147.55			36.000	36.000	36.000	36.000	2.118	3.273			31.764	29.062		

Below 2", see metric

Calculating Pipe Size

Friction Loss Characteristics

Sizing for any piping system consists of two basic components: fluid flow design and pressure integrity design. Fluid flow design determines the minimum acceptable diameter of pipe and pressure integrity design determines the minimum wall thickness required. For normal liquid service applications an acceptable velocity in pipes is 7 ±3 (ft/sec), with a maximum velocity of 7 (ft/sec) at discharge points.

Pressure drops throughout the piping network are designed to provide an optimum balance between the installed cost of the piping system and the operating cost of the pumps.

Pressure loss is caused by friction between the pipe wall and the fluid, minor losses due to obstructions, change in direction, etc. Fluid pressure head loss is added to elevation change to determine pump requirements.

Hazen and Williams Formula

The head losses resulting from various water flow rates in plastic piping may be calculated by means of the Hazen and Williams formula (located in Figure 5):

C Factors

Tests made both with new pipe and pipe that had been in service revealed that (C) factor values for plastic pipe ranged between 160 and 165. Thus the factor of 150 recommended for water in the equation (located in Figure 5) is on the conservative side. On the other hand, the (C) factor for metallic pipe varies from 65 to 125, depending upon the time in service and the interior roughening. The obvious benefit is that with Polyethylene piping systems, it is often possible to use a smaller diameter pipe and still obtain the same or even lower friction losses.

Independent variable for these tests are gallons per minute and nominal pipe size (OD). Dependent variables for these tests are gallons per minute and nominal pipe size OD. Dependent variables are the velocity friction head and pressure drop per 100ft. of pipe, with the interior smooth.

Figure 15 - Hazen Williams Formula

V	- Fluid Velocity (ft/sec)
ΔP	- Head Loss (lb/in² /100 ft of pipe
ΔH	- Head Loss (ft of water /100 ft of pipe)
L	- Length of Pipe Run (ft)
L_e	- Equivalent Length of Pipe for minor losses (ft)
D_i	- Pipe Inside Diameter (in)
Q	- Fluid Flow (gal/min)
C	- Constant for Plastic Pipes (conservative - 150)

Hazen and Williams Formula:

$$\Delta H = (L + L_e) \cdot \left(\frac{V}{1.318 \cdot C \cdot (\frac{D_i}{4})^{0.63}} \right)^{1.852}$$

Step 1: Solve for V:

$$V = \frac{4Q(0.1337)}{60\pi \left(\frac{D_i}{12} \right)^2}$$

Step 2: Solve for ΔH:

$$\Delta H = (L + L_e) \cdot \left(\frac{V}{1.318 \cdot C \cdot (\frac{D_i}{4})^{0.63}} \right)^{1.852}$$

Step 3: Solve for ΔP:

$$\Delta P = \Delta H / 2.31$$

Table 7 - Flow Rate vs. Friction Loss - IPS SDR 7

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		2"			3"			4"			6"	
10	1.49	0.60	0.26									
15	2.23	1.27	0.55	1.03	0.19	0.08						
20	2.98	2.17	0.94	1.37	0.33	0.14						
30	4.47	4.60	1.99	2.06	0.70	0.30	1.25	0.21	0.09			
40	5.96	7.83	3.39	2.74	1.19	0.51	1.66	0.35	0.15			
50	7.45	11.84	5.13	3.43	1.80	0.78	2.08	0.53	0.23	0.96	0.08	0.03
60	8.94	16.60	7.18	4.12	2.52	1.09	2.49	0.74	0.32	1.15	0.11	0.05
70	10.43	22.08	9.56	4.80	3.35	1.45	2.91	0.99	0.43	1.34	0.15	0.06
80	11.92	28.27	12.24	5.49	4.29	1.86	3.32	1.26	0.55	1.53	0.19	0.08
90	13.41	35.17	15.22	6.18	5.33	2.31	3.74	1.57	0.68	1.72	0.24	0.10
100				6.86	6.48	2.81	4.15	1.91	0.83	1.91	0.29	0.13
125				8.58	9.80	4.24	5.19	2.89	1.25	2.39	0.44	0.19
150				10.29	13.74	5.95	6.23	4.05	1.75	2.87	0.62	0.27
175				12.01	18.28	7.91	7.27	5.38	2.33	3.35	0.82	0.35
200				13.72	23.41	10.13	8.30	6.89	2.98	3.83	1.05	0.45
250							10.38	10.42	4.51	4.79	1.59	0.69
300							12.46	14.61	6.32	5.74	2.22	0.96
350							14.53	19.43	8.41	6.70	2.96	1.28
400										7.66	3.79	1.64
450										8.62	4.71	2.04
500										9.57	5.73	2.48
550										10.53	6.83	2.96
600										11.49	8.03	3.47
700										13.40	10.68	4.62

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		8"			10"			12"			14"	
100	1.13	0.08	0.03									
150	1.69	0.17	0.07	1.09	0.06	0.03						
200	2.26	0.29	0.13	1.45	0.10	0.04	1.03	0.04	0.02			
250	2.82	0.44	0.19	1.82	0.15	0.07	1.29	0.07	0.03	1.07	0.04	0.02
300	3.39	0.62	0.27	2.18	0.21	0.09	1.55	0.09	0.04	1.29	0.06	0.03
350	3.95	0.82	0.35	2.55	0.28	0.12	1.81	0.12	0.05	1.50	0.08	0.03
400	4.52	1.05	0.45	2.91	0.36	0.16	2.07	0.16	0.07	1.72	0.10	0.04
450	5.08	1.31	0.57	3.27	0.45	0.19	2.33	0.19	0.08	1.93	0.12	0.05
500	5.65	1.59	0.69	3.64	0.54	0.24	2.59	0.24	0.10	2.14	0.15	0.07
550	6.21	1.89	0.82	4.00	0.65	0.28	2.84	0.28	0.12	2.36	0.18	0.08
600	6.78	2.22	0.96	4.36	0.76	0.33	3.10	0.33	0.14	2.57	0.21	0.09
700	7.91	2.96	1.28	5.09	1.01	0.44	3.62	0.44	0.19	3.00	0.28	0.12
800	9.04	3.79	1.64	5.82	1.30	0.56	4.14	0.57	0.24	3.43	0.36	0.16
900	10.17	4.71	2.04	6.55	1.61	0.70	4.65	0.70	0.30	3.86	0.45	0.19
1000	11.30	5.73	2.48	7.27	1.96	0.85	5.17	0.86	0.37	4.29	0.54	0.23
1200	13.56	8.03	3.48	8.73	2.75	1.19	6.20	1.20	0.52	5.15	0.76	0.33
1400				10.18	3.66	1.58	7.24	1.59	0.69	6.00	1.01	0.44
1600				11.64	4.69	2.03	8.27	2.04	0.88	6.86	1.30	0.56
1800				13.09	5.83	2.52	9.31	2.54	1.10	7.72	1.61	0.70
2000							10.34	3.09	1.34	8.58	1.96	0.85
2400							12.41	4.33	1.87	10.29	2.75	1.19
2600							13.44	5.02	2.17	11.15	3.18	1.38
2800							14.48	5.76	2.49	12.01	3.65	1.58

Table 7 IPS SDR 7 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	16"			18"			20"			22"		
300	0.99	0.03	0.01									
400	1.31	0.05	0.02	1.04	0.03	0.01						
500	1.64	0.08	0.03	1.30	0.04	0.02	1.05	0.03	0.01			
600	1.97	0.11	0.05	1.56	0.06	0.03	1.26	0.04	0.02	1.04	0.02	0.01
700	2.30	0.15	0.06	1.82	0.08	0.04	1.47	0.05	0.02	1.22	0.03	0.01
800	2.63	0.19	0.08	2.08	0.11	0.05	1.68	0.06	0.03	1.39	0.04	0.02
900	2.96	0.23	0.10	2.33	0.13	0.06	1.89	0.08	0.03	1.56	0.05	0.02
1000	3.28	0.28	0.12	2.59	0.16	0.07	2.10	0.10	0.04	1.74	0.06	0.03
1200	3.94	0.40	0.17	3.11	0.22	0.10	2.52	0.13	0.06	2.08	0.08	0.04
1400	4.60	0.53	0.23	3.63	0.30	0.13	2.94	0.18	0.08	2.43	0.11	0.05
1600	5.25	0.68	0.29	4.15	0.38	0.17	3.36	0.23	0.10	2.78	0.14	0.06
1800	5.91	0.84	0.36	4.67	0.47	0.21	3.78	0.28	0.12	3.13	0.18	0.08
2000	6.57	1.02	0.44	5.19	0.58	0.25	4.20	0.35	0.15	3.47	0.22	0.09
2400	7.88	1.43	0.62	6.23	0.81	0.35	5.04	0.48	0.21	4.17	0.30	0.13
2800	9.19	1.91	0.83	7.26	1.08	0.47	5.88	0.64	0.28	4.86	0.41	0.18
3200	10.51	2.44	1.06	8.30	1.38	0.60	6.72	0.82	0.36	5.56	0.52	0.22
3500	11.49	2.88	1.25	9.08	1.63	0.70	7.36	0.97	0.42	6.08	0.61	0.27
4000	13.14	3.69	1.60	10.38	2.08	0.90	8.41	1.25	0.54	6.95	0.78	0.34
5000				12.97	3.15	1.36	10.51	1.89	0.82	8.68	1.19	0.51
5500				14.27	3.75	1.63	11.56	2.25	0.97	9.55	1.41	0.61
6000							12.61	2.64	1.14	10.42	1.66	0.72
7000										12.16	2.21	0.96
8000										13.90	2.83	1.23

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	24"			32"			36"		
700	1.02	0.02	0.01						
800	1.17	0.02	0.01						
900	1.31	0.02	0.01						
1000	1.46	0.03	0.01						
1200	1.75	0.04	0.02	0.72	0.01	0.00			
1400	2.04	0.06	0.02	0.83	0.01	0.00	0.66	0.00	0.00
1600	2.33	0.07	0.03	0.95	0.01	0.00	0.75	0.01	0.00
1800	2.63	0.09	0.04	1.07	0.01	0.01	0.85	0.01	0.00
2000	2.92	0.11	0.05	1.19	0.02	0.01	0.94	0.01	0.00
2400	3.50	0.15	0.07	1.43	0.02	0.01	1.13	0.01	0.01
2800	4.09	0.20	0.09	1.67	0.03	0.01	1.32	0.02	0.01
3200	4.67	0.26	0.11	1.91	0.04	0.02	1.51	0.02	0.01
3500	5.11	0.30	0.13	2.09	0.05	0.02	1.65	0.03	0.01
4000	5.84	0.39	0.17	2.38	0.06	0.03	1.88	0.03	0.01
5000	7.30	0.59	0.25	2.98	0.09	0.04	2.35	0.05	0.02
5500	8.03	0.70	0.30	3.28	0.10	0.05	2.59	0.06	0.03
6000	8.76	0.82	0.36	3.58	0.12	0.05	2.83	0.07	0.03
7000	10.22	1.09	0.47	4.17	0.16	0.07	3.30	0.09	0.04
8000	11.67	1.40	0.61	4.77	0.21	0.09	3.77	0.12	0.05
9000	13.13	1.74	0.75	5.36	0.26	0.11	4.24	0.15	0.06
10000				5.96	0.32	0.14	4.71	0.18	0.08
11000				6.56	0.38	0.16	5.18	0.21	0.09
12000				7.15	0.44	0.19	5.65	0.25	0.11
13000				7.75	0.52	0.22	6.12	0.29	0.13
14000				8.34	0.59	0.26	6.59	0.33	0.14
15000				8.94	0.67	0.29	7.06	0.38	0.16
17500				10.43	0.89	0.39	8.24	0.50	0.22
20000				11.92	1.15	0.50	9.42	0.65	0.28
22500				13.41	1.42	0.62	10.60	0.80	0.35
25000				14.90	1.73	0.75	11.77	0.98	0.42
27500							12.95	1.16	0.50
30000							14.13	1.37	0.59

Table 8 - Flow Rate vs. Friction Loss - IPS SDR 9

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		2"			3"			4"			6"	
10	1.24	0.38	0.17									
15	1.86	0.82	0.35	0.86	0.12	0.05						
20	2.48	1.39	0.60	1.14	0.21	0.09						
30	3.72	2.94	1.27	1.71	0.45	0.19	1.04	0.13	0.06			
40	4.96	5.01	2.17	2.28	0.76	0.33	1.38	0.22	0.10			
50	6.20	7.58	3.28	2.85	1.15	0.50	1.73	0.34	0.15	0.80	0.05	0.02
60	7.44	10.62	4.60	3.43	1.61	0.70	2.07	0.47	0.20	0.96	0.07	0.03
70	8.68	14.13	6.12	4.00	2.14	0.93	2.42	0.63	0.27	1.11	0.10	0.04
80	9.92	18.10	7.84	4.57	2.74	1.19	2.76	0.81	0.35	1.27	0.12	0.05
90	11.16	22.51	9.74	5.14	3.41	1.48	3.11	1.00	0.43	1.43	0.15	0.07
100				5.71	4.15	1.79	3.45	1.22	0.53	1.59	0.19	0.08
125				7.14	6.27	2.71	4.32	1.84	0.80	1.99	0.28	0.12
150				8.56	8.78	3.80	5.18	2.58	1.12	2.39	0.39	0.17
175				9.99	11.69	5.06	6.04	3.44	1.49	2.79	0.52	0.23
200				11.42	14.96	6.48	6.91	4.40	1.91	3.19	0.67	0.29
250							8.63	6.65	2.88	3.98	1.01	0.44
300							10.36	9.33	4.04	4.78	1.42	0.61
350							12.08	12.41	5.37	5.57	1.89	0.82
400										6.37	2.42	1.05
450										7.17	3.01	1.30
500										7.96	3.66	1.58
550										8.76	4.36	1.89
600										9.56	5.13	2.22
700										11.15	6.82	2.95

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		8"			10"			12"			14"	
100	0.94	0.05	0.02									
150	1.41	0.11	0.05	0.91	0.04	0.02						
200	1.88	0.19	0.08	1.21	0.06	0.03	0.86	0.03	0.01			
250	2.35	0.28	0.12	1.51	0.10	0.04	1.08	0.04	0.02	1.00	0.04	0.02
300	2.82	0.39	0.17	1.81	0.13	0.06	1.29	0.06	0.03	1.20	0.05	0.02
350	3.29	0.52	0.23	2.12	0.18	0.08	1.51	0.08	0.03	1.40	0.07	0.03
400	3.76	0.67	0.29	2.42	0.23	0.10	1.72	0.10	0.04	1.60	0.08	0.04
450	4.23	0.83	0.36	2.72	0.29	0.12	1.94	0.12	0.05	1.80	0.10	0.05
500	4.70	1.01	0.44	3.02	0.35	0.15	2.15	0.15	0.07	2.00	0.13	0.05
550	5.17	1.21	0.52	3.33	0.41	0.18	2.37	0.18	0.08	2.20	0.15	0.07
600	5.64	1.42	0.61	3.63	0.49	0.21	2.58	0.21	0.09	2.40	0.18	0.08
700	6.58	1.89	0.82	4.23	0.65	0.28	3.01	0.28	0.12	2.80	0.24	0.10
800	7.52	2.42	1.05	4.84	0.83	0.36	3.44	0.36	0.16	3.20	0.30	0.13
900	8.46	3.01	1.30	5.44	1.03	0.45	3.87	0.45	0.19	3.60	0.38	0.16
1000	9.40	3.66	1.58	6.05	1.25	0.54	4.30	0.55	0.24	4.00	0.46	0.20
1200	11.28	5.13	2.22	7.26	1.76	0.76	5.16	0.77	0.33	4.80	0.64	0.28
1400				8.47	2.33	1.01	6.02	1.02	0.44	5.60	0.85	0.37
1600				9.68	2.99	1.29	6.88	1.30	0.56	6.40	1.09	0.47
1800				10.89	3.72	1.61	7.74	1.62	0.70	7.20	1.36	0.59
2000				12.10	4.52	1.96	8.60	1.97	0.85	8.00	1.65	0.72
2400							10.32	2.77	1.20	9.60	2.32	1.00
2800							12.04	3.68	1.59	11.20	3.08	1.33

Table 8 IPS SDR 9 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		16"			18"			20"			22"	
300	0.82	0.02	0.01									
400	1.09	0.03	0.01	0.86	0.02	0.01						
500	1.37	0.05	0.02	1.08	0.03	0.01	0.87	0.02	0.01			
600	1.64	0.07	0.03	1.29	0.04	0.02	1.05	0.02	0.01	0.87	0.01	0.01
700	1.91	0.09	0.04	1.51	0.05	0.02	1.22	0.03	0.01	1.01	0.02	0.01
800	2.18	0.12	0.05	1.73	0.07	0.03	1.40	0.04	0.02	1.16	0.03	0.01
900	2.46	0.15	0.06	1.94	0.08	0.04	1.57	0.05	0.02	1.30	0.03	0.01
1000	2.73	0.18	0.08	2.16	0.10	0.04	1.75	0.06	0.03	1.44	0.04	0.02
1200	3.28	0.25	0.11	2.59	0.14	0.06	2.10	0.09	0.04	1.73	0.05	0.02
1400	3.82	0.34	0.15	3.02	0.19	0.08	2.45	0.11	0.05	2.02	0.07	0.03
1600	4.37	0.43	0.19	3.45	0.24	0.11	2.80	0.15	0.06	2.31	0.09	0.04
1800	4.92	0.54	0.23	3.88	0.30	0.13	3.15	0.18	0.08	2.60	0.11	0.05
2000	5.46	0.65	0.28	4.32	0.37	0.16	3.50	0.22	0.10	2.89	0.14	0.06
2400	6.55	0.92	0.40	5.18	0.52	0.22	4.19	0.31	0.13	3.47	0.19	0.08
2800	7.65	1.22	0.53	6.04	0.69	0.30	4.89	0.41	0.18	4.04	0.26	0.11
3200	8.74	1.56	0.68	6.91	0.88	0.38	5.59	0.53	0.23	4.62	0.33	0.14
3500	9.56	1.84	0.80	7.55	1.04	0.45	6.12	0.62	0.27	5.05	0.39	0.17
4000	10.92	2.36	1.02	8.63	1.33	0.58	6.99	0.80	0.34	5.78	0.50	0.22
5000				10.79	2.01	0.87	8.74	1.20	0.52	7.22	0.76	0.33
5500							9.61	1.44	0.62	7.94	0.90	0.39
6000							10.49	1.69	0.73	8.67	1.06	0.46
7000										10.11	1.41	0.61
8000										11.55	1.81	0.78

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		24"			26"			28"			30"	
700	0.85	0.01	0.01									
800	0.97	0.02	0.01	0.83	0.01	0.00						
900	1.09	0.02	0.01	0.93	0.01	0.01	0.80	0.01	0.00			
1000	1.21	0.03	0.01	1.03	0.02	0.01	0.89	0.01	0.01	0.78	0.01	0.00
1200	1.46	0.04	0.02	1.24	0.02	0.01	1.07	0.02	0.01	0.93	0.01	0.01
1400	1.70	0.05	0.02	1.45	0.03	0.01	1.25	0.02	0.01	1.09	0.02	0.01
1600	1.94	0.06	0.03	1.65	0.04	0.02	1.43	0.03	0.01	1.24	0.02	0.01
1800	2.18	0.07	0.03	1.86	0.05	0.02	1.61	0.04	0.02	1.40	0.03	0.01
2000	2.43	0.09	0.04	2.07	0.06	0.03	1.78	0.04	0.02	1.55	0.03	0.01
2400	2.91	0.13	0.06	2.48	0.09	0.04	2.14	0.06	0.03	1.86	0.04	0.02
2800	3.40	0.17	0.07	2.90	0.11	0.05	2.50	0.08	0.03	2.17	0.06	0.02
3200	3.88	0.22	0.09	3.31	0.15	0.06	2.85	0.10	0.04	2.49	0.07	0.03
3500	4.25	0.26	0.11	3.62	0.17	0.08	3.12	0.12	0.05	2.72	0.09	0.04
4000	4.86	0.33	0.14	4.14	0.22	0.10	3.57	0.15	0.07	3.11	0.11	0.05
5000	6.07	0.50	0.21	5.17	0.34	0.15	4.46	0.23	0.10	3.88	0.17	0.07
5500	6.68	0.59	0.26	5.69	0.40	0.17	4.90	0.28	0.12	4.27	0.20	0.09
6000	7.28	0.70	0.30	6.21	0.47	0.20	5.35	0.33	0.14	4.66	0.23	0.10
7000	8.50	0.92	0.40	7.24	0.63	0.27	6.24	0.44	0.19	5.44	0.31	0.14
8000	9.71	1.18	0.51	8.27	0.80	0.35	7.13	0.56	0.24	6.21	0.40	0.17
9000	10.92	1.47	0.64	9.31	1.00	0.43	8.03	0.70	0.30	6.99	0.50	0.22
10000	12.14	1.79	0.78	10.34	1.21	0.53	8.92	0.85	0.37	7.77	0.60	0.26
11000				11.38	1.45	0.63	9.81	1.01	0.44	8.54	0.72	0.31
12000							10.70	1.18	0.51	9.32	0.85	0.37
13000							11.59	1.37	0.59	10.10	0.98	0.43
14000										10.87	1.13	0.49

Table 9 - Flow Rate vs. Friction Loss - IPS SDR 11

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		2"			3"			4"			6"	
10	1.08	0.28	0.12									
15	1.62	0.59	0.25	0.75	0.09	0.04						
20	2.16	1.00	0.43	1.00	0.15	0.07						
30	3.25	2.11	0.91	1.49	0.32	0.14	0.90	0.09	0.04			
40	4.33	3.60	1.56	1.99	0.54	0.24	1.21	0.16	0.07			
50	5.41	5.44	2.36	2.49	0.82	0.36	1.51	0.24	0.11	0.70	0.04	0.02
60	6.49	7.63	3.30	2.99	1.15	0.50	1.81	0.34	0.15	0.83	0.05	0.02
70	7.58	10.14	4.39	3.49	1.54	0.66	2.11	0.45	0.20	0.97	0.07	0.03
80	8.66	12.99	5.62	3.98	1.97	0.85	2.41	0.58	0.25	1.11	0.09	0.04
90	9.74	16.16	6.99	4.48	2.45	1.06	2.71	0.72	0.31	1.25	0.11	0.05
100	10.82	19.64	8.50	4.98	2.97	1.29	3.01	0.88	0.38	1.39	0.13	0.06
125	13.53	29.69	12.85	6.23	4.50	1.95	3.77	1.32	0.57	1.74	0.20	0.09
150	16.23	41.62	18.02	7.47	6.30	2.73	4.52	1.86	0.80	2.09	0.28	0.12
175				8.72	8.38	3.63	5.27	2.47	1.07	2.43	0.38	0.16
200				9.96	10.73	4.65	6.03	3.16	1.37	2.78	0.48	0.21
250				12.45	16.23	7.03	7.53	4.78	2.07	3.48	0.73	0.32
300				14.94	22.75	9.85	9.04	6.70	2.90	4.17	1.02	0.44
350							10.55	8.91	3.86	4.87	1.36	0.59
400							12.05	11.41	4.94	5.56	1.74	0.75
450							13.56	14.20	6.15	6.26	2.16	0.94
500										6.95	2.63	1.14
550										7.65	3.13	1.36
600										8.34	3.68	1.59
700										9.73	4.90	2.12
800										11.12	6.27	2.72
900										12.51	7.80	3.38

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		8"			10"			12"			14"	
100	0.82	0.04	0.02									
150	1.23	0.08	0.03	0.79	0.03	0.01						
200	1.64	0.13	0.06	1.06	0.05	0.02	0.75	0.02	0.01			
250	2.05	0.20	0.09	1.32	0.07	0.03	0.94	0.03	0.01	0.78	0.02	0.01
300	2.46	0.28	0.12	1.58	0.10	0.04	1.13	0.04	0.02	0.93	0.03	0.01
350	2.87	0.38	0.16	1.85	0.13	0.06	1.31	0.06	0.02	1.09	0.04	0.02
400	3.28	0.48	0.21	2.11	0.16	0.07	1.50	0.07	0.03	1.25	0.05	0.02
450	3.69	0.60	0.26	2.38	0.21	0.09	1.69	0.09	0.04	1.40	0.06	0.02
500	4.10	0.73	0.32	2.64	0.25	0.11	1.88	0.11	0.05	1.56	0.07	0.03
550	4.51	0.87	0.38	2.90	0.30	0.13	2.06	0.13	0.06	1.71	0.08	0.04
600	4.92	1.02	0.44	3.17	0.35	0.15	2.25	0.15	0.07	1.87	0.10	0.04
700	5.74	1.36	0.59	3.70	0.46	0.20	2.63	0.20	0.09	2.18	0.13	0.06
800	6.56	1.74	0.75	4.22	0.60	0.26	3.00	0.26	0.11	2.49	0.16	0.07
900	7.38	2.16	0.94	4.75	0.74	0.32	3.38	0.32	0.14	2.80	0.20	0.09
1000	8.20	2.63	1.14	5.28	0.90	0.39	3.75	0.39	0.17	3.11	0.25	0.11
1200	9.84	3.68	1.60	6.34	1.26	0.55	4.51	0.55	0.24	3.74	0.35	0.15
1400	11.49	4.90	2.12	7.39	1.68	0.73	5.26	0.73	0.32	4.36	0.46	0.20
1600	13.13	6.28	2.72	8.45	2.15	0.93	6.01	0.94	0.41	4.98	0.59	0.26
1800				9.51	2.67	1.16	6.76	1.17	0.50	5.61	0.74	0.32
2000				10.56	3.25	1.41	7.51	1.42	0.61	6.23	0.90	0.39
2400				12.67	4.55	1.97	9.01	1.99	0.86	7.47	1.26	0.55
2800				14.79	6.06	2.62	10.51	2.64	1.14	8.72	1.68	0.73
3200							12.01	3.38	1.46	9.97	2.15	0.93
3500							13.14	3.99	1.73	10.90	2.53	1.10
4000										12.46	3.25	1.41
4500										14.01	4.04	1.75

Table 9 IPS SDR 11 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		16"			18"			20"			22"	
300	0.72	0.01	0.01									
400	0.95	0.02	0.01	0.75	0.01	0.01						
500	1.19	0.04	0.02	0.94	0.02	0.01	0.76	0.01	0.01			
600	1.43	0.05	0.02	1.13	0.03	0.01	0.92	0.02	0.01	0.76	0.01	0.00
700	1.67	0.07	0.03	1.32	0.04	0.02	1.07	0.02	0.01	0.88	0.01	0.01
800	1.91	0.09	0.04	1.51	0.05	0.02	1.22	0.03	0.01	1.01	0.02	0.01
900	2.15	0.11	0.05	1.70	0.06	0.03	1.37	0.04	0.02	1.13	0.02	0.01
1000	2.38	0.13	0.06	1.88	0.07	0.03	1.53	0.04	0.02	1.26	0.03	0.01
1200	2.86	0.18	0.08	2.26	0.10	0.04	1.83	0.06	0.03	1.51	0.04	0.02
1400	3.34	0.24	0.11	2.64	0.14	0.06	2.14	0.08	0.04	1.77	0.05	0.02
1600	3.81	0.31	0.13	3.01	0.18	0.08	2.44	0.10	0.05	2.02	0.07	0.03
1800	4.29	0.39	0.17	3.39	0.22	0.09	2.75	0.13	0.06	2.27	0.08	0.04
2000	4.77	0.47	0.20	3.77	0.26	0.11	3.05	0.16	0.07	2.52	0.10	0.04
2400	5.72	0.66	0.28	4.52	0.37	0.16	3.66	0.22	0.10	3.03	0.14	0.06
2800	6.68	0.88	0.38	5.27	0.49	0.21	4.27	0.30	0.13	3.53	0.19	0.08
3200	7.63	1.12	0.49	6.03	0.63	0.27	4.88	0.38	0.16	4.04	0.24	0.10
3500	8.35	1.32	0.57	6.59	0.75	0.32	5.34	0.45	0.19	4.41	0.28	0.12
4000	9.54	1.70	0.73	7.53	0.96	0.41	6.10	0.57	0.25	5.04	0.36	0.16
5000	11.92	2.56	1.11	9.42	1.44	0.63	7.63	0.86	0.37	6.30	0.54	0.24
5500	13.11	3.06	1.32	10.36	1.72	0.75	8.39	1.03	0.45	6.94	0.65	0.28
6000				11.30	2.02	0.88	9.15	1.21	0.52	7.57	0.76	0.33
7000				13.18	2.69	1.17	10.68	1.61	0.70	8.83	1.01	0.44
8000							12.21	2.07	0.89	10.09	1.30	0.56
9000							13.73	2.57	1.11	11.35	1.62	0.70
10000										12.61	1.96	0.85

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		24"			26"			28"			30"	
700	0.74	0.01	0.00									
800	0.85	0.01	0.01	0.72	0.01	0.00						
900	0.95	0.01	0.01	0.81	0.01	0.00	0.70	0.01	0.00			
1000	1.06	0.02	0.01	0.90	0.01	0.01	0.78	0.01	0.00	0.68	0.01	0.00
1200	1.27	0.03	0.01	1.08	0.02	0.01	0.93	0.01	0.01	0.81	0.01	0.00
1400	1.48	0.03	0.01	1.26	0.02	0.01	1.09	0.02	0.01	0.95	0.01	0.00
1600	1.70	0.04	0.02	1.44	0.03	0.01	1.25	0.02	0.01	1.08	0.01	0.01
1800	1.91	0.05	0.02	1.63	0.04	0.02	1.40	0.03	0.01	1.22	0.02	0.01
2000	2.12	0.07	0.03	1.81	0.04	0.02	1.56	0.03	0.01	1.36	0.02	0.01
2400	2.54	0.09	0.04	2.17	0.06	0.03	1.87	0.04	0.02	1.63	0.03	0.01
2800	2.97	0.12	0.05	2.53	0.08	0.04	2.18	0.06	0.02	1.90	0.04	0.02
3200	3.39	0.16	0.07	2.89	0.11	0.05	2.49	0.07	0.03	2.17	0.05	0.02
3500	3.71	0.18	0.08	3.16	0.12	0.05	2.72	0.09	0.04	2.37	0.06	0.03
4000	4.24	0.24	0.10	3.61	0.16	0.07	3.11	0.11	0.05	2.71	0.08	0.03
5000	5.30	0.36	0.15	4.51	0.24	0.10	3.89	0.17	0.07	3.39	0.12	0.05
5500	5.83	0.43	0.18	4.97	0.29	0.12	4.28	0.20	0.09	3.73	0.14	0.06
6000	6.36	0.50	0.22	5.42	0.34	0.15	4.67	0.24	0.10	4.07	0.17	0.07
7000	7.42	0.66	0.29	6.32	0.45	0.19	5.45	0.31	0.14	4.75	0.22	0.10
8000	8.48	0.85	0.37	7.22	0.58	0.25	6.23	0.40	0.17	5.42	0.29	0.12
9000	9.54	1.06	0.46	8.13	0.72	0.31	7.01	0.50	0.22	6.10	0.36	0.15
10000	10.60	1.29	0.56	9.03	0.87	0.38	7.78	0.61	0.26	6.78	0.43	0.19
11000	11.66	1.53	0.66	9.93	1.04	0.45	8.56	0.72	0.31	7.46	0.52	0.22
12000	12.72	1.80	0.78	10.83	1.22	0.53	9.34	0.85	0.37	8.14	0.61	0.26
13000				11.74	1.42	0.61	10.12	0.99	0.43	8.82	0.71	0.31
14000				12.64	1.63	0.70	10.90	1.13	0.49	9.49	0.81	0.35
15000							11.68	1.29	0.56	10.17	0.92	0.40
17500							13.62	1.71	0.74	11.87	1.22	0.53
20000										13.56	1.57	0.68

Table 9 IPS SDR 11 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP						
		32"			36"							
1200	0.72	0.01	0.00									
1400	0.83	0.01	0.00	0.66	0.00	0.00						
1600	0.95	0.01	0.00	0.75	0.01	0.00						
1800	1.07	0.01	0.01	0.85	0.01	0.00						
2000	1.19	0.02	0.01	0.94	0.01	0.00						
2400	1.43	0.02	0.01	1.13	0.01	0.01						
2800	1.67	0.03	0.01	1.32	0.02	0.01						
3200	1.91	0.04	0.02	1.51	0.02	0.01						
3500	2.09	0.05	0.02	1.65	0.03	0.01						
4000	2.38	0.06	0.03	1.88	0.03	0.01						
5000	2.98	0.09	0.04	2.35	0.05	0.02						
5500	3.28	0.10	0.05	2.59	0.06	0.03						
6000	3.58	0.12	0.05	2.83	0.07	0.03						
7000	4.17	0.16	0.07	3.30	0.09	0.04						
8000	4.77	0.21	0.09	3.77	0.12	0.05						
9000	5.36	0.26	0.11	4.24	0.15	0.06						
10000	5.96	0.32	0.14	4.71	0.18	0.08						
11000	6.56	0.38	0.16	5.18	0.21	0.09						
12000	7.15	0.44	0.19	5.65	0.25	0.11						
13000	7.75	0.52	0.22	6.12	0.29	0.13						
14000	8.34	0.59	0.26	6.59	0.33	0.14						
15000	8.94	0.67	0.29	7.06	0.38	0.16						
17500	10.43	0.89	0.39	8.24	0.50	0.22						
20000	11.92	1.15	0.50	9.42	0.65	0.28						
22500	13.41	1.42	0.62	10.60	0.80	0.35						
25000				11.77	0.98	0.42						
27500				12.95	1.16	0.50						

Table 10 - Flow Rate vs. Friction Loss - IPS SDR 17

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	2"			3"			4"			6"		
10	0.93	0.19	0.08									
15	1.40	0.41	0.18	0.64	0.06	0.03						
20	1.86	0.69	0.30	0.86	0.10	0.05						
30	2.79	1.46	0.63	1.29	0.22	0.10	0.78	0.07	0.03			
40	3.72	2.49	1.08	1.71	0.38	0.16	1.04	0.11	0.05			
50	4.65	3.77	1.63	2.14	0.57	0.25	1.30	0.17	0.07	0.60	0.03	0.01
60	5.59	5.29	2.29	2.57	0.80	0.35	1.56	0.24	0.10	0.72	0.04	0.02
70	6.52	7.03	3.04	3.00	1.06	0.46	1.81	0.31	0.14	0.84	0.05	0.02
80	7.45	9.01	3.90	3.43	1.36	0.59	2.07	0.40	0.17	0.96	0.06	0.03
90	8.38	11.20	4.85	3.86	1.70	0.73	2.33	0.50	0.22	1.08	0.08	0.03
100	9.31	13.61	5.89	4.28	2.06	0.89	2.59	0.61	0.26	1.20	0.09	0.04
125	11.64	20.58	8.91	5.36	3.12	1.35	3.24	0.92	0.40	1.49	0.14	0.06
150	13.96	28.85	12.49	6.43	4.37	1.89	3.89	1.29	0.56	1.79	0.20	0.08
175				7.50	5.81	2.52	4.54	1.71	0.74	2.09	0.26	0.11
200				8.57	7.44	3.22	5.18	2.19	0.95	2.39	0.33	0.14
250				10.71	11.25	4.87	6.48	3.31	1.43	2.99	0.50	0.22
300				12.85	15.77	6.83	7.78	4.64	2.01	3.59	0.71	0.31
350				15.00	20.98	9.08	9.07	6.18	2.67	4.19	0.94	0.41
400							10.37	7.91	3.43	4.78	1.20	0.52
450							11.66	9.84	4.26	5.38	1.50	0.65
500							12.96	11.96	5.18	5.98	1.82	0.79
550										6.58	2.17	0.94
600										7.18	2.55	1.11
700										8.37	3.40	1.47
800										9.57	4.35	1.88
900										10.76	5.41	2.34
1000										11.96	6.58	2.85

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	8"			10"			12"			14"		
100	0.71	0.03	0.01									
150	1.06	0.05	0.02	0.68	0.02	0.01						
200	1.41	0.09	0.04	0.91	0.03	0.01	0.65	0.01	0.01			
250	1.76	0.14	0.06	1.14	0.05	0.02	0.81	0.02	0.01	0.67	0.01	0.01
300	2.12	0.20	0.08	1.36	0.07	0.03	0.97	0.03	0.01	0.80	0.02	0.01
350	2.47	0.26	0.11	1.59	0.09	0.04	1.13	0.04	0.02	0.94	0.02	0.01
400	2.82	0.33	0.14	1.82	0.11	0.05	1.29	0.05	0.02	1.07	0.03	0.01
450	3.17	0.41	0.18	2.04	0.14	0.06	1.45	0.06	0.03	1.21	0.04	0.02
500	3.53	0.50	0.22	2.27	0.17	0.07	1.61	0.08	0.03	1.34	0.05	0.02
550	3.88	0.60	0.26	2.50	0.21	0.09	1.78	0.09	0.04	1.47	0.06	0.02
600	4.23	0.71	0.31	2.72	0.24	0.10	1.94	0.11	0.05	1.61	0.07	0.03
700	4.94	0.94	0.41	3.18	0.32	0.14	2.26	0.14	0.06	1.87	0.09	0.04
800	5.64	1.20	0.52	3.63	0.41	0.18	2.58	0.18	0.08	2.14	0.11	0.05
900	6.35	1.50	0.65	4.09	0.51	0.22	2.91	0.22	0.10	2.41	0.14	0.06
1000	7.05	1.82	0.79	4.54	0.62	0.27	3.23	0.27	0.12	2.68	0.17	0.07
1200	8.46	2.55	1.10	5.45	0.87	0.38	3.87	0.38	0.16	3.21	0.24	0.10
1400	9.87	3.39	1.47	6.36	1.16	0.50	4.52	0.51	0.22	3.75	0.32	0.14
1600	11.28	4.35	1.88	7.26	1.49	0.64	5.16	0.65	0.28	4.28	0.41	0.18
1800	12.70	5.41	2.34	8.17	1.85	0.80	5.81	0.81	0.35	4.82	0.51	0.22
2000	14.11	6.57	2.84	9.08	2.25	0.97	6.46	0.98	0.42	5.36	0.62	0.27
2400				10.90	3.15	1.37	7.75	1.38	0.60	6.43	0.87	0.38
2800				12.71	4.20	1.82	9.04	1.83	0.79	7.50	1.16	0.50
3200				14.53	5.37	2.33	10.33	2.34	1.01	8.57	1.49	0.64
3500				15.89	6.34	2.75	11.30	2.77	1.20	9.37	1.76	0.76
4000							12.91	3.54	1.53	10.71	2.25	0.97
4500							14.53	4.41	1.91	12.05	2.80	1.21
5000							16.14	5.36	2.32	13.39	3.40	1.47

+GF+

Table 10 IPS SDR 17 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		16"			18"			20"			22"	
300	0.61	0.01	0.00									
400	0.82	0.02	0.01	0.65	0.01	0.00						
500	1.02	0.02	0.01	0.81	0.01	0.01	0.66	0.01	0.00			
600	1.23	0.03	0.02	0.97	0.02	0.01	0.79	0.01	0.01	0.65	0.01	0.00
700	1.43	0.05	0.02	1.13	0.03	0.01	0.92	0.02	0.01	0.76	0.01	0.00
800	1.64	0.06	0.03	1.30	0.03	0.01	1.05	0.02	0.01	0.87	0.01	0.01
900	1.84	0.07	0.03	1.46	0.04	0.02	1.18	0.03	0.01	0.98	0.02	0.01
1000	2.05	0.09	0.04	1.62	0.05	0.02	1.31	0.03	0.01	1.08	0.02	0.01
1200	2.46	0.13	0.05	1.94	0.07	0.03	1.57	0.04	0.02	1.30	0.03	0.01
1400	2.87	0.17	0.07	2.27	0.09	0.04	1.84	0.06	0.02	1.52	0.04	0.02
1600	3.28	0.22	0.09	2.59	0.12	0.05	2.10	0.07	0.03	1.73	0.05	0.02
1800	3.69	0.27	0.12	2.92	0.15	0.07	2.36	0.09	0.04	1.95	0.06	0.02
2000	4.10	0.33	0.14	3.24	0.18	0.08	2.62	0.11	0.05	2.17	0.07	0.03
2400	4.92	0.46	0.20	3.89	0.26	0.11	3.15	0.15	0.07	2.60	0.10	0.04
2800	5.74	0.61	0.26	4.54	0.34	0.15	3.67	0.20	0.09	3.04	0.13	0.06
3200	6.56	0.78	0.34	5.18	0.44	0.19	4.20	0.26	0.11	3.47	0.16	0.07
3500	7.17	0.92	0.40	5.67	0.52	0.22	4.59	0.31	0.13	3.79	0.19	0.08
4000	8.20	1.17	0.51	6.48	0.66	0.29	5.25	0.40	0.17	4.34	0.25	0.11
5000	10.25	1.77	0.77	8.10	1.00	0.43	6.56	0.60	0.26	5.42	0.38	0.16
5500	11.27	2.12	0.92	8.91	1.19	0.52	7.21	0.71	0.31	5.96	0.45	0.19
6000	12.30	2.49	1.08	9.72	1.40	0.61	7.87	0.84	0.36	6.51	0.53	0.23
7000	14.35	3.31	1.43	11.34	1.87	0.81	9.18	1.12	0.48	7.59	0.70	0.30
8000				12.96	2.39	1.03	10.49	1.43	0.62	8.67	0.90	0.39
9000				14.58	2.97	1.29	11.81	1.78	0.77	9.76	1.12	0.48
10000							13.12	2.16	0.94	10.84	1.36	0.59
11000							14.43	2.58	1.12	11.93	1.62	0.70
12000							15.74	3.03	1.31	13.01	1.91	0.83

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		24"			26"			28"			30"	
700	0.64	0.01	0.00									
800	0.73	0.01	0.00	0.62	0.01	0.00						
900	0.82	0.01	0.00	0.70	0.01	0.00	0.60	0.00	0.00			
1000	0.91	0.01	0.01	0.78	0.01	0.00	0.67	0.01	0.00	0.58	0.00	0.00
1200	1.09	0.02	0.01	0.93	0.01	0.01	0.80	0.01	0.00	0.70	0.01	0.00
1400	1.28	0.02	0.01	1.09	0.02	0.01	0.94	0.01	0.00	0.82	0.01	0.00
1600	1.46	0.03	0.01	1.24	0.02	0.01	1.07	0.01	0.01	0.93	0.01	0.00
1800	1.64	0.04	0.02	1.40	0.03	0.01	1.20	0.02	0.01	1.05	0.01	0.01
2000	1.82	0.05	0.02	1.55	0.03	0.01	1.34	0.02	0.01	1.17	0.02	0.01
2400	2.19	0.06	0.03	1.86	0.04	0.02	1.61	0.03	0.01	1.40	0.02	0.01
2800	2.55	0.08	0.04	2.17	0.06	0.02	1.87	0.04	0.02	1.63	0.03	0.01
3200	2.92	0.11	0.05	2.48	0.07	0.03	2.14	0.05	0.02	1.87	0.04	0.02
3500	3.19	0.13	0.06	2.72	0.09	0.04	2.34	0.06	0.03	2.04	0.04	0.02
4000	3.64	0.16	0.07	3.10	0.11	0.05	2.68	0.08	0.03	2.33	0.06	0.02
5000	4.56	0.25	0.11	3.88	0.17	0.07	3.35	0.12	0.05	2.92	0.08	0.04
5500	5.01	0.29	0.13	4.27	0.20	0.09	3.68	0.14	0.06	3.21	0.10	0.04
6000	5.47	0.35	0.15	4.66	0.23	0.10	4.02	0.16	0.07	3.50	0.12	0.05
7000	6.38	0.46	0.20	5.43	0.31	0.13	4.69	0.22	0.09	4.08	0.16	0.07
8000	7.29	0.59	0.26	6.21	0.40	0.17	5.35	0.28	0.12	4.66	0.20	0.09
9000	8.20	0.73	0.32	6.99	0.50	0.21	6.02	0.35	0.15	5.25	0.25	0.11
10000	9.11	0.89	0.39	7.76	0.60	0.26	6.69	0.42	0.18	5.83	0.30	0.13
11000	10.02	1.06	0.46	8.54	0.72	0.31	7.36	0.50	0.22	6.41	0.36	0.16
12000	10.93	1.25	0.54	9.31	0.85	0.37	8.03	0.59	0.26	7.00	0.42	0.18
13000	11.84	1.45	0.63	10.09	0.98	0.42	8.70	0.68	0.30	7.58	0.49	0.21
14000	12.76	1.66	0.72	10.87	1.13	0.49	9.37	0.78	0.34	8.16	0.56	0.24
15000				11.64	1.28	0.55	10.04	0.89	0.39	8.75	0.64	0.28
17500				13.58	1.70	0.74	11.71	1.19	0.51	10.20	0.85	0.37
20000				15.52	2.18	0.94	13.39	1.52	0.66	11.66	1.09	0.47
22500							15.06	1.89	0.82	13.12	1.35	0.58
25000										14.58	1.64	0.71

Table 10 IPS SDR 17 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	32"			36"			42"		
1200	0.61	0.00	0.00				0.36	0.00	0.00
1400	0.72	0.01	0.00	0.57	0.00	0.00	0.42	0.01	0.00
1600	0.82	0.01	0.00	0.65	0.00	0.00	0.48	0.01	0.00
1800	0.92	0.01	0.00	0.73	0.01	0.00	0.54	0.01	0.00
2000	1.02	0.01	0.00	0.81	0.01	0.00	0.60	0.01	0.00
2400	1.23	0.02	0.01	0.97	0.01	0.00	0.73	0.02	0.01
2800	1.43	0.02	0.01	1.13	0.01	0.01	0.85	0.02	0.01
3200	1.64	0.03	0.01	1.30	0.02	0.01	0.97	0.03	0.01
3500	1.79	0.03	0.01	1.42	0.02	0.01	1.06	0.03	0.01
4000	2.05	0.04	0.02	1.62	0.02	0.01	1.21	0.04	0.02
5000	2.56	0.06	0.03	2.02	0.03	0.01	1.51	0.06	0.03
5500	2.82	0.07	0.03	2.23	0.04	0.02	1.66	0.07	0.03
6000	3.07	0.09	0.04	2.43	0.05	0.02	1.81	0.09	0.04
7000	3.59	0.11	0.05	2.83	0.06	0.03	2.12	0.11	0.05
8000	4.10	0.15	0.06	3.24	0.08	0.04	2.42	0.15	0.06
9000	4.61	0.18	0.08	3.64	0.10	0.04	2.72	0.18	0.08
10000	5.12	0.22	0.10	4.05	0.12	0.05	3.02	0.22	0.10
11000	5.64	0.26	0.11	4.45	0.15	0.06	3.33	0.26	0.11
12000	6.15	0.31	0.13	4.86	0.17	0.08	3.63	0.31	0.13
13000	6.66	0.36	0.15	5.26	0.20	0.09	3.93	0.36	0.15
14000	7.17	0.41	0.18	5.67	0.23	0.10	4.23	0.41	0.18
15000	7.69	0.47	0.20	6.07	0.26	0.11	4.53	0.47	0.20
17500	8.97	0.62	0.27	7.09	0.35	0.15	5.29	0.62	0.27
20000	10.25	0.79	0.34	8.10	0.45	0.19	6.05	0.79	0.34
22500	11.53	0.99	0.43	9.11	0.56	0.24	6.80	0.99	0.43
25000	12.81	1.20	0.52	10.12	0.68	0.29	7.56	1.20	0.52
27500	14.09	1.43	0.62	11.14	0.81	0.35	8.31	1.43	0.62
30000				12.15	0.95	0.41	9.07	1.68	0.73
32500				13.16	1.10	0.48	9.83	1.95	0.84
35000							10.58147422	2.24	0.97
37500							11.33729381	2.54	1.10
40000							12.09311339	2.86	1.24
42500							12.84893298	3.20	1.39

+GF+

Table 11 - Flow Rate vs. Friction Loss - DIPS DR 11

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
		4"			6"	
30	0.82	0.07	0.03			
40	1.09	0.13	0.05			
50	1.36	0.19	0.08	0.66	0.03	0.01
60	1.63	0.26	0.11	0.79	0.05	0.02
70	1.90	0.35	0.15	0.92	0.06	0.03
80	2.18	0.45	0.20	1.05	0.08	0.03
90	2.45	0.56	0.24	1.18	0.10	0.04
100	2.72	0.68	0.30	1.32	0.12	0.05
125	3.40	1.03	0.45	1.65	0.18	0.08
150	4.08	1.45	0.63	1.97	0.25	0.11
175	4.76	1.92	0.83	2.30	0.33	0.14
200	5.44	2.46	1.07	2.63	0.42	0.18
250	6.80	3.72	1.61	3.29	0.64	0.28
300	8.16	5.22	2.26	3.95	0.89	0.39
350	9.52	6.94	3.01	4.61	1.19	0.51
400	10.88	8.89	3.85	5.27	1.52	0.66
450	12.24	11.06	4.79	5.92	1.89	0.82
500	13.60	13.44	5.82	6.58	2.30	1.00
550				7.24	2.74	1.19
600				7.90	3.22	1.40
700				9.21	4.29	1.86
800				10.53	5.49	2.38
900				11.85	6.83	2.96
1000				13.16	8.31	3.60

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
		8"			10"	
100	0.77	0.03	0.01			
150	1.15	0.07	0.03	0.76	0.02	0.01
200	1.53	0.11	0.05	1.02	0.04	0.02
250	1.91	0.17	0.07	1.27	0.06	0.03
300	2.30	0.24	0.10	1.53	0.09	0.04
350	2.68	0.32	0.14	1.78	0.12	0.05
400	3.06	0.41	0.18	2.04	0.15	0.07
450	3.45	0.51	0.22	2.29	0.19	0.08
500	3.83	0.62	0.27	2.54	0.23	0.10
550	4.21	0.73	0.32	2.80	0.27	0.12
600	4.59	0.86	0.37	3.05	0.32	0.14
700	5.36	1.15	0.50	3.56	0.42	0.18
800	6.12	1.47	0.64	4.07	0.54	0.24
900	6.89	1.83	0.79	4.58	0.68	0.29
1000	7.66	2.22	0.96	5.09	0.82	0.36
1200	9.19	3.11	1.35	6.11	1.15	0.50
1400	10.72	4.14	1.79	7.12	1.53	0.66
1600	12.25	5.31	2.30	8.14	1.96	0.85
1800	13.78	6.60	2.86	9.16	2.44	1.06
2000				10.18	2.97	1.28
2400				12.21	4.16	1.80
2800				14.25	5.54	2.40

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
		12"			14"	
200	0.72	0.02	0.01			
250	0.90	0.03	0.01	0.67	0.01	0.01
300	1.08	0.04	0.02	0.80	0.02	0.01
350	1.26	0.05	0.02	0.94	0.02	0.01
400	1.44	0.06	0.03	1.07	0.03	0.01
450	1.62	0.08	0.03	1.21	0.04	0.02
500	1.80	0.10	0.04	1.34	0.05	0.02
550	1.98	0.12	0.05	1.47	0.06	0.02
600	2.16	0.14	0.06	1.61	0.07	0.03
700	2.52	0.18	0.08	1.87	0.09	0.04
800	2.88	0.23	0.10	2.14	0.11	0.05
900	3.24	0.29	0.13	2.41	0.14	0.06
1000	3.60	0.35	0.15	2.68	0.17	0.07
1200	4.32	0.50	0.21	3.21	0.24	0.10
1400	5.04	0.66	0.29	3.75	0.32	0.14
1600	5.76	0.85	0.37	4.29	0.41	0.18
1800	6.48	1.05	0.46	4.82	0.51	0.22
2000	7.20	1.28	0.55	5.36	0.62	0.27
2400	8.64	1.79	0.78	6.43	0.87	0.38
2800	10.07	2.38	1.03	7.50	1.16	0.50
3200	11.51	3.05	1.32	8.57	1.49	0.64
3500	12.59	3.60	1.56	9.37	1.76	0.76
4000				10.71	2.25	0.97
4500				12.05	2.80	1.21
5000				13.39	3.40	1.47

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
		16"			18"	
300	0.62	0.01	0.00			
400	0.83	0.02	0.01	0.66	0.01	0.00
500	1.04	0.03	0.01	0.82	0.01	0.01
600	1.24	0.04	0.02	0.99	0.02	0.01
700	1.45	0.05	0.02	1.15	0.03	0.01
800	1.66	0.06	0.03	1.32	0.04	0.02
900	1.86	0.08	0.03	1.48	0.04	0.02
1000	2.07	0.09	0.04	1.65	0.05	0.02
1200	2.49	0.13	0.06	1.98	0.07	0.03
1400	2.90	0.17	0.07	2.31	0.10	0.04
1600	3.31	0.22	0.10	2.64	0.13	0.05
1800	3.73	0.27	0.12	2.97	0.16	0.07
2000	4.14	0.33	0.14	3.30	0.19	0.08
2400	4.97	0.47	0.20	3.96	0.27	0.12
2800	5.80	0.62	0.27	4.62	0.36	0.15
3200	6.63	0.80	0.34	5.28	0.46	0.20
3500	7.25	0.94	0.41	5.77	0.54	0.23
4000	8.28	1.20	0.52	6.60	0.69	0.30
5000	10.35	1.82	0.79	8.24	1.04	0.45
5500	11.39	2.17	0.94	9.07	1.25	0.54
6000	12.43	2.55	1.10	9.89	1.46	0.63
7000	14.50	3.39	1.47	11.54	1.95	0.84
8000				13.19	2.49	1.08
9000				14.84	3.10	1.34

Table 11 DIPS DR 11 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
	20"			24"		
500	0.67	0.01	0.00			
600	0.81	0.01	0.01			
700	0.94	0.02	0.01	0.66	0.01	0.00
800	1.08	0.02	0.01	0.75	0.01	0.00
900	1.21	0.03	0.01	0.85	0.01	0.00
1000	1.34	0.03	0.01	0.94	0.01	0.01
1200	1.61	0.05	0.02	1.13	0.02	0.01
1400	1.88	0.06	0.03	1.32	0.03	0.01
1600	2.15	0.08	0.03	1.51	0.03	0.01
1800	2.42	0.10	0.04	1.70	0.04	0.02
2000	2.69	0.12	0.05	1.88	0.05	0.02
2400	3.23	0.16	0.07	2.26	0.07	0.03
2800	3.76	0.22	0.09	2.64	0.09	0.04
3200	4.30	0.28	0.12	3.01	0.12	0.05
3500	4.70	0.33	0.14	3.30	0.14	0.06
4000	5.38	0.42	0.18	3.77	0.18	0.08
5000	6.72	0.64	0.27	4.71	0.27	0.12
5500	7.39	0.76	0.33	5.18	0.32	0.14
6000	8.06	0.89	0.39	5.65	0.37	0.16
7000	9.41	1.18	0.51	6.59	0.50	0.22
8000	10.75	1.52	0.66	7.53	0.64	0.28
9000	12.09	1.89	0.82	8.48	0.79	0.34
10000	13.44	2.29	0.99	9.42	0.97	0.42
11000				10.36	1.15	0.50
12000				11.30	1.35	0.59
13000				12.24	1.57	0.68
14000				13.18	1.80	0.78

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
	30"			36"		
1200	0.73	0.01	0.00			
1400	0.86	0.01	0.00			
1600	0.98	0.01	0.00			
1800	1.10	0.01	0.01			
2000	1.22	0.02	0.01	0.83	0.01	0.00
2400	1.47	0.02	0.01	1.00	0.01	0.00
2800	1.71	0.03	0.01	1.17	0.01	0.01
3200	1.96	0.04	0.02	1.33	0.02	0.01
3500	2.14	0.05	0.02	1.46	0.02	0.01
4000	2.45	0.06	0.03	1.66	0.02	0.01
5000	3.06	0.09	0.04	2.08	0.04	0.02
5500	3.37	0.11	0.05	2.29	0.04	0.02
6000	3.67	0.13	0.06	2.50	0.05	0.02
7000	4.29	0.17	0.08	2.91	0.07	0.03
8000	4.90	0.22	0.10	3.33	0.09	0.04
9000	5.51	0.28	0.12	3.75	0.11	0.05
10000	6.12	0.34	0.15	4.16	0.13	0.06
11000	6.73	0.40	0.17	4.58	0.16	0.07
12000	7.35	0.47	0.21	4.99	0.19	0.08
13000	7.96	0.55	0.24	5.41	0.22	0.09
14000	8.57	0.63	0.27	5.83	0.25	0.11
15000	9.18	0.72	0.31	6.24	0.28	0.12
17500	10.71	0.95	0.41	7.28	0.37	0.16
20000	12.24	1.22	0.53	8.32	0.48	0.21
22500	13.47	1.46	0.63	9.37	0.59	0.26
25000				10.41	0.72	0.31
27500				11.45	0.86	0.37
30000				12.49	1.01	0.44

Flow Rate (GPM)	V	ΔH	ΔP
	42"		
2800	0.75	0.01	0.01
3200	0.86	0.02	0.01
3500	0.94	0.02	0.01
4000	1.08	0.02	0.01
5000	1.35	0.04	0.02
5500	1.48	0.04	0.02
6000	1.62	0.05	0.02
7000	1.89	0.07	0.03
8000	2.15	0.09	0.04
9000	2.42	0.11	0.05
10000	2.69	0.13	0.06
11000	2.96	0.16	0.07
12000	3.23	0.19	0.08
13000	3.50	0.22	0.09
14000	3.77	0.25	0.11
15000	4.04	0.28	0.12
17500	4.71	0.37	0.16
20000	5.39	0.48	0.21
22500	6.06	0.59	0.26
25000	6.73	0.72	0.31
27500	7.41	0.86	0.37
30000	8.08	1.01	0.44
32500	8.75	1.18	0.51
35000	9.43	1.35	0.58
37500	10.10	1.53	0.66
40000	10.77	1.73	0.75
42500	11.44	1.93	0.84
45000	12.12	2.15	0.93
47500	12.79	2.37	1.03
50000	13.46	2.61	1.13

Table 12 - Flow Rate vs. Friction Loss - DIPS DR 17

Consult factory when flow rate exceeds 10 ft/sec

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP
		4"			6"	
30	0.69	0.05	0.02			
40	0.93	0.08	0.04			
50	1.16	0.13	0.06	0.56	0.02	0.01
60	1.39	0.18	0.08	0.67	0.03	0.01
70	1.62	0.24	0.10	0.78	0.04	0.02
80	1.85	0.30	0.13	0.90	0.05	0.02
90	2.08	0.38	0.16	1.01	0.06	0.03
100	2.31	0.46	0.20	1.12	0.08	0.03
125	2.89	0.70	0.30	1.40	0.12	0.05
150	3.47	0.98	0.42	1.68	0.17	0.07
175	4.05	1.30	0.56	1.96	0.22	0.10
200	4.63	1.66	0.72	2.24	0.28	0.12
250	5.78	2.51	1.09	2.80	0.43	0.19
300	6.94	3.52	1.53	3.36	0.60	0.26
350	8.10	4.69	2.03	3.92	0.80	0.35
400	9.26	6.00	2.60	4.48	1.03	0.44
450	10.41	7.46	3.23	5.04	1.28	0.55
500	11.57	9.07	3.93	5.60	1.55	0.67
550	12.73	10.82	4.69	6.16	1.85	0.80
600	13.88	12.72	5.51	6.72	2.18	0.94
700				7.84	2.90	1.25
800				8.96	3.71	1.61
900				10.08	4.61	2.00
1000				11.20	5.61	2.43
1100				12.32	6.69	2.90
1200				13.44	7.86	3.40

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
		8"			10"			12"			14"	
100	0.77	0.02	0.01									
150	0.98	0.04	0.02	0.64	0.02	0.01						
200	1.30	0.08	0.03	0.86	0.03	0.01	0.61	0.01	0.01			
250	1.63	0.11	0.05	1.07	0.04	0.02	0.76	0.02	0.01	0.57	0.01	0.00
300	1.95	0.16	0.07	1.29	0.06	0.03	0.92	0.03	0.01	0.68	0.01	0.01
350	2.28	0.21	0.09	1.50	0.08	0.03	1.07	0.03	0.01	0.80	0.02	0.01
400	2.60	0.27	0.12	1.72	0.10	0.04	1.22	0.04	0.02	0.91	0.02	0.01
450	2.93	0.34	0.15	1.93	0.12	0.05	1.38	0.05	0.02	1.03	0.03	0.01
500	3.26	0.41	0.18	2.14	0.15	0.07	1.53	0.07	0.03	1.14	0.03	0.01
550	3.58	0.49	0.21	2.36	0.18	0.08	1.68	0.08	0.03	1.25	0.04	0.02
600	3.91	0.58	0.25	2.57	0.21	0.09	1.84	0.09	0.04	1.37	0.05	0.02
700	4.56	0.77	0.33	3.00	0.28	0.12	2.14	0.12	0.05	1.59	0.06	0.03
800	5.21	0.99	0.43	3.43	0.36	0.16	2.45	0.16	0.07	1.82	0.08	0.03
900	5.86	1.23	0.53	3.86	0.45	0.19	2.75	0.20	0.09	2.05	0.10	0.04
1000	6.51	1.50	0.65	4.29	0.54	0.23	3.06	0.24	0.10	2.28	0.12	0.05
1200	7.81	2.10	0.91	5.15	0.76	0.33	3.67	0.33	0.14	2.73	0.16	0.07
1400	9.11	2.79	1.21	6.00	1.01	0.44	4.28	0.45	0.19	3.19	0.22	0.09
1600	10.42	3.58	1.55	6.86	1.30	0.56	4.90	0.57	0.25	3.64	0.28	0.12
1800	11.72	4.45	1.93	7.72	1.61	0.70	5.51	0.71	0.31	4.10	0.35	0.15
2000	13.02	5.41	2.34	8.58	1.96	0.85	6.12	0.86	0.37	4.56	0.42	0.18
2400	15.62	7.58	3.28	10.29	2.74	1.19	7.34	1.21	0.52	5.47	0.59	0.26
2800				12.01	3.65	1.58	8.57	1.61	0.70	6.38	0.78	0.34
3200				13.72	4.68	2.02	9.79	2.06	0.89	7.29	1.00	0.43
3500				15.01	5.52	2.39	10.71	2.43	1.05	7.97	1.18	0.51
4000							12.24	3.11	1.35	9.11	1.52	0.66
4500							13.77	3.87	1.67	10.25	1.89	0.82
5000										11.39	2.29	0.99
5500										12.53	2.74	1.18

Table 12 DIPS DR 17 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	16"			18"			20"			24"		
300	0.53	0.01	0.00									
400	0.70	0.01	0.00	0.56	0.01	0.00						
500	0.88	0.02	0.01	0.70	0.01	0.00	0.57	0.01	0.00			
600	1.06	0.02	0.01	0.84	0.01	0.01	0.69	0.01	0.00			
700	1.23	0.03	0.01	0.98	0.02	0.01	0.80	0.01	0.00	0.56	0.00	0.00
800	1.41	0.04	0.02	1.12	0.02	0.01	0.91	0.01	0.01	0.64	0.01	0.00
900	1.59	0.05	0.02	1.26	0.03	0.01	1.03	0.02	0.01	0.72	0.01	0.00
1000	1.76	0.06	0.03	1.40	0.04	0.02	1.14	0.02	0.01	0.80	0.01	0.00
1200	2.11	0.09	0.04	1.68	0.05	0.02	1.37	0.03	0.01	0.96	0.01	0.01
1400	2.47	0.12	0.05	1.96	0.07	0.03	1.60	0.04	0.02	1.12	0.02	0.01
1600	2.82	0.15	0.06	2.24	0.09	0.04	1.83	0.05	0.02	1.28	0.02	0.01
1800	3.17	0.18	0.08	2.52	0.11	0.05	2.06	0.06	0.03	1.44	0.03	0.01
2000	3.52	0.22	0.10	2.80	0.13	0.06	2.29	0.08	0.03	1.60	0.03	0.01
2400	4.23	0.32	0.14	3.37	0.18	0.08	2.74	0.11	0.05	1.92	0.05	0.02
2800	4.93	0.42	0.18	3.93	0.24	0.10	3.20	0.15	0.06	2.24	0.06	0.03
3200	5.64	0.54	0.23	4.49	0.31	0.13	3.66	0.19	0.08	2.56	0.08	0.03
3500	6.17	0.63	0.27	4.91	0.36	0.16	4.00	0.22	0.10	2.80	0.09	0.04
4000	7.05	0.81	0.35	5.61	0.47	0.20	4.57	0.28	0.12	3.20	0.12	0.05
5000	8.81	1.23	0.53	7.01	0.70	0.31	5.72	0.43	0.19	4.01	0.18	0.08
5500	9.69	1.46	0.63	7.71	0.84	0.36	6.29	0.51	0.22	4.41	0.22	0.09
6000	10.57	1.72	0.74	8.41	0.99	0.43	6.86	0.60	0.26	4.81	0.25	0.11
7000	12.33	2.29	0.99	9.82	1.31	0.57	8.00	0.80	0.35	5.61	0.34	0.15
8000	14.09	2.93	1.27	11.22	1.68	0.73	9.15	1.02	0.44	6.41	0.43	0.19
9000				12.62	2.09	0.91	10.29	1.27	0.55	7.21	0.54	0.23
10000				14.02	2.54	1.10	11.43	1.55	0.67	8.01	0.65	0.28
11000							12.57	1.85	0.80	8.81	0.78	0.34
12000							13.72	2.17	0.94	9.61	0.91	0.40
13000										10.42	1.06	0.46
14000										11.22	1.22	0.53
15000										12.02	1.38	0.60

Table 12 DIPS DR 17 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP
	30"			36"			42"			48"		
1000	0.52	0.00	0.00									
1200	0.62	0.00	0.00									
1400	0.73	0.01	0.00									
1600	0.83	0.01	0.00									
1800	0.94	0.01	0.00									
2000	1.04	0.01	0.01	0.73	0.00	0.00	0.54	0.00	0.00			
2400	1.25	0.02	0.01	0.87	0.01	0.00	0.65	0.00	0.00			
2800	1.46	0.02	0.01	1.02	0.01	0.00	0.75	0.00	0.00	0.58	0.00	0.00
3200	1.67	0.03	0.01	1.16	0.01	0.01	0.86	0.01	0.00	0.66	0.00	0.00
3500	1.82	0.03	0.01	1.27	0.01	0.01	0.94	0.01	0.00	0.72	0.00	0.00
4000	2.08	0.04	0.02	1.45	0.02	0.01	1.08	0.01	0.00	0.83	0.00	0.00
5000	2.60	0.06	0.03	1.82	0.03	0.01	1.35	0.01	0.01	1.03	0.01	0.00
5500	2.86	0.08	0.03	2.00	0.03	0.01	1.48	0.02	0.01	1.14	0.01	0.00
6000	3.12	0.09	0.04	2.18	0.04	0.02	1.62	0.02	0.01	1.24	0.01	0.00
7000	3.64	0.12	0.05	2.54	0.05	0.02	1.89	0.02	0.01	1.45	0.01	0.01
8000	4.16	0.15	0.07	2.91	0.06	0.03	2.15	0.03	0.01	1.65	0.02	0.01
9000	4.69	0.19	0.08	3.27	0.08	0.03	2.42	0.04	0.02	1.86	0.02	0.01
10000	5.21	0.23	0.10	3.64	0.10	0.04	2.69	0.05	0.02	2.07	0.02	0.01
11000	5.73	0.27	0.12	4.00	0.11	0.05	2.96	0.05	0.02	2.27	0.03	0.01
12000	6.25	0.32	0.14	4.36	0.13	0.06	3.23	0.06	0.03	2.48	0.03	0.01
13000	6.77	0.37	0.16	4.73	0.15	0.07	3.50	0.07	0.03	2.69	0.04	0.02
14000	7.29	0.43	0.18	5.09	0.18	0.08	3.77	0.09	0.04	2.89	0.04	0.02
15000	7.81	0.48	0.21	5.45	0.20	0.09	4.04	0.10	0.04	3.10	0.05	0.02
17500	9.11	0.64	0.28	6.36	0.27	0.12	4.71	0.13	0.06	3.62	0.07	0.03
20000	10.41	0.82	0.36	7.27	0.34	0.15	5.39	0.17	0.07	4.13	0.09	0.04
22500	11.71	1.03	0.44	8.18	0.43	0.19	6.06	0.21	0.09	4.65	0.11	0.05
25000	13.01	1.25	0.54	9.09	0.52	0.23	6.73	0.25	0.11	5.17	0.13	0.06
27500				10.00	0.62	0.27	7.41	0.30	0.13	5.68	0.16	0.07
30000				10.91	0.73	0.32	8.08	0.35	0.15	6.20	0.18	0.08
32000				11.63	0.82	0.36	8.62	0.40	0.17	6.61	0.21	0.09
34000				12.36	0.92	0.40	9.16	0.44	0.19	7.03	0.23	0.10
36000				13.09	1.02	0.44	9.69	0.49	0.21	7.44	0.26	0.11
40000							10.77	0.60	0.26	8.27	0.31	0.14
42000							11.31	0.66	0.28	8.68	0.34	0.15
45000							12.12	0.74	0.32	9.30	0.39	0.17
48000							12.93	0.84	0.36	9.92	0.44	0.19
50000							13.47	0.90	0.39	10.33	0.48	0.21
55000										11.37	0.57	0.25
60000										12.40	0.67	0.29

Table 13 - Friction Loss Through Fittings - Equivalent Length of Pipe (ft.)

	Fitting or Valve Type						
Nominal Pipe Size (inch)	90° Elbow	45° Elbow	Tee Flow thru run	Tee Flow thru branch	Branch Wye (Fabricated)	Reducer	Butterfly Valve
2	6.98	3.67	3.49	10.475	6.98	2.60	6.98
2½	6.76	3.55	3.38	10.14	6.76	2.60	6.76
3	10.29	5.40	5.15	15.44	10.29	4.4	10.29
4	13.23	6.95	6.62	19.85	13.23	5.2	13.23
6	19.47	10.22	9.73	29.2	19.47	7	19.47
8	25.37	13.32	12.69	38.055	25.37	10	25.37
10	31.62	16.60	15.81	47.43	31.62	14.6	31.62
12	37.50	19.69	18.75	56.25	37.50	18.9	37.50
14	24.70	15.44	20.59	61.76	41.17	24.6	41.17
16	28.24	17.65	23.53	70.59	47.06	32	47.06
18	31.76	19.85	26.47	79.41	52.94	41.6	52.94
20	35.30	22.06	29.41	88.24	58.83	54.1	58.83
22	38.82	24.27	32.35	97.06	64.71	61	64.71
24	42.35	26.47	35.29	105.88	70.59	70	70.59
26	45.36	28.35	37.80	113.4	75.60	75	75.60
28	49.41	30.88	41.18	123.53	82.35	79	82.35
30	52.94	33.09	44.12	132.35	88.23	89	88.23
32	56.47	35.30	47.06	141.18	94.12	98	94.12
36	63.53	39.71	52.94	158.82	105.88	102	105.88
42	74.12	46.32	61.76	185.29	123.53	110	123.53

Gravity Drain Systems

Flow Rate for Gravity Drain Systems

Drainage flow is caused by gravity due to slope of all drainage piping. Drainage piping is deliberately designed to run only partially full; a full pipe, particularly a stack, could blow out or suck out all the trap seals in the system. For a given type of pipe (friction) the variables in drainage flow are slope and depth of liquid. When these two factors are known, the flow velocity V and flow rate Q can be calculated. The approximate flow rates and velocities can be calculated as follows:

Q - Flow Rate (gpm)
A - Section Area Pipe (ft2)
n - Manning Friction Factor 0.009

R - Hydraulic Radius of pipe ID (ft)/4
S - Hydraulic Gradient - Slope (in/ft)

$$Q = A \cdot \frac{1.486}{n} \cdot R^{2/3} \cdot S^{1/2}$$

$$V = \frac{1.486}{n} \cdot R^{2/3} \cdot \frac{S^{1/2}}{12}$$

Example Problem

System Information	Q - Flow Rate (gpm)	S - Hydraulic Gradient -
Material: 12" PE100 SDR 11	A - Section Area Pipe 0.4108 full = 0.2104 ½full (ft^2)	Slope 1/8 (in/ft) = 0.0104
Outer Diameter: 12.75 (in)	n - Manning Friction Factor 0.009	Slope 1/4 (in/ft) = 0.0208
Inside Diameter: 10.432 (in)	R - Hydraulic Radius of pipe 0.1833 (ft)	Slope 1/2 (in/ft) = 0.0416

$$Q = .2968 \cdot \frac{1.486}{0.009} \cdot (0.2174)^{2/3} \cdot (0.0208)^{1/2}$$

$$Q = 49.00 \cdot 0.362 \cdot 0.144$$

$$Q = 2.55\ (ft^3/sec)$$

$$Q = 1147\ (gpm)$$

$$V = \frac{1.486}{0.009} \cdot (0.2174)^{2/3} \cdot \frac{0.144}{12}$$

$$V = 165.1 \cdot 0.362 \cdot 0.012$$

$$V = 0.72\ (ft/sec)$$

Table 14 - Approximate Discharge Rates and Velocities in Sloping Drains Flowing Half-Full

Nominal Pipe Diameter (inch)	SDR 17					
	⅛ (in/ft) Slope		¼ (in/ft) Slope		½ (in/ft) Slope	
	Flow (GPM)	V (fps)	Flow (GPM)	V (fps)	Flow (GPM)	V (fps)
2	11.21	2.09	15.83	2.95	22.43	4.18
3	31.56	2.70	44.55	3.82	63.12	5.41
4	61.67	3.20	87.06	4.51	123.34	6.39
6	172.61	4.14	243.69	5.84	345.22	8.27
8	349.79	4.93	493.82	6.97	699.58	9.87
10	629.29	5.71	888.42	8.07	1,258.59	11.43
12	991.68	6.40	1,400.02	9.04	1,983.36	12.80
14	1,272.33	6.81	1,796.23	9.62	2,544.65	13.63
16	1,817.03	7.45	2,565.21	10.52	3,634.05	14.90
18	2,487.21	8.06	3,511.36	11.37	4,974.43	16.11
20	3,294.74	8.64	4,651.39	12.20	6,589.47	17.29
22	4,247.69	9.21	5,996.75	13.00	8,495.39	18.42
24	5,356.52	9.76	7,562.15	13.78	10,713.05	19.52
26	6,672.20	10.36	9,362.86	14.53	13,264.06	20.59
28	8,080.52	10.82	11,407.79	15.27	16,161.03	21.63
30	9,712.02	11.33	13,711.09	15.99	19,424.05	22.65
32	11,537.39	11.82	16,288.08	16.69	23,074.79	23.65
36	15,792.82	12.79	22,295.75	18.06	31,585.64	25.58
42	23,820.74	14.17	33,631.54	20.01	47,644.69	28.35

Surge Pressure (Water Hammer)

Surge Pressure (Water Hammer)

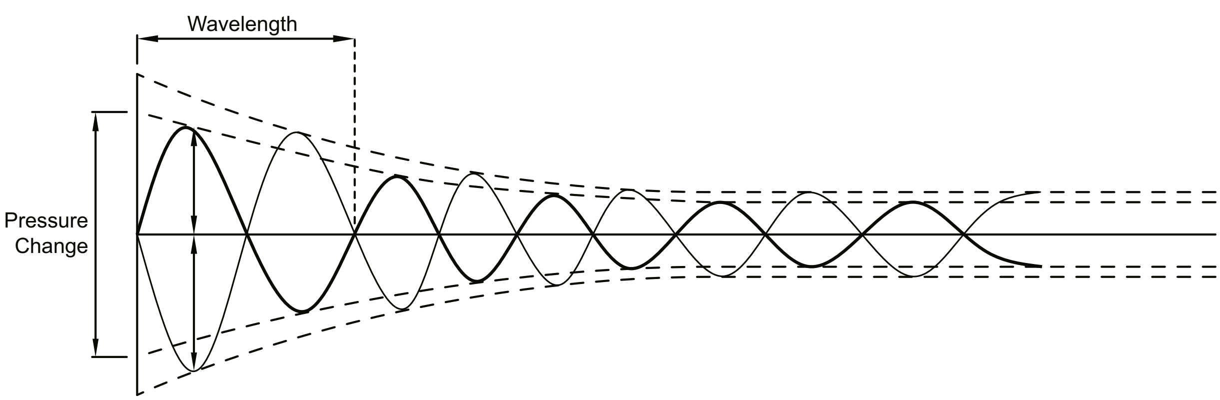
Surge pressure, or water hammer, is a term used to describe dynamic surges caused by pressure changes in a piping system. They occur whenever there is a deviation from the steady state, i.e.; when the velocity of the fluid is increased or decreased, and may be transient or oscillating. Waves of positive or negative pressure may be generated by any of the following:

- Opening or closing of a valve
- Pump startup or shutdown
- Change in pump or turbine speed
- Wave action in a feed tank
- Entrapped air

The pressure waves travel along at speeds limited by the speed of sound in the medium, causing the pipe to expand and contract. The energy carried by the wave is dissipated and the waves are progressively damped (see Figure 6).

The pressure excess to water hammer must be considered in addition to the hydrostatic load, and this total pressure must be sustainable by the piping system. In the case of oscillatory surge pressures, extreme caution is needed as surging at the harmonic frequency of the system could lead to catastrophic damage.

Figure 16 - Pressure Wave



The maximum positive or negative addition of pressure due to surging is a function of fluid velocity, fluid density, bulk fluid density and pipe dimensions of the piping system. It can be calculated using the following steps.

Step 1

Determine the velocity of the pressure wave in pipes.

V_w - Velocity of Pressure Wave (ft./sec)
K - Bulk Density of Water 3.19 x 10^5 (lb/in^2)
n_i - Conversion Factor 1/144 (ft^2/in^2)
δ - Fluid Density of Water 1.937 (slugs/ft^3)

$$V_w = \sqrt{\frac{K}{n_i \cdot \delta}}$$

Step 2

Critical time for valve closure.

t_c - Time for Valve Closure (sec)
V_w - Velocity of Pressure Wave (ft/sec)
L - Upstream Pipe Length (ft)

$$t_c = \frac{2L}{V_w}$$

+GF+

Step 3

Maximum pressure increase; assume valve closure time is less than the critical closure time and fluid velocity goes to 0.

$$P_i = \delta \cdot V \cdot V_w \, n_i$$

P_i - Maximum Total Pressure (lb/in^2)
δ - Fluid Density (slugs/ft^3)
V - Fluid Velocity (ft/sec)
V_w - Velocity of Pressure Wave
n_i - Conversion Factor 1/144 (ft^2/in^2)

Special Consideration

Calculate the Maximum Instantaneous System Pressure.

$$P_{max} = P_i + P_s$$

P_{max} - Maximum System Operating Pressure (lb/in^2)
P_i - Maximum Pressure Increase (lb/in^2)
P_s - Standard System Operating Pressure (lb/in^2)

Cautionary Note

Caution is recommended if P_{max} is greater than the maximum system design pressure multiplied by a design factor of 2x. Example: Pipe is rated at 200 psi. If P_{max} exceeds 400psi (200psi×2 safety factor), then precaution must be implemented in case of maximum pressure wave (i.e. water hammer) to prevent possible pipe failure.

Step 4

Determine the Maximum System Pressure Increase with Gradual Valve Closure

P_g - Gradual Pressure Increase with Valve Closure (lb/in^2)
L - Upstream Pipe Length (ft.)
V - Fluid Velocity (ft./sec)
n_i - Conversion Factor 1/144 (ft^2/in^2)
t_v - Time of Valve Closure (sec)

$$P_g = \frac{2 \cdot \delta \cdot L \cdot V \cdot n_i}{t_v}$$

Example Problem

A water pipeline from a storage tank is connected to a master valve, which is hydraulically actuated with an electrical remote control. The piping system flow rate is 300 (gal/min) with a velocity of 4 (ft./sec); thus requiring a 6" nominal pipeline. The operating pressure of the system will be 50 (lb/in^2), the valve will be 500 (ft.) from the storage tank and the valve closing time is 2.0 (sec). Determine the critical time of closure for the valve, and the internal system pressure should the valve be instantaneously or suddenly closed vs. gradually closing the valve (10 times slower).

System Information		Other Information	
Material:	6" (160mm) PE100 SDR 11	Bulk Water Density (K)	3.19 x 10^5 (lb/in^2)
Flow Rate:	300 (gal/min)	Fluid Density (δ)	1.937 (slugs/ft^3)
Pipeline Length:	500 (ft)	Valve Closing Time	2.0 (sec)
Operating Pressure:	50 (lb/in^2)	Water Velocity	4.6 (ft/sec)

Step 1 - Velocity of Pressure Wave

Determine the Velocity of the Pressure Wave

- V_w - Velocity of Pressure Wave (ft/sec)
- K - Bulk Density of Water 3.19 x 10^5 (lb/in^2)
- n_i - Conversion Factor 1/144 (ft^2/in^2)
- δ - Fluid Density 1.937 (slugs/ft^3)

$$V_w = \sqrt{\frac{K}{n_i \cdot \delta}} \qquad V_w = \sqrt{\frac{3.19 \times 10^5}{\frac{1}{144} \cdot 1.937}}$$

$$V_w = 4870 \text{ (ft/sec)}$$

Step 2 - Critical Valve Closure Time

Determine the Critical Closure Time

- t_c - Critical Closure Time (sec)
- V_w - Velocity of Pressure Wave 4870 (ft/sec)
- L - Upstream Pipe Length 500 (ft)

$$t_c = \frac{2L}{V_w} \qquad t_c = \frac{2 \cdot 500}{4870}$$

$$t_c = 0.2 \text{ (sec)}$$

Step 3 - Maximum Pressure Increase

Determine the Maximum Pressure Increase;

Assume: Valve Closure Time < Critical Closure Time t_c and Fluid Velocity goes to 0.

- P_i - Maximum Pressure Increase (lb/in^2)
- δ - Fluid Density 1.937 (slugs/ft^3)
- V - Fluid Velocity 4 (ft/sec)
- V_w - Velocity of Pressure Wave 4870 (ft/sec)
- n_i - Conversion Factor 1/144 (ft^2/in^2)

$$P_i = \delta \cdot V \cdot V_w n_i \qquad P_i = \frac{1.937 \cdot 4 \cdot 4870}{144}$$

$$P_i = 262 \text{ (lb/in}^2\text{)}$$

Consideration: Maximum Instantaneous System Pressure

Determining the Maximum Instantaneous System Pressure: Caution is recommended if P_{max} is greater than the Maximum System Operating Pressure multiplied by a 2x Service Factor.

P_{max} - Maximum Instantaneous Operating Pressure (lb/in^2)
P_i - Valve Pressure (instantaneous) (lb/in^2)
P_s - Standard System Operating Pressure (lb/in^2)

$$P_{max} = P_i + P_s \qquad P_{max} = 262 + 50$$

$$P_{max} = 312 \text{ (lb/in}^2\text{)}$$

In this case, 6" PE100 SDR11 pipe is rated at 200psi. Therefore, the system design is within safety limits. (Ref: ASTM C906)

Step 4 - Maximum Change in Pressure with Gradual Valve Closure

Determine the Maximum Change in System Pressure with Gradual Valve Closure (2 Second Close Time).

P_g - Maximum Gradual Pressure Change (lb/in^2)
t_v - Valve Closing Time 2 (sec)
L - Upstream Pipe Length 500 (ft)
V - Fluid Velocity 4 (ft/sec)
n_i - Conversion Factor 1/144 (ft^2/in^2)
δ - Fluid Density 1.937 (slugs/ft^3)

$$P_g = \frac{2 \cdot \delta \cdot L \cdot V \cdot n_i}{t_v}$$

$$P_g = \frac{2 \cdot 1.937 \cdot 500 \cdot 4 \cdot \frac{1}{144}}{2}$$

$$P_g = 26.9 \text{ (lb/in}^2\text{)}$$

Expansion/Contraction (Above Ground)

Allowing for Length Changes in PE Pipelines

All materials expand and/or contract. Variations in temperature cause greater length changes in thermoplastic materials than in metals. In the case of above ground, wall or duct mounted pipe work, particularly where subjected to varying working temperatures, it is necessary to make suitable provision for length changes in order to prevent additional stresses.

Calculation and Positioning of Flexible Sections

It is possible to take advantage of the very low modulus of elasticity (Figure 7) of PE by including special sections of pipe which compensate thermal length changes. The length of the flexible section mainly depends upon the pipe diameter and the extent of the length change to be compensated. In order to simplify planning and installation, the third influencing factor—the pipe wall temperature —is not taken into account, particularly as installation usually takes place in the temperature range between 37°F and 77°F.

Where the pipe work changes direction or branches off, there is always a natural flexible section.

There are two primary methods of controlling or compensating for thermal expansion of plastic piping systems: taking advantage of offsets and changes of direction in the piping and expansion loops.

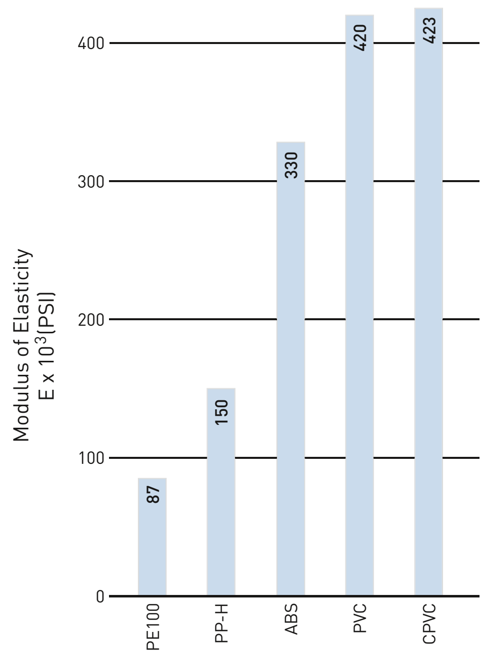


Figure 17 - Modulus of Elasticity of Plastics

Type 1 - Offsets/Changes in Direction

Most piping systems have occasional changes in directions which will allow the thermally included length changes to be taken up in offsets of the pipe beyond the bends. Where this method is employed, the pipe must be able to float except at anchor points.

Figure 18 - Changes in Direction

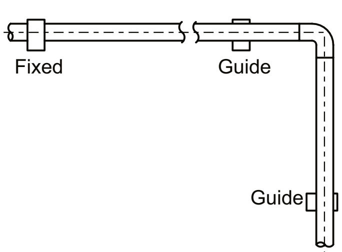
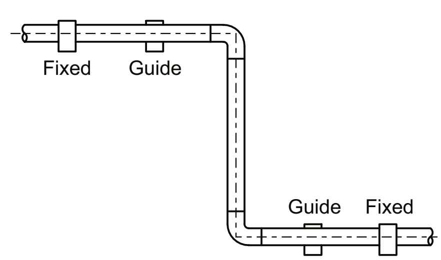


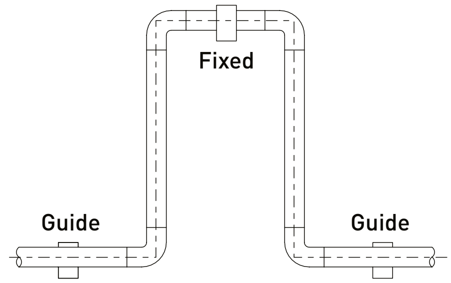
Figure 19 - Offsets



Type 2 -Expansion Loops

For expansion loops the flexible section is broken into two offsets close together. By utilizing the flexible members between the legs and 4 elbows the "a" length is slightly shorter than the "a" in the standalone offset.

Figure 20 - Expansion Loop



Determining the Length Change (ΔL) (Example 1)

In order to determine the length of flexible section (a) required, the extent of the length change must be ascertained first of all, by means of the following formula where

$\Delta L = L \cdot \Delta T \cdot \boldsymbol{\delta}$

(inch) = (inch) · (°F) · (inch/inch°F)

ΔL = Length change in inches

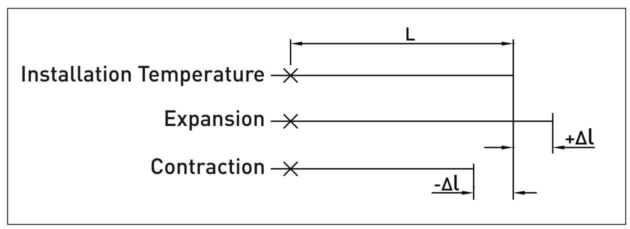
L = Length in inches of the pipe or pipe section where the length change is to be determined

ΔT = Difference between installation temperature and maximum or minimum working temperature in °F

$\boldsymbol{\delta}$ = Coefficient of linear expansion - 0.000110 in/in°F

Important:

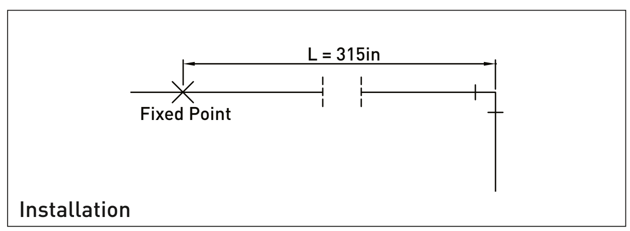
If the operating temperature is higher than the installation temperature, then the pipe becomes longer. If, on the other hand, the operating temperature is lower than the installation temperature, then the pipe contracts its length. The installation temperature must therefore be incorporated into the calculation, as well as the maximum and minimum operating temperatures.

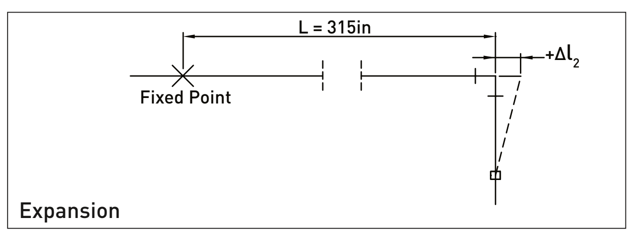


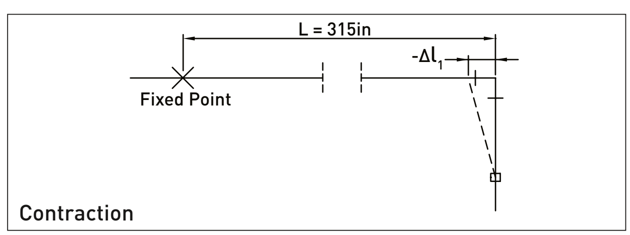
Problem

The procedure is explained using a coolant pipe as an example: Length of the pipe from the fixed point to the branch where:

- Length change is to be taken up: L = 315in
- Installation temperature: T_v = 73°F
- Temperature of the coolant: T_1= 40°F
- Temperature when defrosting and cleaning: T_2= 95°F
- Material: 12" PE100 SDR 11







Difference in Contraction Temperature

$\Delta T_1 = T_v - T_1 = 73°F - 40°F = 33°F$

Difference in Expansion Temperature

$\Delta T_2 = T_2 - T_v = 95°F - 73°F = 22°F$

Contraction during service with coolant

$-\Delta L_1 = L \cdot \Delta T_1 \cdot \delta = 315in \cdot 33 \cdot (0.000110) = 1.14in$

Expansion during defrosting and cleaning

$+\Delta L_2 = L \cdot \Delta T_2 \cdot \delta = 315in \cdot 22 \cdot (0.000110) = 0.76in$

Table 15 - Length Change of Straight Pipe (ΔL) in Inches

(relative to install temperature and operating temperatures)

Temperature Change in (°F)	Length of Pipe Section (ft) 5	10	15	20	25	30	35	40	45	50
5			0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
10		0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7
15	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3
25	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7
30	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
35	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1	2.3
40	0.3	0.5	0.8	1.1	1.3	1.6	1.8	2.1	2.4	2.6
45	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
50	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	3.3
55	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6
60	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
65	0.4	0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.9	4.3
70	0.5	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.2	4.6
80	0.5	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.8	5.3
90	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.3	5.9
100	0.7	1.3	2.0	2.6	3.3	4.0	4.6	5.3	5.9	6.6

Temperature Change in (°F)	Length of Pipe Section (ft) 55	60	65	70	75	80	85	90	95	100
5	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7
10	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.3
15	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
20	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6
25	1.8	2.0	2.1	2.3	2.5	2.6	2.8	3.0	3.1	3.3
30	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
35	2.5	2.8	3.0	3.2	3.5	3.7	3.9	4.2	4.4	4.6
40	2.9	3.2	3.4	3.7	4.0	4.2	4.5	4.8	5.0	5.3
45	3.3	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.6	5.9
50	3.6	4.0	4.3	4.6	5.0	5.3	5.6	5.9	6.3	6.6
55	4.0	4.4	4.7	5.1	5.4	5.8	6.2	6.5	6.9	7.3
60	4.4	4.8	5.1	5.5	5.9	6.3	6.7	7.1	7.5	7.9
65	4.7	5.1	5.6	6.0	6.4	6.9	7.3	7.7	8.2	8.6
70	5.1	5.5	6.0	6.5	6.9	7.4	7.9	8.3	8.8	9.2
80	5.8	6.3	6.9	7.4	7.9	8.4	9.0	9.5	10.0	10.6
90	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.7	11.3	11.9
100	7.3	7.9	8.6	9.2	9.9	10.6	11.2	11.9	12.5	13.2

Determining the Length of the Flexible Section (a) (Example 2)

The values required to determine the length of the flexible (a) section are: The maximum length change ΔL in comparison with the zero position during installation, (which can be either an expansion or a contraction), and the pipe diameter (d).

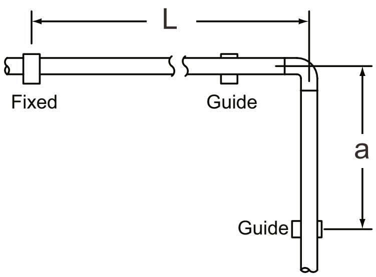
If values ΔL and (d) are known, Table 7 shows the length of flexible section (a) required.

Formula for Flexible Sections (a)

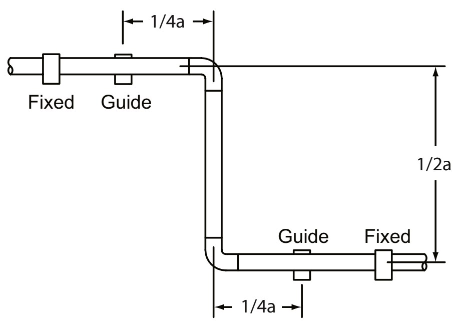
$$a = k\sqrt{\Delta L \cdot d}$$

a = Length of Flexible Section
k = Constant (k = 26)
ΔL = Change in Length
d = Outside Diameter of Pipe

Change of Direction



Offset



Expansion

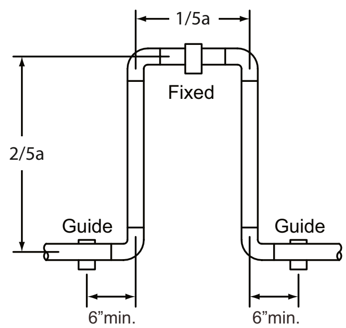


Table 16 - Length of Flexible Sections (a) in Inches

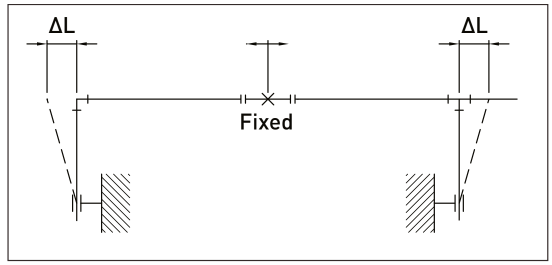
Length Change - ΔL (in)	Nominal Pipe Diameter											
	½" 20mm	¾" 25mm	1" 32mm	1¼" 40mm	1½" 50mm	2" 63mm	2½" 75mm	3" 90mm	4" 110mm	6" 160mm	8" 200mm	10" 250mm
0.1	7	8	9	10	12	13	14	15	17	21	23	26
0.2	10	12	13	15	16	18	20	22	24	29	33	36
0.3	13	14	16	18	20	22	24	27	30	36	40	45
0.4	15	16	18	21	23	26	28	31	34	41	46	52
0.5	16	18	21	23	26	29	32	35	38	46	52	58
0.6	18	20	23	25	28	32	35	38	42	51	57	63
0.7	19	22	24	27	31	34	37	41	45	55	61	68
0.8	21	23	26	29	33	37	40	44	48	58	65	73
0.9	22	24	28	31	35	39	42	46	51	62	69	77
1.0	23	26	29	33	36	41	45	49	54	65	73	82
2.0	33	36	41	46	52	58	63	69	77	92	103	115
3.0	40	45	51	56	63	71	77	85	94	113	126	141
4.0	46	52	58	65	73	82	89	98	108	131	146	163
5.0	52	58	65	73	82	92	100	109	121	146	163	182
6.0	56	63	71	80	89	100	109	120	133	160	179	200
7.0	61	68	77	86	97	108	118	129	143	173	193	216
8.0	65	73	83	92	103	116	126	138	153	185	206	231
9.0	69	77	88	98	109	123	134	147	162	196	219	245
10.0	73	82	92	103	115	129	141	155	171	206	231	258

Length Change - ΔL (in)	Nominal Pipe Diameter											
	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	36"
0.1	29	31	33	35	37	39	40	42	44	45	47	49
0.2	42	44	47	49	52	55	57	59	62	64	66	70
0.3	51	53	57	60	64	67	70	73	75	78	81	85
0.4	59	62	66	70	74	77	81	84	87	90	93	99
0.5	66	69	74	78	82	86	90	94	97	101	104	110
0.6	72	75	81	85	90	94	99	103	107	110	114	121
0.7	78	81	87	92	97	102	107	111	115	119	123	131
0.8	83	87	93	99	104	109	114	119	123	127	132	140
0.9	88	92	99	105	110	116	121	126	131	135	140	148
1.0	93	97	104	110	116	122	127	133	138	142	147	156
2.0	131	138	147	156	164	172	180	187	195	201	208	221
3.0	161	168	180	191	201	211	221	230	238	247	255	270
4.0	186	195	208	221	233	244	255	265	275	285	294	312
5.0	208	218	233	247	260	273	285	296	308			
6.0	227	238	255	270	285	299	312					
7.0	246	257	275	292	308							
8.0	263	275	294	312								
9.0	279	292	312									
10.0	294	308										

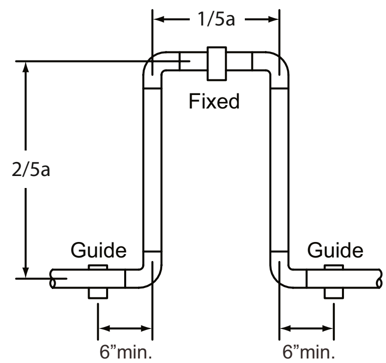
+GF+

Installation Hints

The length changes in pipe sections should be clearly controlled by the arrangement of fixed brackets. It is possible to distribute the length changes in pipe sections using proper positioning of fixed brackets (see adjoining examples).



If it is not possible to include a flexible section at a change of direction or branch, or if extensive length changes must be taken up in straight sections of pipe work, expansion loops may also be installed. In this case, the length change is distributed over two flexible sections.



Note:
To eliminate bilateral expansion thrust blocks are recommended at intersections.

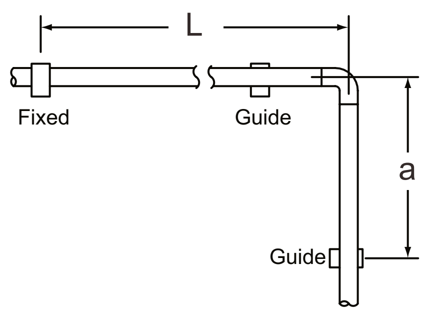
For a 2" expansion loop, (taking Example 2), the length change of 1.44in would require a flexible section length of a = 49.1in.

Pre-Stressing

In particularly difficult cases, where the length changes are large and acting in one direction only, it is also possible to pre-stress the flexible section during installation, in order to reduce the length of a. This procedure is illustrated in the following example:

Installation conditions

L = 315in.
d = 12in. (nominal)
Installation temperature: 73°F
Max. working temperature: 110°F
Material: PE



1 . Length change
$+\Delta L = L \cdot \Delta T \cdot \boldsymbol{\delta} = 315 \cdot 37 \cdot (0.000110) = 1.28$in.

2. Flexible section required to take up length change of ΔL = 1.28in according to Table 7:

a = approx. 105in.

3. If, on the other hand, the flexible section is pre-stressed to ΔL/2, the required length of flexible section is reduced to approx. 77in. The length change, starting from the zero position, then amounts to
±ΔL/2 = 1.28in/2 = 0.64in.

a = approx. 77in. (per Table 7)

In special cases, particularly at high working temperatures, pre-stressing of a flexible section improves the appearance of the pipeline in service, as the flexible section is less strongly deflected.

Installation

The Incorporation of Valves

Valves should be mounted as directly as possible; they should be formed as fixed points. The actuating force is thus transmitted directly, and not through the pipeline. The length changes, starting from the valve, are to be controlled as described previously.

Note:

- All Plastic Valves that include additional accessories, actuators or items that will increase load or stress on the piping system must be fully supported either independently or by mounting points located on the valve body.
- All metal valves must be supported. Should metal valves not be adequately supported, there is a significant risk of stress fatigue and possible system failure.
- For safe mounting of plastic valves, Georg Fischer valves are equipped with metal threaded inserts for direct mounted installation.

Vibration Dampeners

There are two principal ways to control stress caused by vibration. You can usually observe the stability of the system during initial operation and add restraints or supports as required to reduce effects of equipment vibration. Where necessary restraint fittings may be used to effectively hold pipe from lifting or moving laterally.

In special cases where the source of vibration is excessive (such as that resulting from pumps running unbalanced), an elastomeric expansion joint or other vibration absorber may be considered. This may be the case at pumps where restricting the source of vibration is not recommended.

Pipe Bracket Support Centers and Fixation of Plastic Pipelines

General Pipe Supports and Brackets

PE pipelines need to be supported at specific intervals, depending upon the material, the average pipe wall temperature, the specific gravity of the medium, and the diameter and wall thickness of the pipe. The determination of the pipe support centers has been based on the permissible amount of deflection of the pipe between two brackets. The pipe bracket centers given in Table 8 are calculated on the basis of a permissible deflection of max. 0.01 inch (0.25 cm) between two brackets.

Pipe Bracket Spacing in the Case of Fluids with Specific Gravity ≤ 1.0 (62.4 Lb/Ft^3)
Where fluids with a specific gravity exceeding 1g/cm^3 are to be conveyed, the pipe bracket centers given in Table 8 must be divided by the specific gravity of the solution.

Example: 20" pipe carrying media with a specific gravity of 1.6 = 13ft divided by 1.6 = approx. 8.1ft centers.

Installation of Closely Spaced Pipe Brackets
A continuous support may be more advantageous and economical than pipe brackets for small diameter horizontal pipe work, especially in a higher temperature range. Installation in a "V" or "U" shaped support made of metal or heat-resistant plastic material has proven satisfactory.

Pipe Bracket Requirements
When mounted, the inside diameter of the bracket must be greater than the outside diameter of the pipe, in order to allow length changes of the pipe at the specified points. The inside edges of the pipe bracket must be formed in such a way that no damage to the pipe surface is possible. George Fischer pipe brackets meet these requirements. They are made of plastic and may be used under rugged working conditions and also in areas where the pipe work is subjected to the external influence of aggressive atmospheres or media. Georg Fischer pipe brackets are suitable for PE, PVC, CPVC, PP and PVDF pipes.

Arrangement of Fixed Brackets
If the pipe bracket is positioned directly beside a fitting, the length change of the pipeline is limited to one direction only (one-sided fixed point).

If it is, as in most cases, necessary to control the length change of the pipeline in both directions, the pipe bracket must be positioned between two fittings. The pipe bracket must be robust and firmly mounted in order to take up the force arising from the length change in the pipeline. Hanger type brackets are not suitable as fixed points.

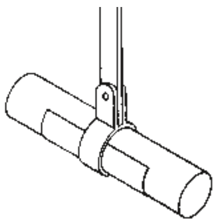
Hangers

There are many hangers and supports suitable for use in plastic piping systems, although some may require modification. It is important in a plastic piping system to provide a wide load-bearing surface and that any restraints recognize that plastic piping systems are somewhat notch sensitive. Also, if the thermal movement of a plastic piping system might cause the pipeline to abrade on a rough surface, such as concrete, some means of isolating the pipe should be considered. Wear pads of plastic can be fashioned from the pipe or wooden isolators can be used.

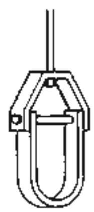
It is also important to recognize the thermal movement in any plastic piping system and the hangers and support structures should allow for, or direct, the expansion that may be in a particular system. Pipe hangers must be carefully aligned and must have no rough or sharp edges that could contact and potentially damage the pipe. The hanger or support system should recognize the thermal expansion in a plastic pipe system and pipe should be allowed to move.

Vertical lines must also be supported at intervals so that the fittings at the lower end of a riser or column are not overloaded. The supports should not exert a compressive strain on the pipe, such as riser–type clamps that squeeze the pipe. A double bolt type, in conjunction with using a fitting shoulder, may afford the best method for supporting vertical systems.

Figure 21 - Recommended Hangers for Plastic Piping Systems

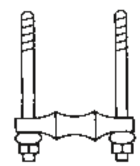


Band Hanger with Protective Sleeve

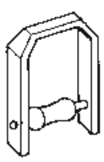


Clevis

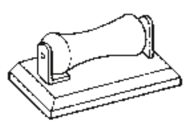
Adjustable Solid Ring Swivel Type



Single Pipe Roller



Roller Hanger



Pipe Roll and Plate

Pipe Sleeves

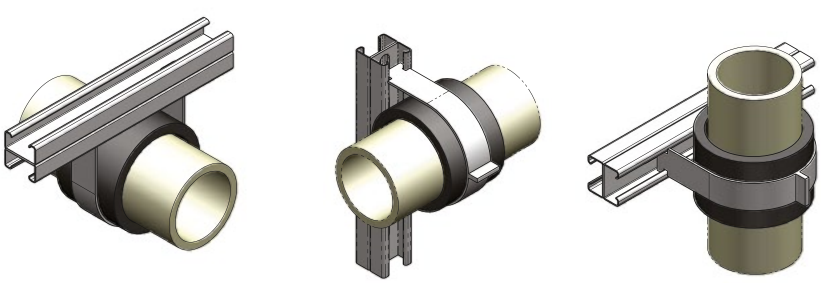


Figure 23 - Pipe Sleeves

Figure 22 - Typical Brackets and Anchor Arrangements

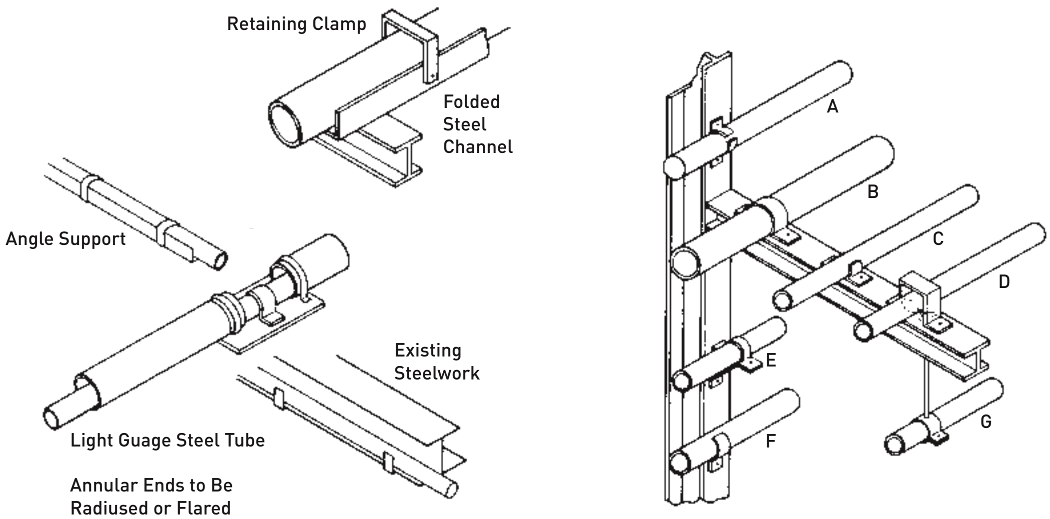


Table 17 - General Pipe Supports and Brackets for Liquids with a Specific Gravity ≤ 1.0 (62.4 lb/ft³)

Nom-inal Pipe Size (inch)	Pipe Bracket Intervals L (ft.) for pipes SDR7					Pipe Bracket Intervals L (ft.) for pipes SDR9					Pipe Bracket Intervals L (ft.) for pipes SDR11					Pipe Bracket Intervals L (ft.) for pipes SDR17				
	≤65 °F	85 °F	105 °F	125 °F	140 °F	≤65 °F	85 °F	105 °F	125 °F	140 °F	≤65 °F	85 °F	105 °F	125 °F	140 °F	≤65 °F	85 °F	105 °F	125 °F	140 °F
½	2.0	1.9	1.8	1.7	1.6	2.0	1.9	1.7	1.6	1.5	1.9	1.8	1.6	1.5	1.3					
¾	2.3	2.2	2.1	1.9	1.9	2.3	2.1	2.0	1.9	1.8	2.1	2.0	1.8	1.8	1.6					
1	2.8	2.7	2.5	2.4	2.2	2.7	2.6	2.4	2.3	2.2	2.5	2.5	2.1	2.1	1.8					
1¼	3.2	3.0	2.8	2.7	2.5	3.1	2.9	2.7	2.6	2.4	3.0	2.8	2.5	2.5	2.1					
1½	3.7	3.5	3.3	3.1	3.0	3.6	3.4	3.2	3.0	2.8	3.4	3.3	3.0	2.8	2.5					
2	4.3	4.1	3.8	3.6	3.4	4.1	3.9	3.6	3.4	3.3	3.9	3.8	3.4	3.3	3.0					
3	5.4	5.1	4.7	4.5	4.3	5.2	4.9	4.6	4.3	4.1	4.9	4.8	4.4	4.1	3.8	4.5	4.3	4.0	3.7	3.4
4	5.8	5.5	5.1	4.8	4.6	5.6	5.3	4.9	4.6	4.4	5.4	5.2	4.9	4.8	4.3	4.9	4.8	4.5	4.3	3.9
6	7.4	7.0	6.5	6.1	5.8	7.1	6.8	6.3	5.9	5.6	6.7	6.4	6.1	5.7	5.2	6.1	5.8	5.5	5.2	4.8
8	8.3	7.9	7.3	6.9	6.6	8.0	7.6	7.1	6.7	6.3	7.5	7.2	6.9	6.6	6.2	6.9	6.6	6.3	6.0	5.7
10	9.6	9.1	8.4	7.9	7.5	9.2	8.7	8.1	7.6	7.3	8.5	8.2	7.9	7.5	6.9	7.8	7.5	7.2	6.9	6.3
12	11.2	10.6	9.8	9.3	8.8	10.8	10.2	9.5	8.9	8.5	10.3	9.8	9.2	8.6	8.1	9.4	9.0	8.4	7.9	7.4
14	11.9	11.3	10.5	9.9	9.4	11.5	10.9	10.1	9.5	9.1	11.0	10.4	9.8	9.2	8.6	10.1	9.5	9.0	8.5	7.9
16	12.8	12.1	11.2	10.6	10.1	12.3	11.6	10.8	10.2	9.7	11.6	11.0	10.4	9.7	9.1	10.7	10.1	9.5	9.0	8.4
18	13.1	12.4	11.5	10.9	10.4	12.6	12.0	11.1	10.5	10.0	12.2	11.6	11.0	10.3	9.6	11.2	10.8	10.0	9.5	8.8
20	14.1	13.4	12.4	11.7	11.2	13.6	12.9	12.0	11.3	10.7	13.0	12.3	11.6	10.9	10.2	11.9	11.3	10.6	10.0	9.3
22	15.0	14.3	13.2	12.5	11.9	14.5	13.7	12.7	12.0	11.4	13.9	13.1	12.4	11.6	10.9	12.8	12.1	11.4	10.7	10.0
24	15.7	14.8	13.8	13.0	12.4	15.1	14.3	13.2	12.5	11.9	14.4	13.6	12.8	12.1	11.3	13.3	12.5	11.8	11.1	10.4
26	16.1	15.3	14.1	13.3	12.7	15.5	14.7	13.6	12.8	12.2	14.9	14.1	13.3	12.5	11.7	13.7	13.0	12.3	11.5	10.8
28	16.8	16.0	14.8	14.0	13.3	16.2	15.4	14.2	13.4	12.8	15.6	14.8	13.9	13.1	12.2	14.3	13.6	12.8	12.0	11.2
30	17.6	16.7	15.5	14.6	13.9	16.9	16.1	14.9	14.1	13.4	16.1	15.3	14.4	13.5	12.6	14.8	14.0	13.2	12.4	11.6
32	18.1	17.2	15.9	15.0	14.3	17.4	16.5	15.3	14.5	13.8	16.8	15.9	15.0	14.1	13.2	15.4	14.6	13.8	12.9	12.1
36	19.4	18.4	17.0	16.1	15.3	18.7	17.7	16.4	15.5	14.7	17.8	16.9	15.9	14.9	14.0	16.4	15.5	14.6	13.8	12.9

+GF+

Restraint

Restraint is rigidly anchoring the pipe runs to the building structure at appropriate places so that thermally-induced dimension changes will be replaced by thermally-induced stresses. This can be accomplished by use of adequately strong clamps or supports along with a properly engineered pipe clamp interface to hold the pipe in place. For horizontal runs, braced clamp type hangers may be used. For floor penetrations, extension riser clamps may be used.

Underground installation in properly backfilled trenches may be considered to be a restrained system and not subject to thermally-induced dimensional changes. For more details, see the FM section.

It should be noted that two unique properties of PE4710 make for the success of these methods of handling thermal expansion. PE4710 is not subject to mechanical stress cracking. It can be stressed for long periods of time in what might be considered unfriendly environments without harm. In addition, PE4710 has an extremely high fatigue life. Its "self-hinge" characteristics are well known and the piping materials will stand repeated drastic flexures without harm.

Cold Weather Installations

In general, it is good practice when possible, to maintain an ambient temperature above 40˚F (4˚C). However, low temperature fusions to -10˚F (-23˚C) are easily accomplished utilizing automatic temperature compensation capable fusion machines (MSA 330/340) from GF.

Note: Material and fusion machines must be the same temperature prior to fusion. This can be achieved when components and machines are in the same environment for 1 hour per ½" material wall thickness.

For further information, please consult you local sales representative.

Flammability and Fire Rated Construction

The fire protection officials and code officials are becoming sensitive to the smoke generation and flammability of plastic materials used in building construction, and plastic piping is naturally included in these concerns. To satisfy the fire safety requirements set out by the authorities, the engineers and architects must have a better understanding of the plastics used in piping, appropriate test methods and means of protection against fire dangers attributed to plastic piping.

To put this into the proper perspective, the architect, engineer and administrative authority must realize that, in the vast majority of cases, fires commonly start and continue to develop in occupied areas of a building and not within the walls and chases where plastic piping is more commonly installed.

Laboratory Fire Tests

The following are common laboratory tests conducted on small samples of plastic material and are useful in characterizing and comparing different plastics. However, these tests are of only limited use in predicting the behavior of the materials in real fire situations.

ASTM D635 - Rate of Burning and/or Extent and Time of Burning of Self Supporting Plastics in a Horizontal Position

One half-inch wide by five-inch long horizontal specimens are exposed to a burner flame. The time of burning and distance burned are recorded. The results are reported as measured, except in the case where the minimum values apply (time of burning is "less than five seconds" and the minimum extent of burning is "less than one quarter-inch").

UL94 - Standard for Safety of Flammability of Plastic Materials

One half-inch wide by five-inch long vertical specimens are exposed repeatedly to a burner flame. Time of burning, possible dripping of burning particles and afterglow are observed. Results are reported as V-0, V-1 or V-2, depending on test results.

ASTM D2843 - Density of Smoke from the Burning or Decomposition of Plastics

A one-quarter inch by one inch by one inch sample is exposed to a propane burner flame and light transmission through the smoke generated by the burning plastic is measured with a standard lamp and photocell for four minutes. Results are reported as light absorption and smoke density.

ASTM D2863 - Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)

A one-eighth inch by one-quarter inch by three to six inch long specimen is burned in a variable oxygen-nitrogen mixture to determine the percentage oxygen required to maintain combustion.

Large Scale Tests

These tests are run on full-sized wall or floor (floor-ceiling) assemblies or on large material specimens. They are intended to determine the response of varying construction methods and materials in actual fire conditions.

ASTM E119 - Fire Tests of Building Construction and Materials

NFPA251

- UL263
- UBC43-1

Wall sections of at least 100 square feet in size are attached as the front wall of a furnace and exposed to a flaming environment. The temperature rises according to a standard time temperature curve. The test specimen may or may not be exposed to vertical or horizontal loads. The specimen, after exposure, may be subjected to a high pressure hose stream to determine its integrity after exposure.

This test is universally accepted as the method of rating wall assemblies for fire resistance as related to time of exposure. Ratings may be 1, 2, 3 or 4 hours, depending on the time for the temperature to rise to not more than 250°F (121°C) above its initial temperature on the non-exposed face. Floor and floor-ceiling assemblies of at least 180 square feet in size are also tested per ASTM E119 as the roofs of a floor-ceiling furnace, and rated on the basis of the time for the temperature to rise 250°F (121°C) above the initial temperature on the unexposed face, as for walls.

ASTM E814 - Fire Tests of Through-Penetration Fire Stops

This test method (published Spring 1982) is essentially identical to the ASTM E119 test except that it is intended to determine the ability of fire-stopping methods and devices to maintain the fire rating (integrity) of rated fire-resistive walls, floors or floor-ceiling assemblies which are penetrated by pipe, conduits or cables.

ASTM E84 - Surface Burning Characteristics of Building Materials

- NFPA255
- UL723
- UBC42-1

As stated, this test is intended for testing of surface finish materials which are capable of supporting themselves or of being supported other than by support on the under-side of the test specimen. Samples are 20 inches (min.) wide by 24 feet long and are attached to the roof of an 18 inch by 30 foot furnace.

Burning characteristics of the samples are stated as percentage of the rate of burning of red oak.

This test, being specifically aimed at testing surface finish materials, is recognized as not applying to plastic pipe by those who understand the test method and application environment. The National Fire Protection Association has stated that the test is not to be applied to plastic pipe and that the pipe should be tested as a component of a wall or floor assembly in the ASTM E119 test, where the materials are most commonly used.

Fire Protection Methods for Wall Penetration and Return Air Plenums

For fire resistance rated wall penetrations, penetrations through horizontal assemblies, etc. use listed and approved firestopping with ratings determined by ASTM E814 or UL1479 for use with plastic piping.

Section 3: FM Factory Mutual

Introduction

Factory mutual (FM) approved piping systems – used for water supply in fire protection systems

Factory Mutual Global (FM) insures and protects the lives, property, and continuity of operation for its insureds, by mitigating fire risk. One component of that risk minimization is the rigorous testing of fire protection system components, which includes underground pipe and fittings. Factory Mutual Research Corp. is the FM Nationally Recognized Testing Laboratory (NRTL) which conducts pipe and fittings testing for FM Global Insc. Fire protection system components are rigorously tested to ensure that all approved products pass the aggressive level of FM performance, efficacy and quality requirements. Every GF product labeled with the Factory Mutual (FM) symbol has met the strenuous requirements for fire protection systems. The GF manufacturing processes and the in-house testing have been audited, approved, and biannually inspected by Factory Mutual Global, to assure product conformance and performance for the Owner's security and peace of mind, now, and into the future.

Benefits and features

Many companies around the world design and build their properties according to the FM standards. An essential part is the selection, construction and installation of the buried fire-protection piping system.

FM – Factory Mutual Global

... is the world's largest industrial property insurance and risk management organization.

FM – Approval

....provides assurance that GF product design and manufacturing, meets your fire system protection needs.

FM – Critical elements

... Fire protection systems require moving water through pipes from its source to its final point of use. Underground pipe and fittings are considered the most critical components.

FM – Performance

... fire prevention systems must be extremely reliable and capable of safely withstanding both internal and external stresses over long periods of time. Rigorous testing and auditing by FM-approved personnel ensure reliability and quality.

Table 18 - Overview of GF Piping Systems products with FM approval (IPS & DIPS diameters)

Product	Class 150 (150 PSI)	Class 200 (200 PSI)	Class 267 (267 PSI)
Pipe	**2 - 24“**	**2 - 24“**	**2 - 24“**
Electrofusion coupler		**4 - 24“**	
Spigot fittings for electro fusion and butt fusion			
45° Elbows	2 - 24”	2 - 24”	2 - 24”
90° Elbows	2 - 24”	2 - 24“	2 - 24”
22.5° Elbows	2 - 24”	2 - 24“	2 - 24”
Tee equal	4 - 24”	4 - 24“	2 - 24”
Tee reduced branch	2 - 24”	2 - 24“	2 - 24”
Flange adaptor	2 - 36”	2 - 30“	4 - 24”
Backing ring	2 - 36”	2 - 30“	4 - 24”
Reducer	2 - 24”	2 - 24“	2 - 24”
Branch saddle	2 - 12“ outlet	2 - 12“ outlet	2 - 12“ outlet
Anchor ring	2 - 24”	2 - 24“	2 - 24”
Mechanical joint adaptor	2 - 24”	2 - 24“	2 - 16”
PE to metal transition	4 - 12”	6 - 16”	

Table 19 - Comparison of your FM solutions for underground fire protection systems

	Gasketed Ductile Iron	Gasketed PVC	FM Approved HDPE
Longevity (Up to 100 year design life)			■
Resistant to Surge	■		■
Resistant to Crack Proposition	■		■
Corrosive Resistance		■	■
Reduced Insurance Premiums			■
Non-Gasket Joining			■
Earthquake Resistant			■
Freeze Tolerant			■
Ductile Material	■		■
Scratch Tolerant	■		■

System Specification: Factory Mutual Approved Pipe and Fittings Model

NOTICE: This document is intended as assistance and as a guide to support the design of fire protection piping systems. However, it shall not be used as a substitute for the advice of a professional engineer to owners. GF has taken reasonable effort to ensure the accuracy of this sample specification document, but it does not provide all necessary information, particularly with respect to custom or unusual installations. No warranty or guarantee of piping installations is expressed nor implied. This sample specification is not intended to provide nor act as a substitute for installation training nor instructions. This document may be changed from time to time without notice.

1. General Terms and Conditions

1.1 Scope

This specification covers Factory Mutual (FM) Approved and listed high-density polyethylene piping for underground fire main use, made in accordance with the specification requirements of FM. All work shall be performed in accordance with these specifications. http://www.fmglobal.com/assets/pdf/fmapprovals/1613.pdf

1.2 Engineered and Approved Plans

Underground fire main construction shall be performed in accordance with engineered construction plans for the work prepared under the direction of a Professional Engineer. Guidance for polyethylene pipe design and construction is provided in the Plastic Pipe Institute's "Handbook of Polyethylene Pipe", available at : http://www.plasticpipe.org/publications/pe-handbook.html

1.3 Referenced Standards

Where all or part of a NSF, AWWA, ASTM, FM, NFPA, etc., standard specification is incorporated by reference in this document, the reference standard shall be the latest edition and revision.

1.4 Licenses and Permits

A licensed and bonded contractor shall perform all underground fire main construction work. The contractor shall secure all necessary permits before commencing construction.

1.5 Inspections

All work shall be inspected by an authorized representative of the owner who shall have the authority to halt construction if, in his opinion, these specifications or standard construction practices are not being followed. Whenever any portion of these specifications is violated, the project engineer or his authorized representative shall, by written notice, order further construction to cease until all deficiencies are corrected. A copy of the order shall be filed with the contractor's license application for future review. If the deficiencies are not corrected, performance shall be required of the contractor's surety.

2. Polyethylene Pipe and Fittings

2.1 Qualification of Manufacturers

The manufacturer shall have manufacturing facilities and a quality assurance program that are FM Approved as being capable of producing and assuring the quality of the pipe and fittings required by these specifications. The manufacturer's production facilities shall be open for inspection by the customer or his authorized representative. The project engineer shall approve qualified manufacturers.

2.2 Approved Manufacturers

Manufacturers qualified and approved by the project engineer are listed below. Products from unapproved manufacturers are prohibited.

Georg Fischer Central Plastics LLC
www.gfcp.com
GF Piping Systems (Global)

2.3 Materials

Materials used for the manufacture of polyethylene pipe and fittings shall be USA PE 4710 high density polyethylene meeting ASTM D3350 cell classification 445574C for black or 445574E for color stripes, and shall be listed in PPI (Plastics Pipe Institute) TR-4 with a standard grade HDB rating of 1600 psi at 73°F. This pipe grade HDPE material meets and exceeds the minimum performance requirements of PE3608 material, and is accepted and approved by FM for use in Class 150, Class 200, and Class 267 pipe and fittings.

2.3.1 Potable Water

When the main provides firewater and potable water service, the material shall also be listed and approved for potable water in accordance with AWWA C901 and AWWA C906.

2.4 Interchangeability of Pipe and Fittings

The FM Approved manufacturer who is qualified and approved by the project engineer shall supply both polyethylene pipe and fittings. Products from non-approved manufacturers are prohibited. In the event of an emergency, pipe and fittings from different manufacturers may be used if authorized by the engineer of record, if both are FM Approved and listed, and if both have the same FM Approved ASTM material designation and material cell classification.

2.5 Polyethylene Pipe

Fire main pipe shall be FM Approved Class 150, Class 200, or Class 267 IPS and/or DIPS OD- size polyethylene pipe, and shall be marked with the authorized FM Approved logo. Each production lot of material or pipe shall be tested for melt index, density, and percent carbon-black concentration. Each production lot of pipe shall be tested for dimensions and ring tensile strength. The Pipe shall be produced, inspected, and tested IAW AWWA C901 and AWWA C906.

2.5.1 Service Identification Stripes

FM Approved pipe surface may be provided as all black, or black with red stripes. Permanent identification of the striping shall be provided by co-extruding at least 4 color stripes into the pipe outside surface. The striping material shall be the same material as the pipe material except for color. IPS & DIPS sized pipes shall have four equally spaced, longitudinal color stripes. Except as provided in 2.5.2, the optional stripe color shall be red.

2.5.2 Potable Water and Fire Main Pipe

Dual-certified potable water and fire main pipe shall be FM Approved and AWWA approved, with an all-black surface or as black with 4 blue stripes.

2.6 Polyethylene Fittings

Polyethylene fittings can be molded or fabricated. The fittings manufacturer shall be FM Approved. Each fittings shall be marked with the authorized FM Approval logo. Molded Fittings shall be provided by Georg Fischer-Central Plastics,LLC. Fabricated fittings shall be provided by Georg Fischer Central Plastics LLC, an FM Approved fabrication manufacturer.

2.6.1 Polyethylene Flange Adapters

Flange adapters shall be FM Approved and shall be marked with the authorized FM Approval logo. Flange adapters shall have sufficient through-bore length to be clamped in the butt fusion joining machine without the use of a stub-end holder. Flange Adapters shall be joined in accordance with the guidance of the Plastic Pipe Institute Technical Note #38: http://www.plasticpipe.org/pdf/tn-38_bolt_torque_flanged_joints.pdf

2.6.2 Back-up Rings & Flange Bolts

Class 150, Class 200 and Class 267 flange adapters shall be fitted with FM Approved Bolt Rings. Flange bolts and nuts shall be grade 3 or higher. Anodic corrosion protection of bolts should be considered for buried flange installations. http://marswater.com/PDFs/SpecSheets/ZincCaps.pdf

2.6.3 MJ Adapters

MJ Adapters of each pressure class shall be FM Approved and shall be marked with the authorized FM Approval logo. MJ Gland Rings shall be the C110 heavy Duty style, with all bolts evenly torqued to a range of 60-90 ft-lbs, per AWWA C600.

2.7 Compliance Tests

In case of conflict with manufacturer's certifications, the contractor, project engineer or customer may request retesting by the manufacturer or have retests performed by an outside testing service. All retesting shall be at the requestor's expense and shall be performed in accordance with these specifications.

3. Joining

3.1 Heat Fusion Joining

Joints between plain end pipes and fittings shall be made by butt fusion using only procedures that are recommended by the pipe and fitting manufacturer. The contractor shall ensure that persons making heat fusion joints have received training in the manufacturer's recommended procedure. The contractor shall maintain records of trained personnel and shall certify that training was received not more than 12 months prior to construction. External and internal beads do not need to be removed.

3.2 Heat Fusion Training Assistance

Upon request and at the requestor's expense, training personnel from the manufacturer or his representative shall be made available.

3.2.1 Butt Fusion of Unlike Wall Thickness

Butt fusion shall be performed between pipe ends, or, between pipe ends and fitting spigots having the same outside diameter and pressure class. Butt fusion joining between ends differing by one SDR is permitted, however, the system pressure rating retains the lowest rated component's pressure class. Transitions between Class 150, Class 200 and Class 267 shall be made with approved flange connections, transition fittings, or MJs.

3.3 Mechanical Joining

Polyethylene pipe and fittings may be joined together or to other materials by means of FM Approved flange adapters and back-up rings or FM Approved MJ adapters, or listed Transition Fittings. Where FM Approved pipe or fittings are connected to the socket of Di mechanical joint pipe, fittings or appurtenances, an FM Approved MJ adapter shall be used. Plain end pipe with or without an ID stiffener shall not be installed into the hub of a mechanical joint component. Unlisted Mechanical couplings and external joint restraints shall not be used to connect FM Approved polyethylene pipe nor fittings.

3.4 Flange Installation

Mechanical joint and flange connections shall be installed in accordance with the manufacturer's recommended procedure. MJ adapters and flanges shall be centered and aligned to the mating components before assembling and tightening bolts. In no case shall MJ gland or flange bolts be used to draw the connection into alignment. Bolt threads shall be lubricated and flat washers should be used under the nuts. Bolts shall be evenly tightened according to the tightening pattern and torque step recommendations of the manufacturer. At least 1 hour after initial assembly, flange connections shall be re-tightened following the tightening pattern and torque step recommendations of PPI TN-38. The final seating torque shall be as recommended by the specifying engineer IAW Tn-38 guidance.

4. Installation

4.1 General

When delivered, a receiving inspection shall be performed and any shipping damage shall be reported to the manufacturer within 7 days. Installation shall be in accordance with ASTM D 2774, manufacturer's recommendations, the PPI Polyethylene Pipe Handbook, and this specification. All precautions shall be taken to ensure a safe working environment in accordance with all applicable safety codes and standards.

4.2 Excavation

Trench and trenchless installations shall conform to the plans and drawings, as otherwise authorized in writing by the project engineer or his approved representative, and in accordance with all applicable codes. Where necessary, trench walls shall be shored or reinforced and all precautions shall be taken to ensure a safe working environment.

4.3 Large Diameter Fabricated Fittings

A maximum of one leg of a fabricated directional fitting of 16" IPS & DIPS or larger diameter shall be butt fused to the end of a pipe string. The remaining fitting connections shall be made in the trench using butt fusion, flange, MJ, or Electrofusion couplers. Flange and MJ adapter connections shall be assembled and tightened in accordance with the TN-38 and AWWA C600. Handling, lifting, moving or lowering a 16" IPS & DIPS or larger diameter fabricated fitting that is connected to more than one pipe length is prohibited. If multiple legs of large diameter fittings are fused to long pipe strings and then moved without proper support or design consideration, damage to the fitting may occur. The contractor, at his expense, shall correct fitting damage caused by such improper handling.

4.4 Foundation & Bedding

Pipe shall be laid on grade and on a stable foundation. Unstable trench bottom soils shall be removed and a 6" foundation or bedding of compacted Cass I material shall be installed to pipe bottom grade. Excess groundwater shall be removed from the trench before laying the foundation or bedding for the pipe. A trench cut in rock or stony soil shall be excavated to 6" below pipe bottom grade and brought back to grade with compacted Class I bedding. All ledge rock, boulders and large stones shall be removed. (ASTM D2774 & D2321)

4.5 Pipe Handling

When lifting with slings, only wide fabric choker slings capable of safely carrying the load shall be used to lift, move or lower pipe and fittings. Lifting or moving polyethylene pipe or components using wire rope and chain is prohibited.

4.6 Backfilling

Embedment material soil type and particle size shall be in accordance with ASTM D 2774. Embedment shall be placed and compacted to at least 90% Standard Proctor Density in 6" lifts to at least 6" above the pipe crown. During embedment placement and compaction, care shall be taken to ensure that the haunch areas below the pipe spring-line are completely filled and free of voids. Properly formulated and poured quick setting flowable-fill is allowed.

4.7 Protection against shear and bending loads

In accordance with ASTM D 2774, connections shall be protected where an underground polyethylene branch or service pipe is joined to a branch fitting such as a service saddle, branch saddle or tapping tee on a main pipe and where pipes enter or exit casings or walls. The area surrounding the connection shall be embedded in properly placed, compacted backfill, preferably in combination with a protective sleeve or other mechanical structural support to protect the polyethylene pipe against shear and bending loads. Properly formulated and poured quick setting flowable-fill is allowed.

4.8 Final Backfilling

Final backfill shall be placed and compacted to finished grade. Native soils may be used provided they are free from debris, stones, boulders, clumps, frozen clods or the like larger than 8" in their largest dimension.

5. Testing

5.1 Fusion Quality

The contractor shall ensure the field set-up and operation of the fusion equipment and the fusion procedure used by the contractor's fusion operator while on site. Upon request by the owner, the contractor shall verify field fusion quality by making and testing a trial fusion. The trial fusion shall be allowed to cool completely, then test straps shall be cut out and bent strap tested in accordance with ASTM F2620. If the bent strap test of the trial fusion fails at the joint, the field fusions represented by the trial fusion shall be rejected. The contractor at his expense shall make all necessary corrections to equipment, set-up, operation and fusion procedure, and shall re-make the rejected fusions.

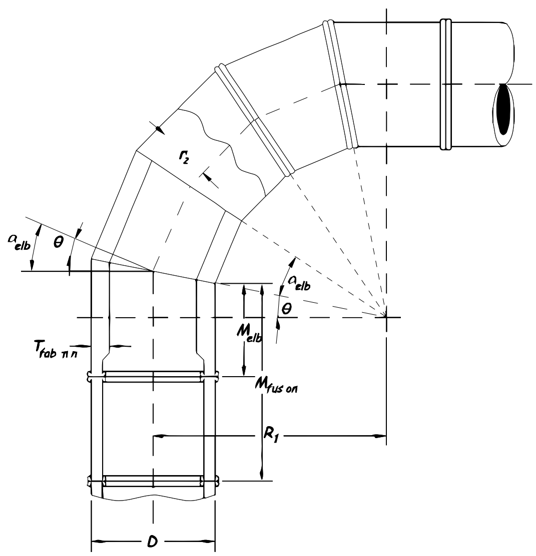
5.2 Acceptance Leak Testing

Hydrostatic leak testing shall be conducted in accordance with the guidance of the Plastic Pipe Institute Technical Note #46: http://www.plasticpipe.org/pdf/tn-46-guidance-field-hydro-test-hdpe-pressure-considerations.pdf and ASTM F2164. Pneumatic pressure testing is prohibited.t

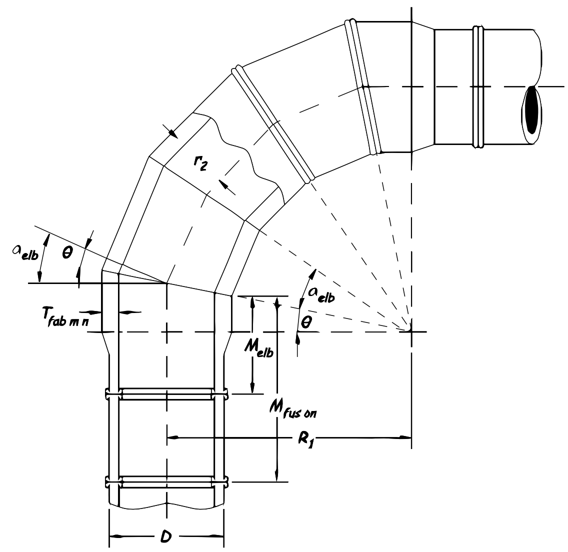
Class Definition: CL150, CL200, CL267

FM pressure class (Class 150, Class 200, Class 267) is the pressure rating in PSI assigned to pipe and fittings which will hold four times that pressure for five minutes at 73°F.

Internal/External Reinforcement Examples



Nomenclature for Constant OD, 5-segment, reinforced, 90° elbow



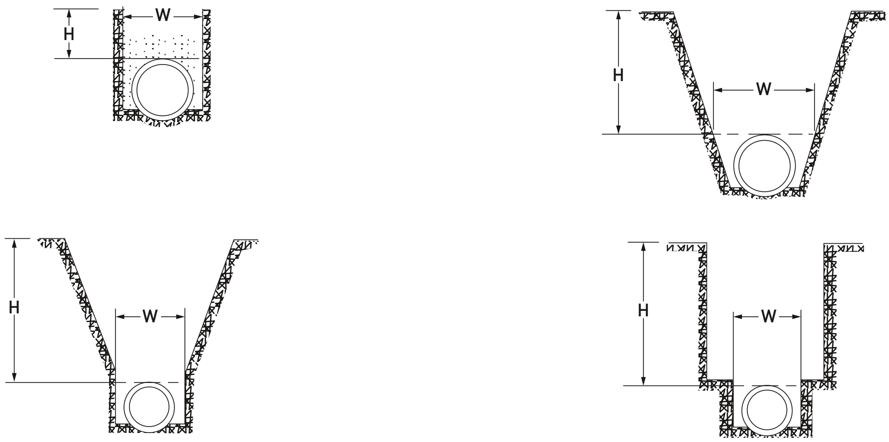
Nomenclature for Constant ID, 5-segment, reinforced, 90° elbow

Below Ground Installations

Instruction for Underground Trenching

1. The bottom of the trench shall be of stable material. Where ground water is encountered, the bottom shall be stabilized a with granular material of ½" maximum particle size. A 4" cushion shall be placed over rock or hardpan.
2. Trench width should be sufficient to provide working room if the pipe is to be joined in the trench. Minimum width may be used if pipe is to be joined before placing in the trench.
3. Trench depth under building slabs should allow for 12" cover over the pipe. Trenches in exposed locations should permit burial of pipe at least 12" below maximum expected frost penetration. A minimum of 24" cover should be provided where pipe may be exposed to heavy overhead traffic. Applicable plumbing codes may require greater trench depth and cover than technically required.
4. Trench Widths for Polyethylene

Figure 24 - Underground Trench Examples



Note: "W" = Width of Trench at Top of Pipe

Bedding and Backfill Material

The backfill material surrounding the pipe shall be readily compactible and shall consist of coarse sand, sand with gravel or clay, sand that is free from frozen lumps, stones larger than ½" and fine compact silt or clay. The material shall fall within the Highway Research Board Classification Group A-1, A-2 (Plasticity Index less than 10) or A-3.

Bedding and Backfilling - ASTM D2321 and D2774

1. Bedding — Install in 6" maximum layers. Level final grade by hand. Minimum depth 4" (6" in rock cuts).
2. Haunching — Install in 6" maximum layers. Work around pipe by hand to provide uniform support.
3. Initial Backfill — Install to a minimum of 6" above pipe crown.
4. Embedment Compaction — Minimum density 95% Standard Proctor per ASTM D698. Use hand tampers or vibratory compactors.
5. Final Backfill — Compact as required by the engineer.

Also see http://plasticpipe.org/pdf/chapter07.pdf
Also see FM Class 1613

Mechanical Joint Anchor Fittings

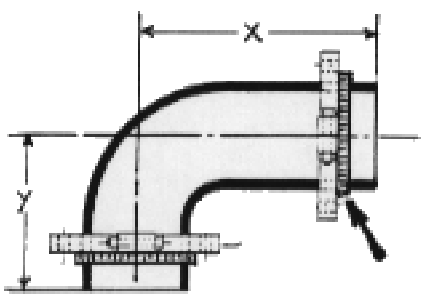
MJ Adapter Design Information

Over 40 years ago, anchor fittings were developed for mechanical joint bell and spigot connections. Anchor fittings evolved from water-stop fittings, which also provide positive anchoring and axial restraint. Anchor fittings eliminate the need for labor consuming tie-rods, strapping and/or thrust blocking. This design keeps the pipe from separating under hydraulic pressure and/or soil movement.

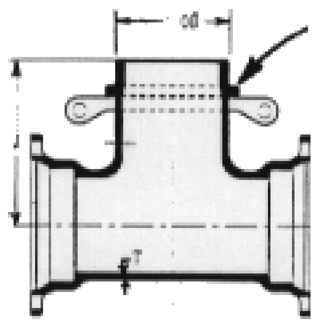
The rotating ring gland permits assembly to accommodate any orientation of the bolt holes in existing metal MJ pipe or fittings to which it is connected. As the tee-bolts are tightened, the rotating ring gland pushes against the stop-shoulder, which in turn compresses the hard rubber gasket captured within the joint. The rotating ring gland, in combination with the stop-shoulder makes a fully restrained joint, just like a back up ring pushing on a flange or water-stop. This design has been adopted for plastic pipe as a simple transition between HDPE pipe and metal DI pipe.

The anchor fitting design has been used for over three decades on hydrant tees, swivel tees, anchor couplings/spools/pipes and anchor elbows. *

MJ anchoring elbow



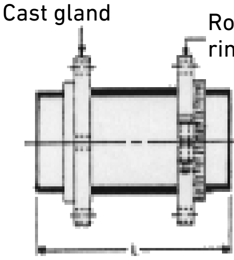
MJ anchoring tee



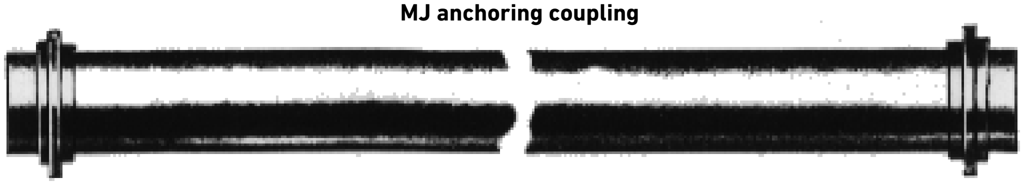
MJ anchoring coupling

Cast gland

Rotating ring gland



MJ anchoring coupling



Anchoring pipe, 4", 6", 8" and 12" sizes

* References: Ductile-Iron Pipe Research Accoc., U.S. Pipe and Foundry Inc., Tyler Pipe, Clow Corp., Griffin Pipe Products, Union Foundry, Pacific States Corp., American Ductile Iron Pipe Co.

Table 20 - Soil Load and Pipe Resistance

Nominal Pipe Size (inch)	Wc' = Load Resistance of Pipe (lb./ft.)											
	PE100 - SDR 17		PE100 - SDR 11		PE100 - SDR 9		PE100 - SDR 7		DIPS DR 17		DIPS DR 11	
	E'=200	E'=700	E'=200	E'=700	E'=200	E'=700	E'=200	E'=700	E'=200	E'=700	E'=200	E'=700
2 - 63mm	281	536	769	1006	1342	1568	2798	3005				
3 - 90mm	413	789	1131	1480	1978	2310	4134	4439				
4 - 110mm	531	1015	1455	1904	2541	2968	5319	5711	564	1081	1550	2029
6 - 160mm	781	1494	2141	2802	3739	4367	7815	8393	813	1556	2230	2919
8 - 200mm	1014	1943	2790	3651	4865	5683	10185	10936	1064	2038	2931	3834
10 - 250mm	1264	2422	3476	4549	6063	7083	12705	13642	1307	2502	3591	4699
12	1501	2874	4125	5397	7203	8413	15050	16161	1552	2973	4271	5589
14	1650	3157	4532	5930	7911	9239	16537	17757	1801	3448	4951	6479
16	1883	3606	5181	6778	9036	10555	18907	20301	2050	3923	5632	7369
18	2120	4058	5821	7618	10162	11870	21252	22820	2296	4395	6312	8258
20	2353	4506	6470	8466	11288	13186	23621	25364	2545	4870	6992	9148
22	2590	4958	7118	9314	12414	14502	25991	27908				
24	2827	5410	7767	10163	13555	15832	28360	30452	3039	5816	8344	10919
26	3060	5859	8416	11011	14681							
28	3296	6311	9055	11850	15807							
30	3533	6763	9704	12699	16932							
32	3766	7211	10353	13547								
36	3820	7724	11651	15244								

$$Wc' = \frac{\Delta x \bullet (E \bullet I + 0.061 \bullet E' \bullet r^3) \bullet 80}{r^3}$$

Wc' = Load Resistance of the Pipe (lb./ft)

Δx = Deflection in Inches @ 5% (.05 x I.D.)

E = Modulus of Elasticity = 0.87×10^5 (lbs/in^2)

t = Pipe Wall Thickness (in)

r = Mean Radius of Pipe (O.D. - t)/2

E' = Modulus of Passive Soil Resistance (lbs/in^2)

H = Height of Fill Above top of Pipe (ft)

I = Moment of Inertia $t^3/12$

Note 1: Figures are calculated from minimum soil resistance values (E' = 200 PSI for uncompacted sandy clay loam) and compacted soil (E' = 700 for side-fill soil that is compacted to 90% or more of Proctor Density for a distance of two pipe diameters on each side of the pipe). If Wc' is less than Wc at a given trench depth and width, then soil compaction will be necessary.

Note 2: These are soil loads only and do not include live loads.

Section 4: Metric

System Specification - ecoFIT Piping Systems Metric Polyethylene (PE)

1.0 Scope

This specification covers the requirements for the Georg Fischer ecoFIT (PE) Metric and IPS Piping Systems intended for a wide range of industrial applications including water, wastewater and effluent treatment as well as a wide range of chemical applications. The components of the ecoFIT Metric and IPS (PE) piping system are in accordance with the following standards.

2.0 Basic System Data

2.1 Material Specification for ecoFIT (PE) Metric Pipe & Fittings

A. All ecoFIT (PE) metric pipe shall be manufactured from PE100 and comply with a MRS class of 10. Pipe manufactured according to EN ISO 15494, DIN 8074 (dimensions) and DIN 8075 (quality specifications) as well as ASTM D3350. The pipes are NSF 61 approved. Pipe shall be manufactured to SDR 11 or SDR 17 dimensions with a pressure rating of 200 psi or 130 psi respectively when measured at 68°F. Pipe shall be supplied capped off at the extruder and supplied in 5 Meter lengths.

B. All ecoFIT (PE) metric fittings and valves from Georg Fischer Piping Systems are manufactured according to ASTM D3350 from PE100 with a value of MRS 10 MPa, designed for 25 years operational life with water at 20°C. Fittings shall be manufactured to SDR 11 or SDR 17 dimensions with a pressure rating of 200 psi or 130 psi respectively when measured at 68°F. The material is designed for use with pressure bearing piping systems with long-term hydrostatic properties in accordance with EN ISO 15494, as supplied by Georg Fischer Piping Systems.

3.0 Material Specification for ecoFIT (PE) Metric Ball Valves

All valves shall be metric sizes manufactured by Georg Fischer Piping Systems or equal in accordance with EN ISO 16135, 16136, 16137, 16138, tested according to the same standard.

3.1 Ball Valves

A. Ball valves consist of a valve body out of PP, ABS, or PVC combined with connection parts in PE.

3.1.1 Manual operated Ball Valves

A. All ecoFIT (PE) ball valves with metric sizes d20mm – d110mm, shall be Georg Fischer Piping Systems Type 546, 543, 523 with true double union design manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16135. Incorporated into its design shall be a safety stem with a predetermined breaking point above the bottom O-ring, preventing any media leaking in the event of damage. The valve nut threads shall be buttress type to allow fast and safe radial mounting and dismounting of the valve during installation or maintenance work. Seats shall be PTFE with backing rings creating self-adjusting seals and constant operating torque. Backing rings and seals shall be EPDM or FPM. The handle shall include in its design an integrated tool for removal of the union bush. Union bushes shall have left-hand threads to prevent possible unscrewing when threaded end connectors are removed from pipe.

3.1.2 Ball Valve Accessories

A. A Multi-Functional Model (MFM) in PPGF equipped with internal limit switches for reliable electrical position feedback, is mounted directly between the valve body and the valve handle. This MFM is also the necessary interface for later mounting of actuators.

B. Mounting plate in PPGF with integrated inserts for mounting on any support

C. Lockable multi-functional handle

3.1.3 Electrically Actuated Ball Valves

A. Electric actuators shall be Types EA11 (sizes DN10-50), EA21 (sizes DN10-50), EA31 (sizes DN65-100) shall be available manufactured by Georg Fischer Piping Systems in accordance with EN 61010-1, EC directives 2004/108/EC (EMC) and 2006/95/EC, LVD and needs to be CE marked. Actuator housing shall be made of PPGF (polypropylene glass fiber reinforced), flame retardant with external stainless steel screws. All electric actuators shall have an integrated emergency manual override and integrated optical position indication. All electric actuator types (with the exception of EA11) shall have the following accessories available:
- Fail-safe unit
- Heating element
- Cycle extension, cycle time monitoring, and cycle counting
- Motor current monitoring
- Position signalization
- Positioner Type PE25
- Limit switch kits Ag-Ni, Au, NPN, PNP, NAMUR
- AS Interface Plug Module

3.1.4 Pneumatically Actuated Ball Valves

A. Pneumatic actuators shall be Georg Fischer Piping Systems Types PA11 (for valve sizes d20-32mm) and PA21 (for valve sizes d40-63mm). They shall be manufactured by Georg Fischer Piping Systems. Pneumatic actuators shall be available as fail safe close, fail safe open and double acting and have an integrated optical position indication. Actuator housing shall be made of Polypropylene fiber glass reinforced (PPGF) and flame retardant. Actuators shall contain a pre-loaded spring assembly to ensure safe actuator operation and maintenance. Actuators shall contain integrated Namur interface for the easy mounting of positioners, limit switches and accessories. The valve shall be equipped optionally with a Multi-functional-module for reliable electric feedback, mounted directly between the valve body and the actuator as manufactured by Georg Fischer Piping Systems.
- For valve size d75mm pneumatic actuators shall be Type PA 30 (fail safe to close or open function), Type PA35 (double acting function).
- For valve size d90mm pneumatic actuators shall be Type PA 35 (fail safe to close or open function), Type PA40 (double acting function).
- For valve size d110 mm pneumatic actuators shall be Type PA 45 (fail safe to close or open function), Type PA45 (double acting function)

B. Pneumatic actuators shall have an integrated optical position indicator. Actuator housing shall be made of hardened anodized aluminum. Actuators shall contain integrated Namur interface for the easy mounting of positioners, limit switches and accessories.

C. All pneumatically actuated ball valves shall have the following accessories available:
- Pilot valve remote or direct mounted in voltages 24VDC/AC, 110VAC, 230VAC
- Positioner Type DSR 500-3
- Limit switch kits Ag-Ni, Au, NPN, PNP
- Stroke limiter
- Manual override for all sizes up to d110
- AS Interface control module with incorporated position feedback and a solenoid pilot valve

3.2 Material Specification for ecoFIT (PE) Metric Diaphragm Valves

Diaphragm valves consist of valve body out of PP-H, ABS, or PVC combined with connection parts in PE.

3.2.1 Manual Diaphragm Valves

3.2.1.1 Diaphragm Valves d20mm to d63mm

A. All ecoFIT (PE) diaphragm valves, metric sized from d20mm to d63mm, shall be either:
- Type 514 (true double union design)
- Type 517 (flange design)

B. All diaphragm Valves shall be manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16138. The upper body shall be PPGF (polypropylene glass fiber reinforced) connected to the lower body with a central union avoiding exposed screws.

C. A two colored position indicator integrated into the hand wheel must be present to determine diaphragm position. The hand wheel shall have an integrated locking mechanism. Diaphragms are to be EPDM, FPM, NBR, PTFE with EPDM or FPM supporting diaphragm. Following options shall be available:
- Electrical feedback unit with either Ag-Ni or AU contacts
- Pressure proof housing

3.2.1.2 Diaphragm Valves d75mm to d160mm

A. All ecoFIT (PE) diaphragm valves, metric sized, shall be Type 317 (flanged design) consisting of valve body out of PP-H or PVC-U with integrated fixed flange. All diaphragm valves shall be manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16138. The upper body shall be PPGF (polypropylene glass fiber reinforced) connected to the lower body with exposed stainless steel bolts. A position indicator integrated into the hand wheel must be present to determine diaphragm position. Diaphragms are to be EPDM, FPM, NBR, or PTFE with EPDM or FPM supporting diaphragm.

3.2.2 Pneumatic Diaphragm Valves

3.2.2.1 Pneumatic Diaphragm Valves d20mm to d63mm

A. All ecoFIT (PE) diaphragm Valves, metric sized from d20mm to d63mm, shall be either:
- Type 514: true double union design
- Type 517: flange design

B. All diaphragm Valves shall be manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16138. The upper body shall be connected to the lower body with a central union avoiding exposed screws.

C. Diaphragms have to be EPDM, FPM, NBR, PTFE with EPDM or FOM supporting diaphragm.

D. The mode of operation shall be fail safe close (FC), fail safe open (FO) and double acting (DA). The valves shall have an integrated optical position indicator. Actuator housing shall be made of PPGF (polypropylene glass fiber reinforced). Actuators with FC mode shall contain a pre-loaded galvanized steel spring assembly to ensure safe actuator operation and maintenance. The actuator DIASTAR Ten, DIASTAR Ten Plus and DIASTAR Sixteen shall have following accessories available:
- Solenoid pilot valve remote or direct mounted in voltages 24VDC/AC, 110VAC, 230VAC
- Positioner Type DSR 500-1
- Feedback with following limit switches Ag-Ni, Au, NPN, PNP, NAMUR
- Stroke limiter & emergency manual override
- ASI controller

3.2.2.2 Pneumatic Diaphragm Valves d75mm to d160mm

A. All ecoFIT (PE) diaphragm valves, metric sized, shall be flanged design consisting of valve body out of PP-H, ABS or PVC with integrated fixed flange.

B. All diaphragm valves shall be manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16138. The upper body shall be connected to the lower body with exposed stainless steel bolts. Diaphragms are to be EPDM, FPM, NBR, or PTFE with EPDM or FPM supporting diaphragm.

C. Pneumatic diaphragm actuators shall be Georg Fischer Piping Systems Type DIASTAR Type 025. The mode of operation shall be fail safe close (FC), fail safe open (FO) and double acting (DA). The valves shall have an integrated optical position indicator. Actuator housing shall be made of PPGF (polypropylene glass fiber reinforced

D. Actuators with FC mode shall contain a pre-loaded galvanized steel spring assembly to ensure safe actuator operation and maintenance. The actuator DIASTAR 025 shall have following accessories available:
- Solenoid pilot valve remote or direct mounted in voltages 24VDC/AC, 110VAC, 230VAC
- Positioner Type DSR 500-2
- Feedback with following limit switches Ag-Ni, Au, NPN, PNP, NAMUR
- Stroke limiter & emergency manual override
- ASI Controller

3.3 Butterfly Valves

3.3.1 Plastic Butterfly Valves

A. Butterfly valves suitable for the ecoFIT (PE) System of Georg Fischer Piping Systems are made from PP-H or PVC Material.

B. All butterfly valves, metric sizes 2" (d63mm) – 10" (d250mm), shall be Georg Fischer Piping Systems Type 567/568/563 wafer/lug type with a double eccentric disc design manufactured by Georg Fischer Piping Systems in accordance with EN ISO 16136. Seals shall be available in EPDM, FPM and PTFE/FPM. The lever handle shall be lockable in increments of 5 degrees. There shall always be six teeth engaged between the ratchet and the index plate to ensure accurate and safe positioning of the lever. There shall be the option of fine adjustment by use of a specific hand lever, allowing the disc to be exposed at any angle between 0° and 90°. As an option, the hand lever shall be lockable. The hand lever shall be manufactured of high strength PPGF (polypropylene glass fiber reinforced). The option of an integrated electric position indicator shall be available. As an option the valves can be actuated by gear box with hand wheel. The electric position indicator shall be integrated into the mounting flange. Butterfly valves shall have low actuation torque to enable easy operation. All butterfly valves Type 567/568 manufactured by Georg Fischer Piping Systems are designed for a nominal pressure rate of 10 bar. All butterfly valves Type 563 are designed for a nominal pressure rate of 4 bar.

3.3.1.1 Electrically Actuated Butterfly Valves

A. Electric actuators shall be Georg Fischer Piping Systems Types EA31 or EA42 dependent on valve size. They shall be manufactured by Georg Fischer Piping Systems in accordance with EN 61010-1, as per the above specifications. Actuator housing shall be made of PPGF (polypropylene glass fiber reinforced), flame retardant and feature external stainless steel screws. All electric actuators shall have an integrated emergency manual override and integrated optical position indication.

B. All electric actuator types shall have the following accessories available:
- Fail-safe unit
- Heating element
- Cycle extension, monitoring, and counting
- Motor current monitoring
- Position signalization
- Positioner Type PE25
- Limit switch kits Ag-Ni, Au, NPN, PNP
- Manual override
- AS-Interface Plug Module

3.3.1.2 Pneumatically Actuated Butterfly Valves

A. Pneumatic actuators shall be Georg Fischer Piping Systems Types PA 35 (metric sizes d63-75mm), PA40 (metric size d90mm only), PA45 (metric size d110mm), PA55 (metric size d160mm), PA60 (metric sizes d225mm FC), PA65. They shall be supplied by Georg Fischer Piping Systems. Pneumatic actuators shall be available as fail safe close, fail safe open and double acting and have an integrated optical position indication. Actuator housing shall be made of hardened anodized aluminum. Actuators shall contain integrated Namur interfaces for the easy mounting of positioners, limit switches and accessories. All pneumatically actuated butterfly valves shall have the following accessories available:
- Solenoid pilot valve remote or direct mounted in voltages 24VDC/AC, 110VAC, 230VAC
- Positioner Type DSR 500-3
- Feedback with following limit switches Ag-Ni, Au, NPN, PNP, NAMUR
- Stroke limiter & emergency manual override
- ASI-controller

3.4 Material Specification for ecoFIT (PE) Metric Check Valves

A. Check valves consist of valve body out of PP-H, ABS, or PVC combined with connection parts in PE or flanged.

B. All cone check valves, according to EN ISO 16137, metric sizes d20-d110mm metric, shall be Type 561/562 true double union design. Seals shall be EPDM or FPM. Union bushes shall have a left hand thread to prevent possible unscrewing when threaded end connectors are removed from pipe. This valve shall be suitable for mounting in a vertical and horizontal position. Type 562 shall be equipped with a spring made of stainless steel (V2A, Nimonic, halar coated) to allow position independent installation. The valves are designed for a nominal pressure of 16 bar.

3.5 Ventilating and Bleed Valves

A. All ecoFIT (PE) Ventilating and Bleed valves shall be Georg Fischer Type 591. Dimensions d20-d110mm are with pressure rating PN10. They shall be equipped with a PP-H floater with density of 0,91 g/cm^3.

3.6 Ventilating Valves

A. All ecoFIT (PE) Ventilating valves shall be Georg Fischer Type 595. Dimensions d20-d110mm are with pressure rating PN10. They shall be equipped with plastic coated stainless steel spring with minimal opening pressure (10-80 mbar).

5.0 Welding and Assembly

A. All electrofusion fittings shall be manufactured under strict quality requirements as stated by the manufacturer such as ISO9001:2000 or equivalent. All electrofusion fittings must be packaged to ensure cleanliness and protection from contamination. All electrofusion fittings shall be manufactured with molded built-in restraint capabilities in sizes 20mm – 63mm. Sizes above 63mm shall use external restraint type clamps. All metric electrofusion fittings shall be made with fusion indicators to visually indicate that the fusion process has been made.

B. All butt fusion fittings and valves shall also be manufactured with laying lengths designed for use with electrofusion capabilities with model MSA330/340 and for butt fusion machines according to DVS 2207-11 model TM160, TM315, TM400, and TM630 including CNC control parameters from Georg Fischer Piping Systems.

C. Optional IR Plus fusion machines, IR63 Plus, IR225 Plus use non-contact radiant heating. The cooling time for is calculated on the basis of ambient temperature and the bead surface temperature. To increase the cooling capacity, an additional cooling fan is included in the IR-225 Plus.

D. Only authorized and certified welders by Georg Fischer Piping Systems are allowed to perform fusion on GF approved equipment.

E. The welding and the installation should be in accordance with Georg Fischer Piping Systems guidelines.

6.0 Quality

6.1 Production Conditions

Pipes, fittings, valves and accessories shall be manufactured in an environment equivalent to, or meeting the requirements of a Quality Assurance System such as ISO 9001.

6.2 Uniformity

Pipes, fittings, valves and welding machines shall be supplied from one manufacturer, namely Georg Fischer Piping Systems to ensure correct and proper jointing between components and uniform chemical and physical properties of the piping system.

6.3 Handling of Material

A. Material shall be stored in original packaging and protected from environmental damage until installation.

B. Pipe shall be supported sufficiently to prevent sagging. Care shall be taken not to gouge or otherwise notch the pipe in excess of 10% of the wall thickness.

6.4 Training, Certification and Installation

A. Site personnel, involved with ecoFIT (PE) piping installation, shall undergo training and certification from an authorized local institution prior to performing any jointing operations on site.

6.5 Testing

A. The system shall be tested in accordance with the manufacturers' recommendations.

B. Following is a general test procedure for Georg Fischer Piping Systems. It applies to most applications. Certain applications may require additional consideration. For further questions regarding your application, please contact your local GF representative.

6. All piping systems should be pressure tested prior to being placed into operation.
7. All pressure tests should be conducted in accordance with the appropriate building, plumbing, mechanical and safety codes for the area where the piping is being installed.
8. When testing plastic piping systems, all tests should be conducted hydrostatically and should not exceed the pressure

rating of the lowest rated component in the piping system (often a valve). Test the system at 150% of the designed operational pressure. (i.e.: If the system is designed to operate at 80PSI, then the test will be conducted at 120PSI.)

9. When hydrostatic pressure is introduced to the system, it should be done gradually through a low point in the piping system with care taken to eliminate any entrapped air by bleeding at high points within the system. This should be done in four stages, waiting ten minutes at each stage (adding ¼ the total desired pressure at each stage).
10. Allow one hour for system to stabilize after reaching desired pressure. After the hour, in case of pressure drop, increase pressure back to desired amount and hold for 30 minutes. If pressure drops by more than 6%, check system for leaks.

Note: If ambient temperature changes by more than 10°F during the test, a retest may be necessary.

Pressure/Temperature

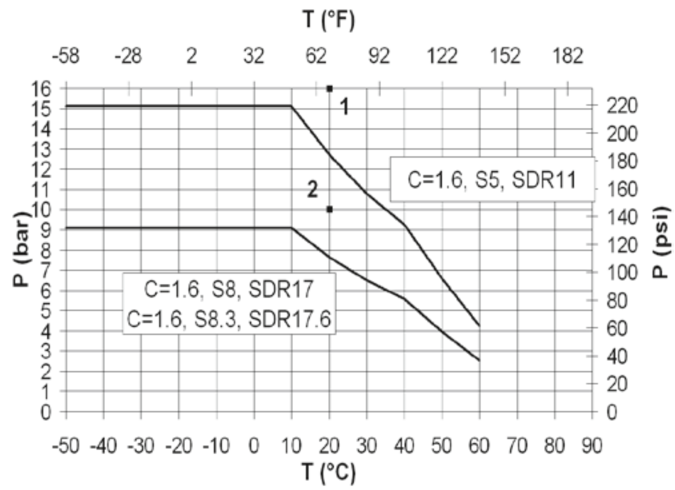
Pressure/temperature diagram for PE 100

The following pressure/temperature diagram for PE100 pipes and fittings is valid for a lifetime of 25 years. The design factor of 1.6 (respective 1.25) recommended by GF is incorporated.

It can be used for water or media resembling water, in other words, media which have no derating factor regarding the chemical resistance.

Remark: Please take into account the pressure/temperature diagrams for valves and special fittings. Because of the construction and/or sealing material used, differences are possible when compared with pipes and fittings. This information can be found in the planning fundamentals of the relevant types of valves, respectively special fittings.

In case of long-term applications at continuous pressure with temperatures above 40°C, please contact your GF representative.



1 Design Factor C = 1.25, S5, SDR11 for 20 °C water, 50 years
2 Design Factor C=1.25, S8.3, SDR17.6 and S8, SDR17 for 20°C water, 50 years
P Permissible pressure in bar, psi
T Temperature in °C, °F

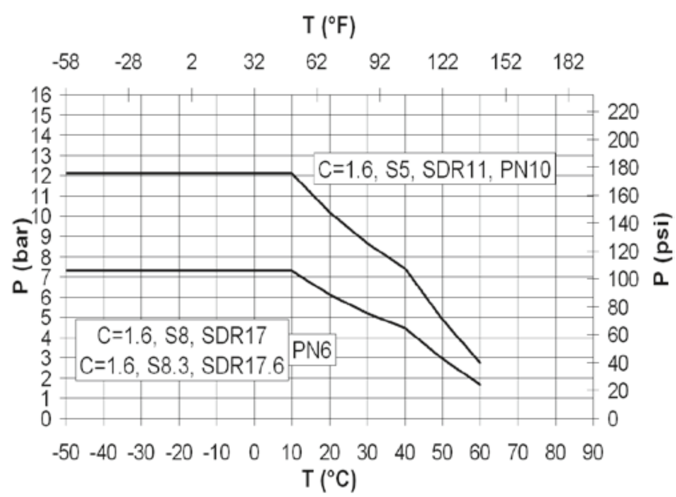
Pressure/temperature diagram for PE 80

The following pressure/temperature diagram for PE80 pipes and fittings is valid for a lifetime of 25 years.

The design factor of 1.6 recommended by GF is incorporated. It can be used for water or media resembling water, in other words, media which have no derating factor regarding the chemical resistance.

Remark: Please take into account the pressure/temperature diagrams for valves and special fittings. Because of the construction and/or sealing material used, differences are possible when compared with pipes and fittings. This information can be found in the planning fundamentals of the relevant types of valves, respectively special fittings.

In case of long-term applications at continuous pressure with temperatures above 40°C, please contact your GF representative.



P Permissible pressure in bar, psi
T Temperature in °C, °F

Comparison of nominal pressure for SDR17 and SDR17.6

Ascertaining the nominal pressure (PN)

According to the standard, the nominal pressure is a numeric measure of the size of a pipeline part, which refers to the mechanical properties of that pipeline part. Besides the geometric sizes such as SDR, the creep strength/dimensioning tension and the minimum design factor are also taken into consideration.

For plastic piping systems intended to carry water, the nominal pressure value indicates the maximum permitted operating pressure in bar, at a temperature of 20°C, and 50 years in water, referenced to the minimum value of the total (calculation) coefficients. It is calculated using the following equation:

[PN] = 10 • σ_S / [S] = 20 • σ_S / (SDR – 1) (σ_S in MPa, PNin bar)

Minimum required strength (MRS)

The value of σ_{LCL} at 20°C and 50 years in water, rounded down to the next value in the R10 standard series of numbers.

σ_{LCL} is understood to mean the equivalent stress ascertained for a given period and a given temperature from the time-dependent creep diagram. LCL stands for Lower Confidence Limit. The R10 standard series of numbers is a Renard standard series of numbers as per ISO 3 and ISO 497.

Design stress (σ_S)

The permitted stress for a particular application or operating conditions stated in megapascal. It is derived by dividing the MRS by coefficient C and is calculated as shown in the equation below:

σ_S = MRS / C

The calculated value is rounded down to the next value in the R10 standard series of numbers.

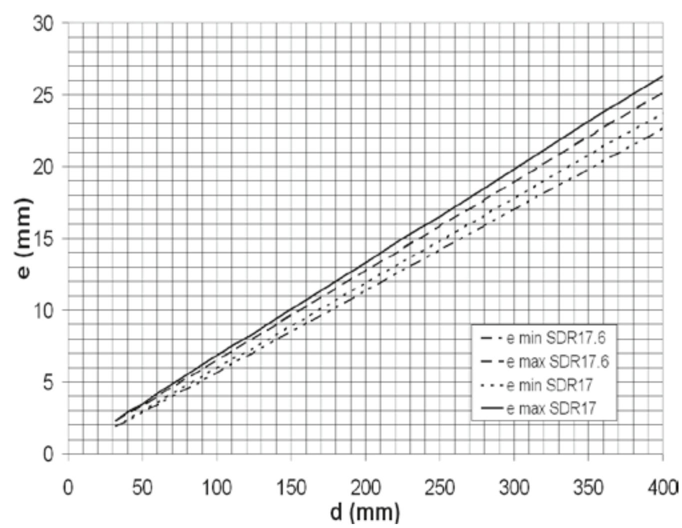
Total operating (calculation) coefficient (C)

A total coefficient having a value greater than one, which takes into account both the operating conditions and also the characteristics of the pipeline component that have not yet been entered into the lower confidence limit σ_{LCL}.

If we use the above definition to calculate the relevant nominal pressure for both SDR classes, the result for a PE 100 pipe is as follows:

SDR17	SDR17.6
MRS = 10 MPa	MRS = 10 MPa
C = 1.25 (minimum factor)	C = 1.25 (minimum factor)
σ = 8.0 MPa	σ = 8.0 MPa
PN = 10 bar	PN = 9.6 bar

For butt fusion the wall thickness gap may not exceed 10%. Looking at the differences of the wall thicknesses of SDR17 and SDR17.6 the resulting gap is much lower, that means butt fusion of both SDR's is
no problem.



d Outside pipe diameter
e Wall thickness

Calculating Pipe Size

Friction Loss Characteristics

Sizing for any piping system consists of two basic components: fluid flow design and pressure integrity design. Fluid flow design determines the minimum acceptable diameter of pipe and pressure integrity design determines the minimum wall thickness required. For normal liquid service applications an acceptable velocity in pipes is 7 ±3 (ft/sec), with a maximum velocity of 7 (ft/sec) at discharge points.

Pressure drops throughout the piping network are designed to provide an optimum balance between the installed cost of the piping system and the operating cost of the pumps.

Pressure loss is caused by friction between the pipe wall and the fluid, minor losses due to obstructions, change in direction, etc. Fluid pressure head loss is added to elevation change to determine pump requirements.

Hazen and Williams Formula

The head losses resulting from various water flow rates in plastic piping may be calculated by means of the Hazen and Williams formula (located in Figure 5):

C Factors

Tests made both with new pipe and pipe that had been in service revealed that (C) factor values for plastic pipe ranged between 160 and 165. Thus the factor of 150 recommended for water in the equation (located in Figure 5) is on the conservative side. On the other hand, the (C) factor for metallic pipe varies from 65 to 125, depending upon the time in service and the interior roughening. The obvious benefit is that with Polyethylene piping systems, it is often possible to use a smaller diameter pipe and still obtain the same or even lower friction losses.

Independent variable for these tests are gallons per minute and nominal pipe size (OD). Dependent variables for these tests are gallons per minute and nominal pipe size OD. Dependent variables are the velocity friction head and pressure drop per 100ft. of pipe, with the interior smooth.

Figure 25 - Hazen Williams Formula

V - Fluid Velocity (ft/sec)
ΔP - Head Loss (lb/in^2 /100 ft of pipe
ΔH - Head Loss (ft of water /100 ft of pipe)
L - Length of Pipe Run (ft)
L_e - Equivalent Length of Pipe for minor losses (ft)
D_i - Pipe Inside Diameter (ft)
Q - Fluid Flow (gal/min)
C - Constant for Plastic Pipes (conservative - 150)

Hazen and Williams Formula:

$$\Delta H = (L + L_e) \cdot \left(\frac{V}{1.318 \cdot C \cdot (\frac{D_i}{4})^{0.63}} \right)^{1.852}$$

Step 1: Solve for V:

$$V = \frac{4Q(0.1337)}{60\pi \left(\frac{D_i}{12} \right)^2}$$

Step 2: Solve for ΔH:

$$\Delta H = (L + L_e) \cdot \left(\frac{V}{1.318 \cdot C \cdot (\frac{D_i}{4})^{0.63}} \right)^{1.852}$$

Step 3: Solve for ΔP:

$$\Delta P = \Delta H / 2.31$$

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Surge Pressure (Water Hammer)

Surge Pressure (Water Hammer)

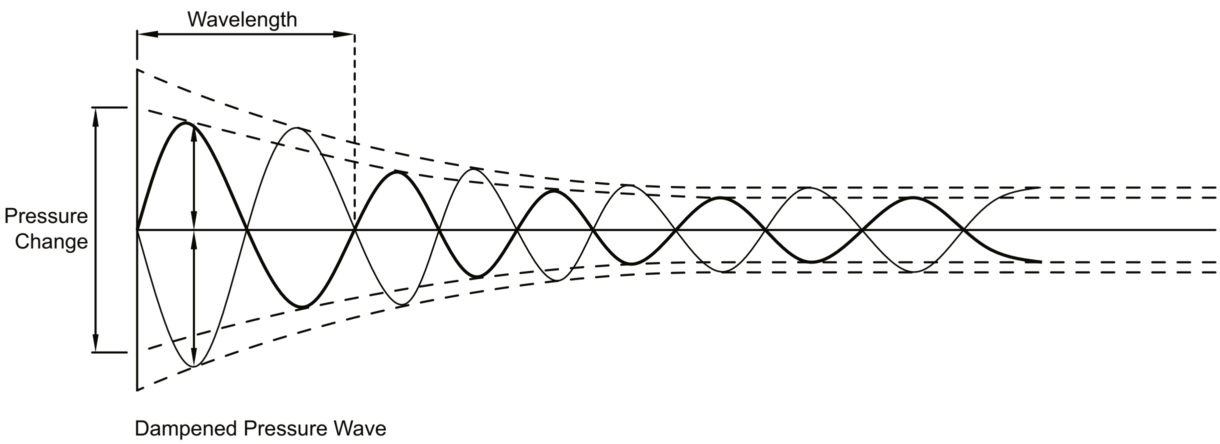
Surge pressure, or water hammer, is a term used to describe dynamic surges caused by pressure changes in a piping system. They occur whenever there is a deviation from the steady state, i.e.; when the velocity of the fluid is increased or decreased, and may be transient or oscillating. Waves of positive or negative pressure may be generated by any of the following:

- Opening or closing of a valve
- Pump startup or shutdown
- Change in pump or turbine speed
- Wave action in a feed tank
- Entrapped air

The pressure waves travel along at speeds limited by the speed of sound in the medium, causing the pipe to expand and contract. The energy carried by the wave is dissipated and the waves are progressively damped (see Figure 6).

The pressure excess to water hammer must be considered in addition to the hydrostatic load, and this total pressure must be sustainable by the piping system. In the case of oscillatory surge pressures, extreme caution is needed as surging at the harmonic frequency of the system could lead to catastrophic damage.

Figure 26 - Pressure Wave



The maximum positive or negative addition of pressure due to surging is a function of fluid velocity, fluid density, bulk fluid density and pipe dimensions of the piping system. It can be calculated using the following steps.

Step 1

Determine the velocity of the pressure wave in pipes.

V_w - Velocity of Pressure Wave (ft./sec)
K - Bulk Modules of Elasticity 3.19×10^5 (lb/in^2)
n_i - Conversion Factor 1/144 (ft^2/in^2)
δ - Fluid Density of Water 1.937 (slugs/ft^3)

$$V_w = \sqrt{\frac{K}{n_i \cdot \delta}}$$

Step 2

Critical time for valve closure.

$$t_c = \frac{2L}{V_w}$$

t_c - Time for Valve Closure (sec)
V_w - Velocity of Pressure Wave (ft/sec)
L - Upstream Pipe Length (ft)

Step 3

Maximum pressure increase; assume valve closure time is less than the critical closure time and fluid velocity goes to 0.

$$P_i = \delta \cdot V \cdot V_w \, n_i$$

P_i - Maximum Total Pressure (lb/in^2)
δ - Fluid Density ($slugs/ft^3$)
V - Fluid Velocity (ft/sec)
V_w - Velocity of Pressure Wave
n_i - Conversion Factor 1/144 (ft^2/in^2)

Special Consideration

Calculate the Maximum Instantaneous System Pressure.

$$P_{max} = P_i + P_s$$

P_{max} - Maximum System Operating Pressure (lb/in^2)
P_i - Maximum Pressure Increase (lb/in^2)
P_s - Standard System Operating Pressure (lb/in^2)

Cautionary Note

Caution is recommended if P_{max} is greater than the maximum system design pressure multiplied by a safety factor of 2x. Example: Pipe is rated at 200 psi. If P_{max} exceeds 400psi (200psi x 2 safety factor), then precaution must be implemented in case of maximum pressure wave (i.e. water hammer) to prevent possible pipe failure.

Step 4

Determine the Maximum System Pressure Increase with Gradual Valve Closure

P_g - Gradual Pressure Increase with Valve Closure (lb/in^2)
L - Upstream Pipe Length (ft.)
V - Fluid Velocity (ft./sec)
n_i - Conversion Factor 1/144 (ft^2/in^2)
t_v - Time of Valve Closure (sec)

$$P_g = \frac{2 \cdot \delta \cdot L \cdot V \cdot n_i}{t_v}$$

Example Problem

A water pipeline from a storage tank is connected to a master valve, which is hydraulically actuated with an electrical remote control. The piping system flow rate is 300 (gal/min) with a velocity of 4 (ft./sec); thus requiring a 6" nominal pipeline. The operating pressure of the system will be 50 (lb/in^2), the valve will be 500 (ft.) from the storage tank and the valve closing time is 2.0 (sec). Determine the critical time of closure for the valve, and the internal system pressure should the valve be instantaneously or suddenly closed vs. gradually closing the valve (10 times slower).

System Information		Other Information	
Material:	6" (160mm) PE100 SDR 11	Bulk Water Density (K)	3.19 x 10^5 (lb/in^2)
Flow Rate:	300 (gal/min)	Fluid Density (δ)	1.937 (slugs/ft^3)
Pipeline Length:	500 (ft)	Valve Closing Time	2.0 (sec)
Operating Pressure:	50 (lb/in^2)	Water Velocity	4.6 (ft/sec)

Step 1 - Velocity of Pressure Wave

Determine the Velocity of the Pressure Wave

- V_w - Velocity of Pressure Wave (ft/sec)
- K - Bulk Modules of Elasticity 3.19 × 10^5 (lb/in^2)
- n_i - Conversion Factor 1/144 (ft^2/in^2)
- δ - Fluid Density 1.937 (slugs/ft^3)

$$V_w = \sqrt{\frac{K}{n_i \cdot \delta}} \qquad V_w = \sqrt{\frac{3.19 \times 10^5}{\frac{1}{144} \cdot 1.937}}$$

$$V_w = 4870 \text{ (ft/sec)}$$

Step 2 - Critical Valve Closure Time

Determine the Critical Closure Time

- t_c - Critical Closure Time (sec)
- V_w - Velocity of Pressure Wave 4870 (ft/sec)
- L - Upstream Pipe Length 500 (ft)

$$t_c = \frac{2L}{V_w} \qquad t_c = \frac{2 \cdot 500}{4870}$$

$$t_c = 0.2 \text{ (sec)}$$

Step 3 - Maximum Pressure Increase

Determine the Maximum Pressure Increase;

Assume: Valve Closure Time < Critical Closure Time t_c and Fluid Velocity goes to 0.

- P_i - Maximum Pressure Increase (lb/in^2)
- δ - Fluid Density 1.937 (slugs/ft^3)
- V - Fluid Velocity 4 (ft/sec)
- V_w - Velocity of Pressure Wave 4870 (ft/sec)
- n_i - Conversion Factor 1/144 (ft^2/in^2)

$$P_i = \delta \cdot V \cdot V_w \, n_i \qquad P_i = \frac{1.937 \cdot 4 \cdot 4870}{144}$$

$$P_i = 262 \text{ (lb/in}^2\text{)}$$

Consideration: Maximum Instantaneous System Pressure

Determining the Maximum Instantaneous System Pressure: Caution is recommended if P_{max} is greater than the Maximum System Operating Pressure multiplied by a 2x Service Factor.

P_{max} - Maximum Instantaneous Operating Pressure (lb/in^2)
P_i - Valve Pressure (instantaneous) (lb/in^2)
P_s - Standard System Operating Pressure (lb/in^2)

$$P_{max} = P_i + P_s \qquad P_{max} = 262 + 50$$

$$P_{max} = 312\ (lb/in^2)$$

In this case, 6" PE100 SDR11 pipe is rated at 200psi. Therefore, the system design is within safety limits.

Step 4 - Maximum Change in Pressure with Gradual Valve Closure

Determine the Maximum Change in System Pressure with Gradual Valve Closure (2 Second Close Time).

P_g - Maximum Gradual Pressure Change (lb/in^2)
t_v - Valve Closing Time 2 (sec)
L - Upstream Pipe Length 500 (ft)
V - Fluid Velocity 4 (ft/sec)
n_i - Conversion Factor 1/144 (ft^2/in^2)
δ - Fluid Density 1.937 ($slugs/ft^3$)

$$P_g = \frac{2 \cdot \delta \cdot L \cdot V \cdot n_i}{t_v}$$

$$P_g = \frac{2 \cdot 1.937 \cdot 500 \cdot 4 \cdot \frac{1}{144}}{2}$$

$$P_g = 26.9\ (lb/in^2)$$

Expansion/Contraction

Allowing for Length Changes in PE Pipelines

All materials expand and/or contract. Variations in temperature cause greater length changes in thermoplastic materials than in metals. In the case of above ground, wall or duct mounted pipe work, particularly where subjected to varying working temperatures, it is necessary to make suitable provision for length changes in order to prevent additional stresses.

Calculation and Positioning of Flexible Sections

It is possible to take advantage of the very low modulus of elasticity (Figure 7) of PE by including special sections of pipe which compensate thermal length changes. The length of the flexible section mainly depends upon the pipe diameter and the extent of the length change to be compensated. In order to simplify planning and installation, the third influencing factor—the pipe wall temperature —is not taken into account, particularly as installation usually takes place in the temperature range between 37°F and 77°F.

Where the pipe work changes direction or branches off, there is always a natural flexible section.

There are two primary methods of controlling or compensating for thermal expansion of plastic piping systems: taking advantage of offsets and changes of direction in the piping and expansion loops.

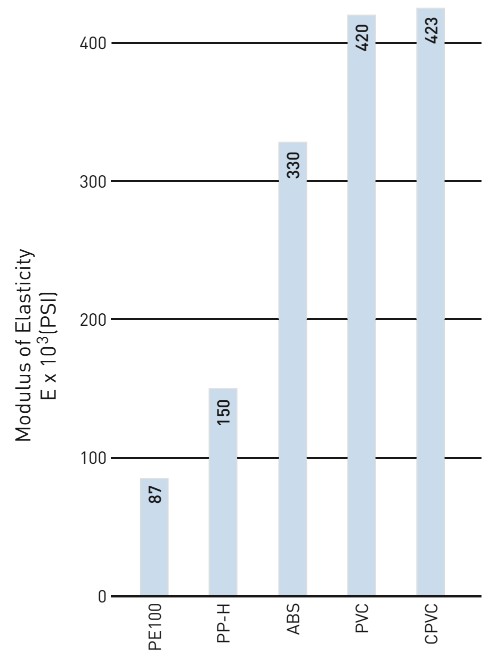


Figure 7 - Modulus of Elasticity of Plastics

Type 1 - Offsets/Changes in Direction

Most piping systems have occasional changes in directions which will allow the thermally included length changes to be taken up in offsets of the pipe beyond the bends. Where this method is employed, the pipe must be able to float except at anchor points.

Figure 27 - Changes in Direction

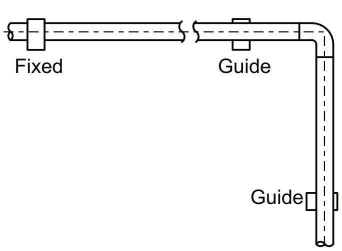
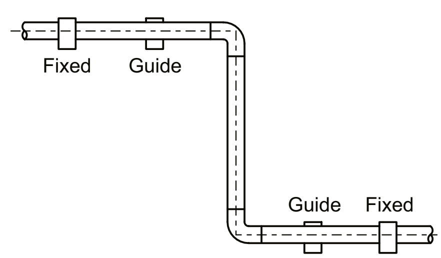


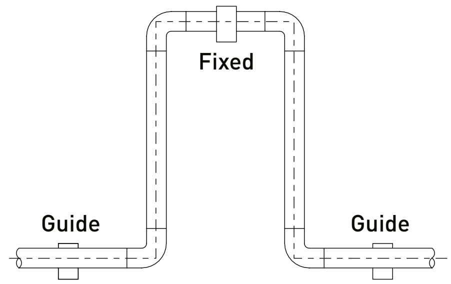
Figure 28 - Offsets



Type 2 -Expansion Loops

For expansion loops the flexible section is broken into two offsets close together. By utilizing the flexible members between the legs and 4 elbows the “a” length is slightly shorter than the “a” in the standalone offset.

Figure 29 - Expansion Loop



Determining the Length Change (ΔL) (Example 1)

In order to determine the length of flexible section (a) required, the extent of the length change must be ascertained first of all, by means of the following formula where

$\Delta L = L \cdot \Delta T \cdot \boldsymbol{\delta}$

(inch) = (inch) · (°F) · (inch/inch°F)

ΔL = Length change in inches

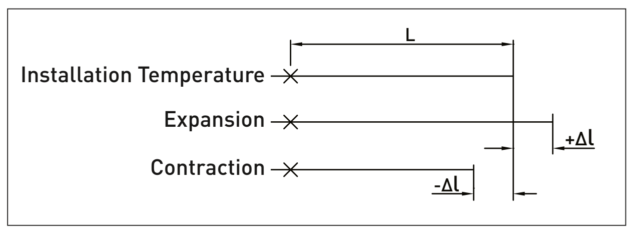
L = Length in inches of the pipe or pipe section where the length change is to be determined

ΔT = Difference between installation temperature and maximum or minimum working temperature in °F

$\boldsymbol{\delta}$ = Coefficient of linear expansion - 0.000110 in/in°F

Important:

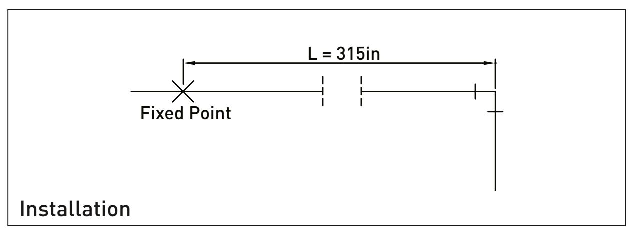
If the operating temperature is higher than the installation temperature, then the pipe becomes longer. If, on the other hand, the operating temperature is lower than the installation temperature, then the pipe contracts its length. The installation temperature must therefore be incorporated into the calculation, as well as the maximum and minimum operating temperatures.

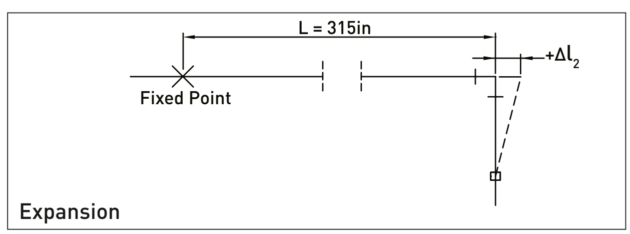


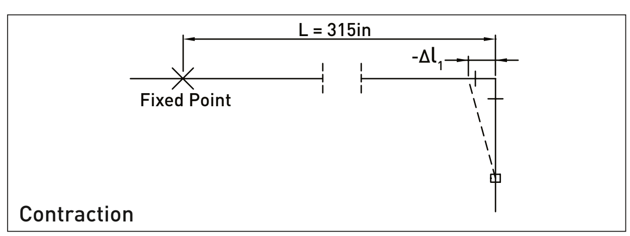
Problem

The procedure is explained using a coolant pipe as an example:
Length of the pipe from the fixed point to the branch where:

- Length change is to be taken up: L = 315in
- Installation temperature: T_v = 73°F
- Temperature of the coolant: T_1= 40°F
- Temperature when defrosting and cleaning: T_2= 95°F
- Material: 12” PE100 SDR 11







Difference in Contraction Temperature

$\Delta T_1 = T_v - T_1 = 73°F - 40°F = 33°F$

Difference in Expansion Temperature

$\Delta T_2 = T_2 - T_v = 95°F - 73°F = 22°F$

Contraction during service with coolant

$-\Delta L_1 = L \cdot \Delta T_1 \cdot \delta = 315in \cdot 33 \cdot (0.000110) = 1.14in$

Expansion during defrosting and cleaning

$+\Delta L_2 = L \cdot \Delta T_2 \cdot \delta = 315in \cdot 22 \cdot (0.000110) = 0.76in$

Table 21 - Length Change of Straight Pipe (ΔL) in Inches

(relative to install temperature and operating temperatures)

Temperature Change in (°F)	Length of Pipe Section (ft)									
	5	10	15	20	25	30	35	40	45	50
5			0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
10		0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7
15	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
20	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3
25	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7
30	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
35	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1	2.3
40	0.3	0.5	0.8	1.1	1.3	1.6	1.8	2.1	2.4	2.6
45	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
50	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	3.3
55	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6
60	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
65	0.4	0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.9	4.3
70	0.5	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.2	4.6
80	0.5	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.8	5.3
90	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.3	5.9
100	0.7	1.3	2.0	2.6	3.3	4.0	4.6	5.3	5.9	6.6

Temperature Change in (°F)	Length of Pipe Section (ft)									
	55	60	65	70	75	80	85	90	95	100
5	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.7
10	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.3
15	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
20	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6
25	1.8	2.0	2.1	2.3	2.5	2.6	2.8	3.0	3.1	3.3
30	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
35	2.5	2.8	3.0	3.2	3.5	3.7	3.9	4.2	4.4	4.6
40	2.9	3.2	3.4	3.7	4.0	4.2	4.5	4.8	5.0	5.3
45	3.3	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.6	5.9
50	3.6	4.0	4.3	4.6	5.0	5.3	5.6	5.9	6.3	6.6
55	4.0	4.4	4.7	5.1	5.4	5.8	6.2	6.5	6.9	7.3
60	4.4	4.8	5.1	5.5	5.9	6.3	6.7	7.1	7.5	7.9
65	4.7	5.1	5.6	6.0	6.4	6.9	7.3	7.7	8.2	8.6
70	5.1	5.5	6.0	6.5	6.9	7.4	7.9	8.3	8.8	9.2
80	5.8	6.3	6.9	7.4	7.9	8.4	9.0	9.5	10.0	10.6
90	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.7	11.3	11.9
100	7.3	7.9	8.6	9.2	9.9	10.6	11.2	11.9	12.5	13.2

Determining the Length of the Flexible Section (a) (Example 2)

The values required to determine the length of the flexible (a) section are: The maximum length change ΔL in comparison with the zero position during installation, (which can be either an expansion or a contraction), and the pipe diameter (d).

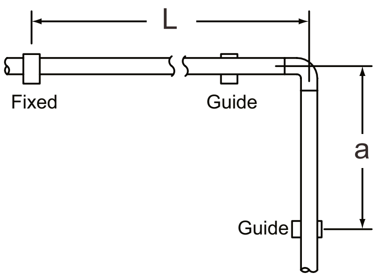
If values ΔL and (d) are known, Table 22 shows the length of flexible section (a) required.

Formula for Flexible Sections (a)

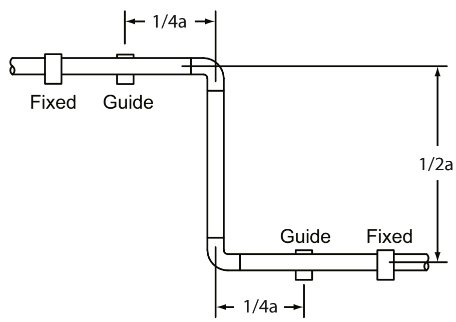
$$a = k\sqrt{\Delta L \cdot d}$$

a = Length of Flexible Section
k = Constant (k = 26)
ΔL = Change in Length
d = Outside Diameter of Pipe

Change of Direction



Offset



Expansion

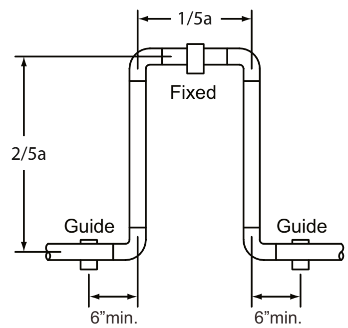


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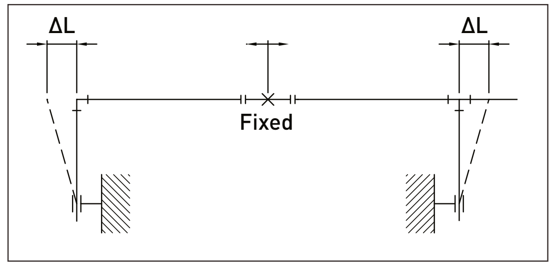
Table 22 - Length of Flexible Sections (a) in Inches

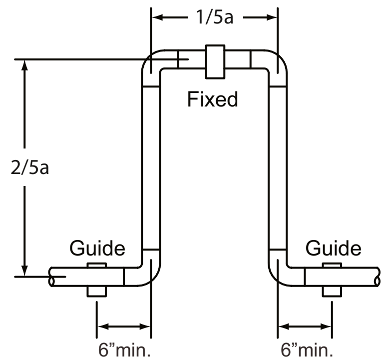
Length Change - ΔL (in)	Nominal Pipe Diameter 63 mm	75 mm	90 mm	110 mm	160 mm	200 mm	250 mm
0.1	13	14	15	17	21	23	26
0.2	18	20	22	24	29	33	36
0.3	22	24	27	30	36	40	45
0.4	26	28	31	34	41	46	52
0.5	29	32	35	38	46	52	58
0.6	32	35	38	42	51	57	63
0.7	34	37	41	45	55	61	68
0.8	37	40	44	48	58	65	73
0.9	39	42	46	51	62	69	77
1.0	41	45	49	54	65	73	82
2.0	58	63	69	77	92	103	115
3.0	71	77	85	94	113	126	141
4.0	82	89	98	108	131	146	163
5.0	92	100	109	121	146	163	182
6.0	100	109	120	133	160	179	200
7.0	108	118	129	143	173	193	216
8.0	116	126	138	153	185	206	231
9.0	123	134	147	162	196	219	245
10.0	129	141	155	171	206	231	258

Installation Hints

The length changes in pipe sections should be clearly controlled by the arrangement of fixed brackets. It is possible to distribute the length changes in pipe sections using proper positioning of fixed brackets (see adjoining examples).



If it is not possible to include a flexible section at a change of direction or branch, or if extensive length changes must be taken up in straight sections of pipe work, expansion loops may also be installed. In this case, the length change is distributed over two flexible sections.



Note:
To eliminate bilateral expansion thrust blocks are recommended at intersections.

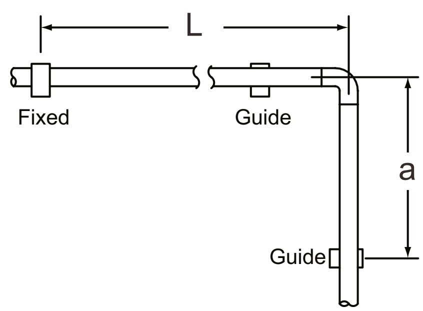
For a 2" expansion loop, (taking Example 2), the length change of 1.44in would require a flexible section length of a = 49.1in.

Pre-Stressing

In particularly difficult cases, where the length changes are large and acting in one direction only, it is also possible to pre-stress the flexible section during installation, in order to reduce the length of a. This procedure is illustrated in the following example:

Installation conditions

L = 315in.
d = 12in. (nominal)
Installation temperature: 73°F
Max. working temperature: 110°F
Material: PE



1 . Length change
$+\Delta L = L \cdot \Delta T \cdot \delta = 315 \cdot 37 \cdot (0.000110) = 1.28$in.

2. Flexible section required to take up length change of ΔL = 1.28in according to Table 7:

a = approx. 105in.

3. If, on the other hand, the flexible section is pre-stressed to ΔL/2, the required length of flexible section is reduced to approx. 77in. The length change, starting from the zero position, then amounts to
$\pm\Delta L/2 = 1.28\text{in}/2 = 0.64$in.

a = approx. 77in. (per Table 7)

In special cases, particularly at high working temperatures, pre-stressing of a flexible section improves the appearance of the pipeline in service, as the flexible section is less strongly deflected.

Installation

The Incorporation of Valves

Valves should be mounted as directly as possible; they should be formed as fixed points. The actuating force is thus transmitted directly, and not through the pipeline. The length changes, starting from the valve, are to be controlled as described previously.

Note:

- All Plastic Valves that include additional accessories, actuators or items that will increase load or stress on the piping system must be fully supported either independently or by mounting points located on the valve body.
- All metal valves must be supported. Should metal valves not be adequately supported, there is a significant risk of stress fatigue and possible system failure.
- For safe mounting of plastic valves, Georg Fischer valves are equipped with metal threaded inserts for direct mounted installation.

Vibration Dampeners

There are two principal ways to control stress caused by vibration. You can usually observe the stability of the system during initial operation and add restraints or supports as required to reduce effects of equipment vibration. Where necessary restraint fittings may be used to effectively hold pipe from lifting or moving laterally.

In special cases where the source of vibration is excessive (such as that resulting from pumps running unbalanced), an elastomeric expansion joint or other vibration absorber may be considered. This may be the case at pumps where restricting the source of vibration is not recommended.

Pipe Bracket Support Centers and Fixation of Plastic Pipelines

General Pipe Supports and Brackets

PE pipelines need to be supported at specific intervals, depending upon the material, the average pipe wall temperature, the specific gravity of the medium, and the diameter and wall thickness of the pipe. The determination of the pipe support centers has been based on the permissible amount of deflection of the pipe between two brackets. The pipe bracket centers given in Table 8 are calculated on the basis of a permissible deflection of max. 0.01 inch (0.25 cm) between two brackets.

Pipe Bracket Spacing in the Case of Fluids with Specific Gravity ≤ 1.0 (62.4 Lb/Ft^3)

Where fluids with a specific gravity exceeding 1g/cm^3 are to be conveyed, the pipe bracket centers given in Table 8 must be divided by the specific gravity of the solution.

Example: 20" pipe carrying media with a specific gravity of 1.6 = 13ft divided by 1.6 = approx. 8.1ft centers.

Installation of Closely Spaced Pipe Brackets

A continuous support may be more advantageous and economical than pipe brackets for small diameter horizontal pipe work, especially in a higher temperature range. Installation in a "V" or "U" shaped support made of metal or heat-resistant plastic material has proven satisfactory.

Pipe Bracket Requirements

When mounted, the inside diameter of the bracket must be greater than the outside diameter of the pipe, in order to allow length changes of the pipe at the specified points. The inside edges of the pipe bracket must be formed in such a way that no damage to the pipe surface is possible. George Fischer pipe brackets meet these requirements. They are made of plastic and may be used under rugged working conditions and also in areas where the pipe work is subjected to the external influence of aggressive atmospheres or media. Georg Fischer pipe brackets are suitable for PE, PVC, CPVC, PP and PVDF pipes.

Arrangement of Fixed Brackets

If the pipe bracket is positioned directly beside a fitting, the length change of the pipeline is limited to one direction only (one-sided fixed point).

If it is, as in most cases, necessary to control the length change of the pipeline in both directions, the pipe bracket must be positioned between two fittings. The pipe bracket must be robust and firmly mounted in order to take up the force arising from the length change in the pipeline. Hanger type brackets are not suitable as fixed points.

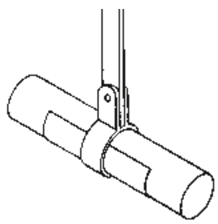
Hangers

There are many hangers and supports suitable for use in plastic piping systems, although some may require modification. It is important in a plastic piping system to provide a wide load-bearing surface and that any restraints recognize that plastic piping systems are somewhat notch sensitive. Also, if the thermal movement of a plastic piping system might cause the pipeline to abrade on a rough surface, such as concrete, some means of isolating the pipe should be considered. Wear pads of plastic can be fashioned from the pipe or wooden isolators can be used.

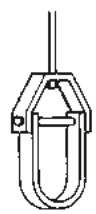
It is also important to recognize the thermal movement in any plastic piping system and the hangers and support structures should allow for, or direct, the expansion that may be in a particular system. Pipe hangers must be carefully aligned and must have no rough or sharp edges that could contact and potentially damage the pipe. The hanger or support system should recognize the thermal expansion in a plastic pipe system and pipe should be allowed to move.

Vertical lines must also be supported at intervals so that the fittings at the lower end of a riser or column are not overloaded. The supports should not exert a compressive strain on the pipe, such as riser–type clamps that squeeze the pipe. A double bolt type, in conjunction with using a fitting shoulder, may afford the best method for supporting vertical systems.

Figure 30 - Recommended Hangers for Plastic Piping Systems

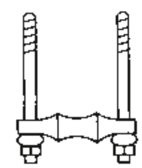


Band Hanger with Protective Sleeve

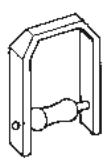


Clevis

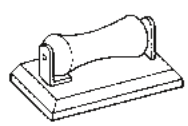
Adjustable Solid Ring Swivel Type



Single Pipe Roller



Roller Hanger



Pipe Roll and Plate

Pipe Sleeves

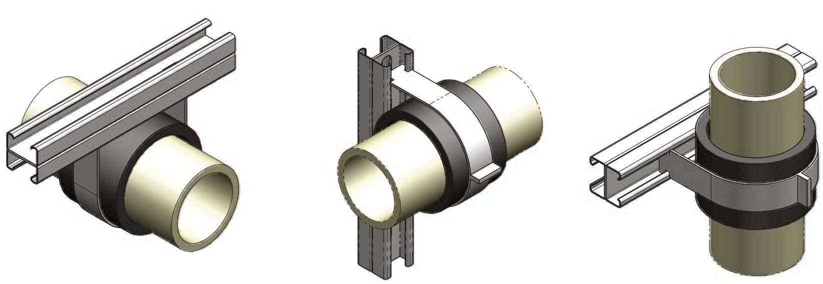


Figure 31 - Pipe Sleeves

Figure 32 - Typical Brackets and Anchor Arrangements

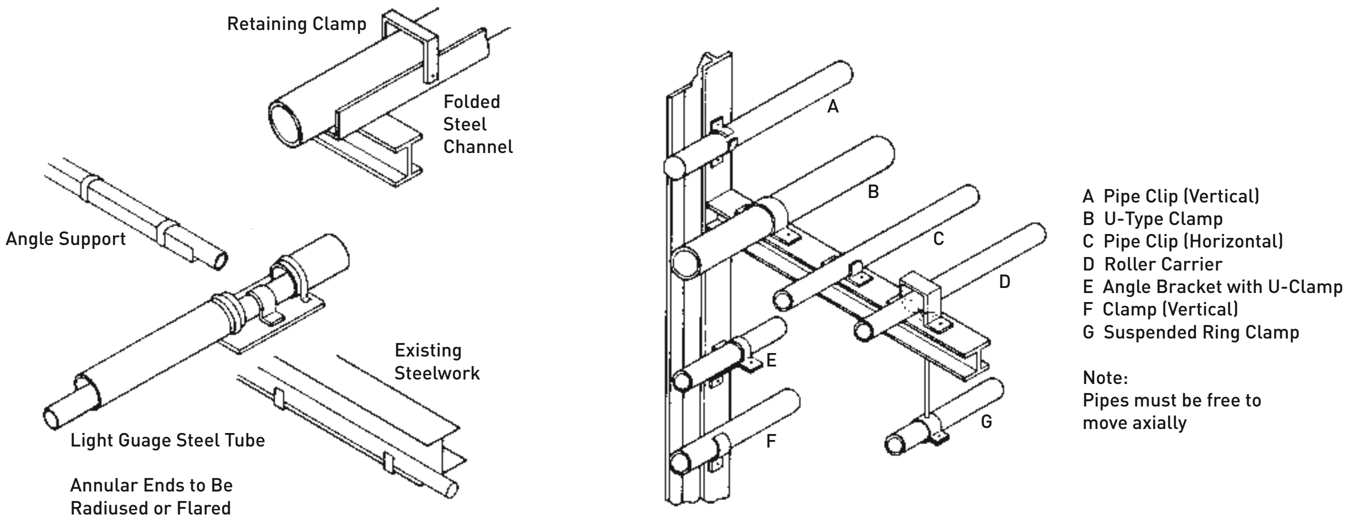


Table 23 - General Pipe Supports and Brackets for Liquids with a Specific Gravity ≤ 1.0 (62.4 lb/ft^3)

Nominal Pipe Size (mm)	Pipe Bracket Intervals L (ft.) for pipes SDR11					Pipe Bracket Intervals L (ft.) for pipes SDR17				
	≤65 °F	85 °F	105 °F	125 °F	140 °F	≤65 °F	85 °F	105 °F	125 °F	140 °F
63	3.9	3.8	3.4	3.3	3.0					
90	4.9	4.8	4.4	4.1	3.8	4.5	4.3	4.0	3.7	3.4
110	5.4	5.2	4.9	4.8	4.3	4.9	4.8	4.5	4.3	3.9
160	6.7	6.4	6.1	5.7	5.2	6.1	5.8	5.5	5.2	4.8
225	7.5	7.2	6.9	6.6	6.2	6.9	6.6	6.3	6.0	5.7
250	8.5	8.2	7.9	7.5	6.9	7.8	7.5	7.2	6.9	6.3

Restraint

Restraint is rigidly anchoring the pipe runs to the building structure at appropriate places so that thermally-induced dimension changes will be replaced by thermally-induced stresses. This can be accomplished by use of adequately strong clamps or supports along with a properly engineered pipe clamp interface to hold the pipe in place. For horizontal runs, braced clamp type hangers may be used. For floor penetrations, extension riser clamps may be used.

Underground installation in properly backfilled trenches may be considered to be a restrained system and not subject to thermally-induced dimensional changes. For more details, see the FM section.

It should be noted that two unique properties of PE4710 make for the success of these methods of handling thermal expansion. PE4710 is not subject to mechanical stress cracking. It can be stressed for long periods of time in what might be considered unfriendly environments without harm. In addition, PE4710 has an extremely high fatigue life. Its "self-hinge" characteristics are well known and the piping materials will stand repeated drastic flexures without harm.

Cold Weather Installations

In general, it is good practice when possible, to maintain an ambient temperature above 40˚F (4˚C). However, low temperature fusions to -10˚F (-23˚C) are easily accomplished utilizing automatic temperature compensation capable fusion machines (MSA 330/340) from GF.

Note: Material and fusion machines must be the same temperature prior to fusion. This can be achieved when components and machines are in the same environment for 1 hour per ½" material wall thickness.

For further information, please consult you local sales representative.

Flammability and Fire Rated Construction

The fire protection officials and code officials are becoming sensitive to the smoke generation and flammability of plastic materials used in building construction, and plastic piping is naturally included in these concerns. To satisfy the fire safety requirements set out by the authorities, the engineers and architects must have a better understanding of the plastics used in piping, appropriate test methods and means of protection against fire dangers attributed to plastic piping.

To put this into the proper perspective, the architect, engineer and administrative authority must realize that, in the vast majority of cases, fires commonly start and continue to develop in occupied areas of a building and not within the walls and chases where plastic piping is more commonly installed.

Laboratory Fire Tests

The following are common laboratory tests conducted on small samples of plastic material and are useful in characterizing and comparing different plastics. However, these tests are of only limited use in predicting the behavior of the materials in real fire situations.

ASTM D635 - Rate of Burning and/or Extent and Time of Burning of Self Supporting Plastics in a Horizontal Position

One half-inch wide by five-inch long horizontal specimens are exposed to a burner flame. The time of burning and distance burned are recorded. The results are reported as measured, except in the case where the minimum values apply (time of burning is "less than five seconds" and the minimum extent of burning is "less than one quarter-inch").

UL94 - Standard for Safety of Flammability of Plastic Materials

One half-inch wide by five-inch long vertical specimens are exposed repeatedly to a burner flame. Time of burning, possible dripping of burning particles and afterglow are observed. Results are reported as V-0, V-1 or V-2, depending on test results.

ASTM D2843 - Density of Smoke from the Burning or Decomposition of Plastics

A one-quarter inch by one inch by one inch sample is exposed to a propane burner flame and light transmission through the smoke generated by the burning plastic is measured with a standard lamp and photocell for four minutes. Results are reported as light absorption and smoke density.

ASTM D2863 - Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)

A one-eighth inch by one-quarter inch by three to six inch long specimen is burned in a variable oxygen-nitrogen mixture to determine the percentage oxygen required to maintain combustion.

Large Scale Tests

These tests are run on full-sized wall or floor (floor-ceiling) assemblies or on large material specimens. They are intended to determine the response of varying construction methods and materials in actual fire conditions.

ASTM E119 - Fire Tests of Building Construction and Materials

NFPA251

- UL263
- UBC43-1

Wall sections of at least 100 square feet in size are attached as the front wall of a furnace and exposed to a flaming environment. The temperature rises according to a standard time temperature curve. The test specimen may or may not be exposed to vertical or horizontal loads. The specimen, after exposure, may be subjected to a high pressure hose stream to determine its integrity after exposure.

This test is universally accepted as the method of rating wall assemblies for fire resistance as related to time of exposure. Ratings may be 1, 2, 3 or 4 hours, depending on the time for the temperature to rise to not more than 250°F (121°C) above its initial temperature on the non-exposed face. Floor and floor-ceiling assemblies of at least 180 square feet in size are also tested per ASTM E119 as the roofs of a floor-ceiling furnace, and rated on the basis of the time for the temperature to rise 250°F (121°C) above the initial temperature on the unexposed face, as for walls.

ASTM E814 - Fire Tests of Through-Penetration Fire Stops

This test method (published Spring 1982) is essentially identical to the ASTM E119 test except that it is intended to determine the ability of fire-stopping methods and devices to maintain the fire rating (integrity) of rated fire-resistive walls, floors or floor-ceiling assemblies which are penetrated by pipe, conduits or cables.

ASTM E84 - Surface Burning Characteristics of Building Materials

- NFPA255
- UL723
- UBC42-1

As stated, this test is intended for testing of surface finish materials which are capable of supporting themselves or of being supported other than by support on the under-side of the test specimen. Samples are 20 inches (min.) wide by 24 feet long and are attached to the roof of an 18 inch by 30 foot furnace.

Burning characteristics of the samples are stated as percentage of the rate of burning of red oak.

This test, being specifically aimed at testing surface finish materials, is recognized as not applying to plastic pipe by those who understand the test method and application environment. The National Fire Protection Association has stated that the test is not to be applied to plastic pipe and that the pipe should be tested as a component of a wall or floor assembly in the ASTM E119 test, where the materials are most commonly used.

Fire Protection Methods for Wall Penetration and Return Air Plenums

For fire resistance rated wall penetrations, penetrations through horizontal assemblies, etc. use listed and approved firestopping with ratings determined by ASTM E814 or UL1479 for use with plastic piping.

GF Piping Systems
Tel. (714) 731-8800, Toll Free (800) 854-4090
Fax (800) 426-7188
us.ps@georgfischer.com
www.gfpiping.com

Argentina / Southern South America
Georg Fischer Central Plastics
Sudamérica S.R.L.
Buenos Aires, Argentina
Phone +54 11 4512 02 90
gfcentral.ps.ar@georgfischer.com
www.gfps.com/ar

Australia
George Fischer Pty Ltd
Riverwood NSW 2210 Australia
Phone +61 (0) 2 9502 8000
australia.ps@georgfischer.com
www.gfps.com/au

Austria
Georg Fischer
Rohrleitungssysteme GmbH
3130 Herzogenburg
Phone +43 (0) 2782 856 43-0
austria.ps@georgfischer.com
www.gfps.com/at

Belgium / Luxembourg
Georg Fischer NV/SA
1070 Bruxelles/Brüssel
Phone +32 (0) 2 556 40 20
be.ps@georgfischer.com
www.gfps.com/be

Brazil
Georg Fischer Sist. de Tub. Ltda.
04795-100 São Paulo
Phone +55 (0) 11 5525 1311
br.ps@georgfischer.com
www.gfps.com/br

Canada
Georg Fischer Piping Systems Ltd
Mississauga, ON L5T 2B2
Phone +1 (905) 670 8005
Fax +1 (905) 670 8513
ca.ps@georgfischer.com
www.gfps.com/ca

China
Georg Fischer Piping Systems Ltd
Shanghai 201319
Phone +86 21 3899 3899
china.ps@georgfischer.com
www.gfps.com/cn

Denmark / Iceland
Georg Fischer A/S
2630 Taastrup
Phone +45 (0) 70 22 19 75
info.dk.ps@georgfischer.com
www.gfps.com/dk

Finland
Georg Fischer AB
01510 VANTAA
Phone +358 (0) 9 586 58 25
Fax +358 (0) 9 586 58 29
info.fi.ps@georgfischer.com
www.gfps.com/fi

France
Georg Fischer SAS
95932 Roissy Charles de Gaulle Cedex
Phone +33 (0) 1 41 84 68 84
fr.ps@georgfischer.com
www.gfps.com/fr

Germany
Georg Fischer GmbH
73095 Albershausen
Phone +49 (0) 7161 302-0
info.de.ps@georgfischer.com
www.gfps.com/de

India
Georg Fischer Piping Systems Ltd
400 076 Mumbai
Phone +91 224007 2001
branchoffice@georgfischer.com
www.gfps.com/in

Italy
Georg Fischer S.p.A.
20063 Cernusco S/N (MI)
Phone +39 02 921 861
it.ps@georgfischer.com
www.gfps.com/it

Japan
Georg Fischer Ltd
556-0011 Osaka,
Phone +81 (0) 6 6635 2691
jp.ps@georgfischer.com
www.gfps.com/jp

Korea
Georg Fischer Piping Systems
271-3 Seohyeon-dong Bundang-gu
Seongnam-si, Gyeonggi-do
Seoul 463-824
Phone +82 31 8017 1450
Fax +82 31 8017 1454
kor.ps@georgfischer.com
www.gfps.com/kr

Malaysia
George Fischer (M) Sdn. Bhd.
40460 Shah Alam, Selangor Darul Ehsan
Phone +60 (0) 3 5122 5585
my.ps@georgfischer.com
www.gfps.com/my

Mexico / Northern Latin America
Georg Fischer S.A. de C.V.
Apodaca, Nuevo Leon
CP66636 Mexico
Phone +52 (81) 1340 8586
Fax +52 (81) 1522 8906
mx.ps@georgfischer.com
www.gfps.com/mx

Middle East
Georg Fischer
Piping Systems (Switzerland) Ltd
Dubai, United Arab Emirates
Phone +971 4 289 49 60
gcc.ps@georgfischer.com
www.gfps.com/int

Netherlands
Georg Fischer N.V.
8161 PA Epe
Phone +31 (0) 578 678 222
nl.ps@georgfischer.com
www.gfps.com/nl

New Zealand
Georg Fischer Ltd
13 Jupiter Grove, Upper Hutt 5018
PO Box 40399, Upper Hutt 5140
Phone +64 (0) 4 527 9813
nz.ps@georgfischer.com
www.gfps.com/nz

Norway
Georg Fischer AS
1351 Rud
Phone +47 67 18 29 00
no.ps@georgfischer.com
www.gfps.com/no

Poland
Georg Fischer Sp. z o.o.
05-090 Sekocin Nowy
Phone +48 (0) 22 31 31 0 50
poland.ps@georgfischer.com
www.gfps.com/pl

Romania
Georg Fischer
Piping Systems (Switzerland) Ltd
020257 Bucharest - Sector 2
Phone +40 (0) 21 230 53 80
ro.ps@georgfischer.com
www.gfps.com/int

Russia
Georg Fischer
Piping Systems (Switzerland) Ltd
Moscow 125047
Phone +7 495 258 60 80
ru.ps@georgfischer.com
www.gfps.com/ru

Singapore
George Fischer Pte Ltd
11 Tampines Street 92, #04-01/07
528 872 Singapore
Phone +65 6747 0611
sgp.ps@georgfischer.com
www.gfps.com/sg

Spain / Portugal
Georg Fischer S.A.
28046 Madrid
Phone +34 (0) 91 781 98 90
es.ps@georgfischer.com
www.gfps.com/es

Sweden
Georg Fischer AB
117 43 Stockholm
Phone +46 (0) 8 506 775 00
info.se.ps@georgfischer.com
www.gfps.com/se

Switzerland
Georg Fischer
Rohrleitungssysteme (Schweiz) AG
8201 Schaffhausen
Phone +41 (0) 52 631 30 26
ch.ps@georgfischer.com
www.gfps.com/ch

Taiwan
Georg Fischer Co., Ltd
San Chung Dist., New Taipei City
Phone +886 2 8512 2822
Fax +886 2 8512 2823
www.gfps.com/tw

United Kingdom / Ireland
George Fischer Sales Limited
Coventry, CV2 2ST
Phone +44 (0) 2476 535 535
uk.ps@georgfischer.com
www.gfps.com/uk

USA / Caribbean
Georg Fischer LLC
Irvine, CA 92618
Phone +1 (714) 731-8800
Toll Free +1 (800) 854-4090
us.ps@georgfischer.com
www.gfpiping.com

Vietnam
George Fischer Pte Ltd
136E Tran Vu, Ba Dinh District, Hanoi
Phone +84 4 3715 3290
Fax +84 4 3715 3285

International
Georg Fischer
Piping Systems (Switzerland) Ltd
8201 Schaffhausen/Switzerland
Phone +41 (0) 52 631 30 03
Fax +41 (0) 52 631 28 93
info.export@georgfischer.com
www.gfps.com/int

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