Technical Handbook

GF PE100 Industrial Polyethylene

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GEORG FISCHER
PIPING SYSTEMS

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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, we offer three joining techniques in our product range: Infrared Butt Fusion, Contact Butt Fusion and Electrofusion.

The advantages of Polyethylene include

- Lower installed cost*
- Low weight
- Excellent impact resistance (-58°F through 140°F)
- 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) degrade or limit physical properties of other thermoplastic piping systems.

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

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.

Like all thermoplastics, PE shows a higher thermal expansion than metal. Our PE100 has a coefficient of linear thermal expansion of 1.10 x 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.

At higher temperatures, the tensile strength and stiffness of the material are reduced. Therefore, please consult the pressure-temperature diagram (**Figure 3**) for further information.

Combustion Behavior

Polyethylene is considered a flammable plastic with oxygen index amounts ≤17%. (Materials that burn with less than 21% of oxygen in the air are considered to be flammable).

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.

Complete System of Pipe, Valves and Fittings

Georg Fischer's Polyethylene (PE100) piping system easily transitions between PP and PVC and is available with pipes, fittings and valves in sizes from 2" to 36" (SDR11), 2" to 36" (SDR17).

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

This system includes all commonly required pressure pipe fittings, including threaded adaptors and flanges for ease of mating to equipment or other piping materials. Ball valves are available in sizes up to 2" (PP), diaphragm valves up to 4" (PP) and butterfly valves in sizes up to 36" (metal external bodies with elastomer seals). Other valves, including check valves and metering valves are also available for this system.

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 Georg Fischer's PE100 are available and commonly used in today's demanding applications. These include socket electrofusion, conventional butt fusion, and Infrared (IR) butt fusion.

IR Plus® Infrared Butt Fusion Joining

IR Plus® Infrared Butt Fusion Joining is an ideal method to join IR fusion fittings in the size range of up to 8" to achieve the maximum joint consistency. Regular butt fusion can also be used to join IR and contact butt fusion fittings in the size range up to 36".

Using the process-controlled fusion machinery, high-strength butt fusion joints can be made with many advantages over the conventional, pressure type butt fusion methods. A non-contact IR heating plate is used, along with a predetermined overlap to join the pipe (or fitting) ends together eliminating the potential for operator error. Reliable, reproducible, high strength joints with smaller internal and external beads can be achieved.

Advantages

- Non-contact heating
- Smaller internal and external beads repeatability
- Low stress joint
- Ease of operation due to fully automated fusion machinery
- Automatic fusion joining record (if desired) using optional printer or PC download

Contact (Conventional) Butt Fusion Joining

Georg Fischer's Contact Butt Fusion joining is an alternative to IR Butt Fusion for smaller dimension pipe and fittings 8" and below, while also being an industry standard fusion method through 36".

Butt fusion pipe and fittings both have the same 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

Electrofusion Joining

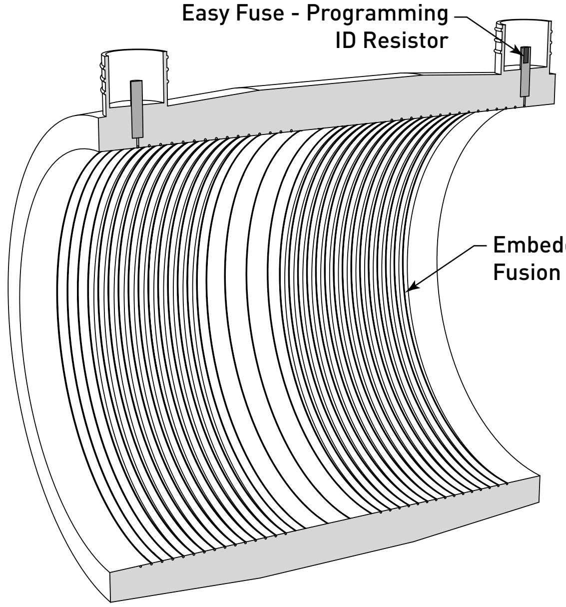
Electrofusion joining is an excellent solution for final connection of prefab spool assemblies within a system: hard-to-reach field joints, places where a mechanical connection poses a process risk, or for future connections onto an existing system.

GF's advanced electrofusion technology uses the resistance of the coil as well as ambient conditions to ensure the highest 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



General Properties (PE100)

Material Data

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

Mechanical

Properties	Unit	PE100	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	32,000	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

Thermodynamics

Properties	Unit	PE100	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-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	ASTM Test
Volume Resistivity	Ohm-cm	2.6×10^{16}	ASTM D991
Water Absorption	%	<1%	
Poisson's Ratio @ 73°F		0.38	
ASTM Cell Classification		445574C	ASTM D3350
Industry Standard Color		Black	RAL 9005
NSF Potable Water Approved		Yes	NSF-61

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

Specification

PART 2 - PRODUCTS – MATERIALS

2.01 POLYETHYLENE PIPE AND FITTINGS

A. Polyethylene Pipe shall be manufactured from a high density copolymer resin meeting the requirements of ASTM 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 shall conform to the requirements of ASTM D2837 for hydrostatic design basis. Pipe shall be supplied capped off at the extruder and supplied in 20ft lengths.

B. Polyethylene Fittings shall be manufactured from a high density bimodal resin meeting the requirements of ASTM D3035. Fittings in sizes through 36" shall be butt fusion type, suitable for heat fusion joining. All fittings through 8" shall have spigot lengths compatible for infrared (IR) joining technology. All fittings through 36" shall be compatible 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 flanged shall be manufactured to SDR 11 dimensions with a pressure rating of 150 psi when measured at 68°F. 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).

C. All components of the pipe and fitting system shall conform to the following applicable ASTM Standards, D3035, D638, D2837, 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 full traceability.

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 PE100 Industrial Polyethylene as manufactured by Georg Fischer LLC.

2.02 VALVES

A. Ball Valves: Ball valves shall be full port true union type with polyethylene true union ends constructed of the same material as pipe and fittings. Valves shall have double o-ring stem seals, seats shall be PTFE and O-rings shall be EPDM or FPM with adjustable reverse thread seal carrier.

Valves shall be Type 546 True-Union Ball Valves as manufactured by GF Piping Systems LLC.

B. Diaphragm Valves: Diaphragm valves shall be constructed with polyethylene true union ends constructed of the same material as pipe and fittings. Valves shall have EPDM or FPM o-ring seals, EPDM or PTFE Seal configurations and EPDM backing.

Valves shall be Type 314 Diaphragm Valves as manufactured by GF Piping Systems LLC.

Diaphragm valves 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 LLC to ensure proper system operation.

PART 3 - EXECUTION

3.1 HANDLING

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

3.2 INSTALLATION

A. System components shall be installed by factory trained and certified installers using approved joining equipment as outlined below:

An on-site installation training shall be conducted by personnel who are certified by the manufacturer. Training topics shall include all aspects of product installation (storage, set up, support spacing, fusion process, machine care, testing procedure, etc.). At the conclusion of the training, all installers will be given a written certification test and will be required to prepare and complete one fusion joint of the type being implemented on the project. Upon successful completion of said test, the installer will be issued a certification card verifying that they have met the requirements of the manufacturer with regards to knowledge of proper product installation and testing methods.

B. All fusion equipment shall be equipped with Computer Numerically Controlled (CNC) fusion capabilities and have the ability to document and record fusion parameters. All fusion records shall be electronically transferable. Installers shall use approved joining equipment as outlined below:

For IR PLUS® Fusion Installation – IR63Plus, IR225 Plus, Infrared Butt Fusion Machines

For Butt Fusion Installations – GF160, GF250, GF315, GF500 with SUVI 50-400 controllers per manufacturer specifications for specific field piping parameters.

For Electrofusion - Easy Fuse Electrofusion equipment as manufactured by GF Piping Systems, LLC

3.3 TESTING

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

Following is a general test procedure for Georg Fischer plastic piping. 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 piping systems should be pressure tested prior to being placed into operational service.

2 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.

3 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.

4 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 1/4 the total desired pressure at each stage).

5 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

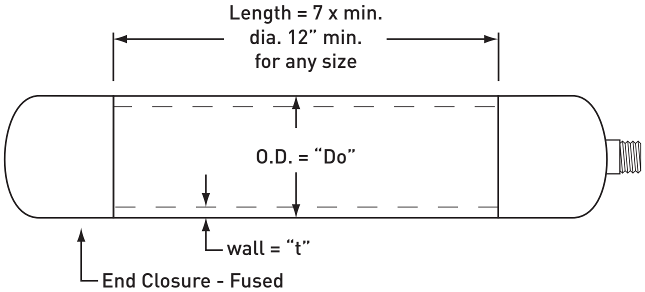
To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends **(Figure 1)** and subjected to various internal pressures, to produce circumferential stresses that will predict failure in from 10hrs to 50yrs. The test is run according to **ASTM D1598**, "Standard Test 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**) 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

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

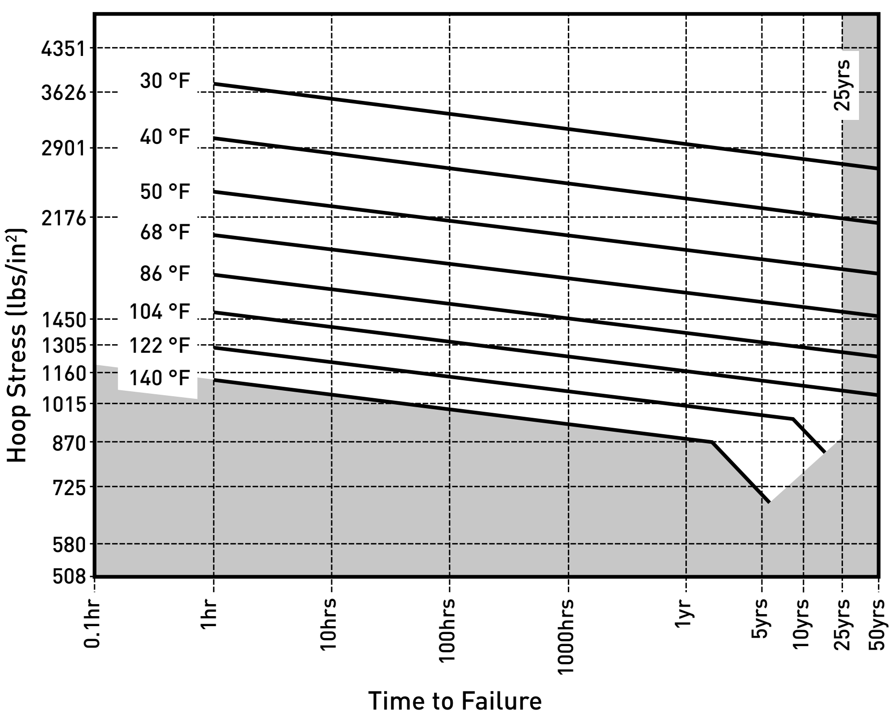
Where *a* and *b* are constants describing the slope and intercept of the curve, and T and S are time-to-failure and stress, respectively.

Figure 1



The regression curve may be plotted on log-log paper as shown in **Figure 2** 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 2



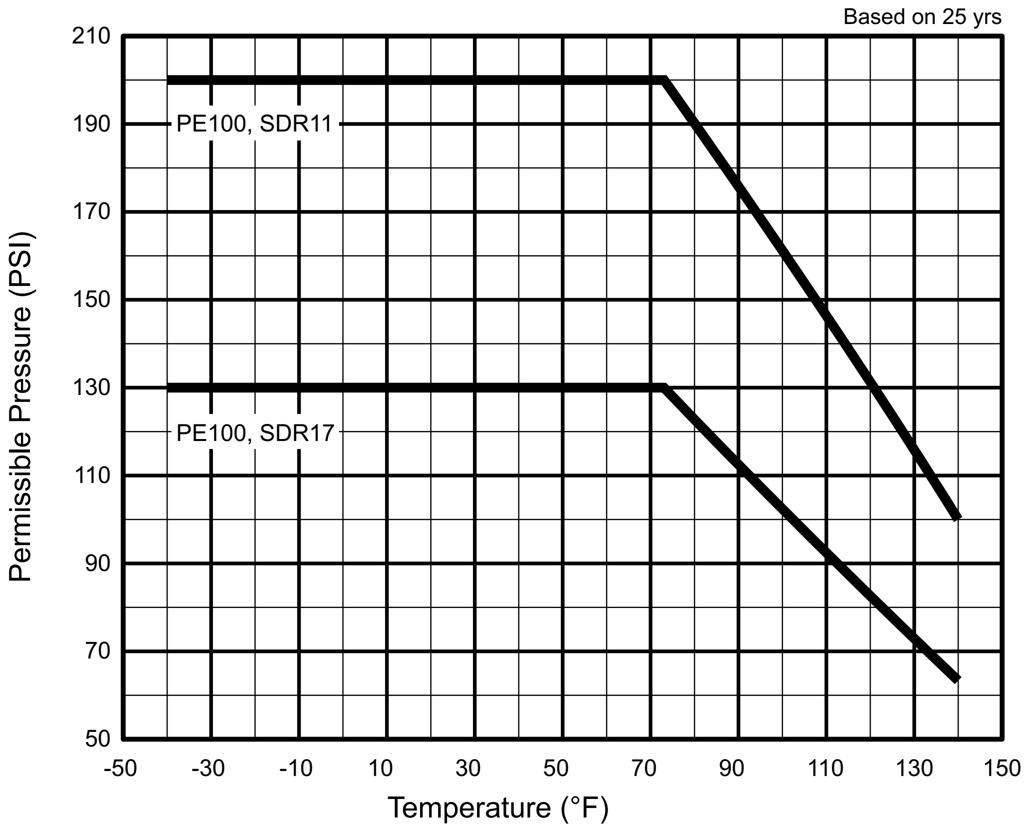
Regression Curve - Stress/Time to failure for PE100 Pipe

Outside Recommended Operating Parameters

Working Temperature and Pressures for PE100 Pipe and Fittings

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

Figure 3



Dimensional Pipe Size - SDR vs Schedule Rating

Pipe Size Comparison

Table 1

	Weight of PE100 Pipe (lbs/ft)		Outside Dimensions			Wall Thickness			Inside Dimensions		
Nominal Outside Diameter (inch)	SDR11	SDR17	SDR 11	SDR 17	PVC Sch80	SDR 11	SDR 17	PVC Sch80	SDR 11	SDR 17	PVC Sch80
2	0.64	0.43	2.375	2.375	2.375	0.216	0.140	0.218	1.943	2.095	1.939
3	1.39	0.94	3.500	3.500	3.500	0.318	0.206	0.300	2.864	3.088	2.900
4	2.31	1.55	4.500	4.500	4.500	0.409	0.265	0.337	3.682	3.970	3.826
6	5.00	3.36	6.625	6.625	6.625	0.602	0.390	0.432	5.421	5.845	5.761
8	8.47	5.69	8.625	8.625	8.625	0.784	0.507	0.500	7.057	7.611	7.625
10	13.16	8.83	10.750	10.750	10.750	0.977	0.632	0.593	8.796	9.486	9.564
12	18.51	12.43	12.750	12.750	12.750	1.159	0.750	0.687	10.432	11.250	11.376
14	22.32	14.98	14.000	14.000	14.000	1.273	0.824	0.750	11.454	12.352	12.500
16	29.15	19.57	16.000	16.000	16.000	1.455	0.941	0.843	13.090	14.118	14.314
18	36.89	24.77	18.000	18.000	—	1.636	1.059	—	14.728	15.882	—
20	45.54	30.58	20.000	20.000	—	1.818	1.176	—	16.364	17.648	—
22	55.10	37.00	22.000	22.000	—	2.000	1.294	—	18.000	19.412	—
24	65.58	44.03	24.000	24.000	—	2.182	1.412	—	19.636	21.176	—
26	76.96	54.67	26.000	26.000	—	2.364	1.529	—	21.272	22.942	—
28	89.26	59.93	28.000	28.000	—	2.545	1.647	—	22.910	24.706	—
30	102.47	68.80	30.000	30.000	—	2.727	1.765	—	24.546	26.470	—
32	116.58	78.28	32.000	32.000	—	2.909	1.882	—	26.182	28.236	—
36	147.55	99.07	36.000	36.000	—	3.273	2.118	—	29.454	31.764	—

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 4):**

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 4)** 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 4

- 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:

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

Flow Rate vs. Friction Loss - SDR11

Table 2

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	2" (SDR11)			3" (SDR11)			4" (SDR11)			6" (SDR11)			
10	1.08	0.28	0.12										**10**
15	1.62	0.59	0.25	0.75	0.09	0.04							**15**
20	2.16	1.00	0.43	1.00	0.15	0.07							**20**
30	3.25	2.11	0.91	1.49	0.32	0.14	0.90	0.09	0.04				**30**
40	4.33	3.60	1.56	1.99	0.54	0.24	1.21	0.16	0.07				**40**
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	**50**
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	**60**
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	**70**
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	**80**
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	**90**
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	**100**
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	**125**
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	**150**
175				8.72	8.38	3.63	5.27	2.47	1.07	2.43	0.38	0.16	**175**
200				9.96	10.73	4.65	6.03	3.16	1.37	2.78	0.48	0.21	**200**
250				12.45	16.23	7.03	7.53	4.78	2.07	3.48	0.73	0.32	**250**
300				14.94	22.75	9.85	9.04	6.70	2.90	4.17	1.02	0.44	**300**
350							10.55	8.91	3.86	4.87	1.36	0.59	**350**
400							12.05	11.41	4.94	5.56	1.74	0.75	**400**
450							13.56	14.20	6.15	6.26	2.16	0.94	**450**
500										6.95	2.63	1.14	**500**
550										7.65	3.13	1.36	**550**
600										8.34	3.68	1.59	**600**
700										9.73	4.90	2.12	**700**
800										11.12	6.27	2.72	**800**
900										12.51	7.80	3.38	**900**

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR11

Table 2 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	8" (SDR11)			10" (SDR11)			12" (SDR11)			14" (SDR11)			
100	0.82	0.04	0.02										100
150	1.23	0.08	0.03	0.79	0.03	0.01							150
200	1.64	0.13	0.06	1.06	0.05	0.02	0.75	0.02	0.01				200
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	250
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	300
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	350
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	400
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	450
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	500
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	550
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	600
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	700
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	800
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	900
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	1000
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	1200
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	1400
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	1600
1800				9.51	2.67	1.16	6.76	1.17	0.50	5.61	0.74	0.32	1800
2000				10.56	3.25	1.41	7.51	1.42	0.61	6.23	0.90	0.39	2000
2400				12.67	4.55	1.97	9.01	1.99	0.86	7.47	1.26	0.55	2400
2800				14.79	6.06	2.62	10.51	2.64	1.14	8.72	1.68	0.73	2800
3200							12.01	3.38	1.46	9.97	2.15	0.93	3200
3500							13.14	3.99	1.73	10.90	2.53	1.10	3500
4000										12.46	3.25	1.41	4000
4500										14.01	4.04	1.75	4500

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR11

Table 2 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	16" (SDR11)			18" (SDR11)			20" (SDR11)			22" (SDR11)			
300	0.72	0.01	0.01										300
400	0.95	0.02	0.01	0.75	0.01	0.01							400
500	1.19	0.04	0.02	0.94	0.02	0.01	0.76	0.01	0.01				500
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	600
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	700
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	800
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	900
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	1000
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	1200
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	1400
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	1600
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	1800
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	2000
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	2400
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	2800
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	3200
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	3500
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	4000
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	5000
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	5500
6000				11.30	2.02	0.88	9.15	1.21	0.52	7.57	0.76	0.33	6000
7000				13.18	2.69	1.17	10.68	1.61	0.70	8.83	1.01	0.44	7000
8000							12.21	2.07	0.89	10.09	1.30	0.56	8000
9000							13.73	2.57	1.11	11.35	1.62	0.70	9000
10000										12.61	1.96	0.85	10000

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR11

Table 2 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	24" (SDR11)			26" (SDR11)			28" (SDR11)			30" (SDR11)			
700	0.74	0.01	0.00										700
800	0.85	0.01	0.01	0.72	0.01	0.00							800
900	0.95	0.01	0.01	0.81	0.01	0.00	0.70	0.01	0.00				900
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	1000
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	1200
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	1400
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	1600
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	1800
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	2000
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	2400
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	2800
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	3200
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	3500
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	4000
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	5000
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	5500
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	6000
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	7000
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	8000
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	9000
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	10000
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	11000
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	12000
13000				11.74	1.42	0.61	10.12	0.99	0.43	8.82	0.71	0.31	13000
14000				12.64	1.63	0.70	10.90	1.13	0.49	9.49	0.81	0.35	14000
15000							11.68	1.29	0.56	10.17	0.92	0.40	15000
17500							13.62	1.71	0.74	11.87	1.22	0.53	17500
20000										13.56	1.57	0.68	20000

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR11

Table 2 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	32" (SDR11)			36" (SDR11)			
1200	0.72	0.01	0.00				1200
1400	0.83	0.01	0.00				1400
1600	0.95	0.01	0.00	0.75	0.01	0.00	1600
1800	1.07	0.01	0.01	0.85	0.01	0.00	1800
2000	1.19	0.02	0.01	0.94	0.01	0.00	2000
2400	1.43	0.02	0.01	1.13	0.01	0.01	2400
2800	1.67	0.03	0.01	1.32	0.02	0.01	2800
3200	1.91	0.04	0.02	1.51	0.02	0.01	3200
3500	2.09	0.05	0.02	1.65	0.03	0.01	3500
4000	2.38	0.06	0.03	1.88	0.03	0.01	4000
5000	2.98	0.09	0.04	2.35	0.05	0.02	5000
5500	3.28	0.10	0.05	2.59	0.06	0.03	5500
6000	3.58	0.12	0.05	2.83	0.07	0.03	6000
7000	4.17	0.16	0.07	3.30	0.09	0.04	7000
8000	4.77	0.21	0.09	3.77	0.12	0.05	8000
9000	5.36	0.26	0.11	4.24	0.15	0.06	9000
10000	5.96	0.32	0.14	4.71	0.18	0.08	10000
11000	6.56	0.38	0.16	5.18	0.21	0.09	11000
12000	7.15	0.44	0.19	5.65	0.25	0.11	12000
13000	7.75	0.52	0.22	6.12	0.29	0.13	13000
14000	8.34	0.59	0.26	6.59	0.33	0.14	14000
15000	8.94	0.67	0.29	7.06	0.38	0.16	15000
17500	10.43	0.89	0.39	8.24	0.50	0.22	17500
20000	11.92	1.15	0.50	9.42	0.65	0.28	20000
22500	13.41	1.42	0.62	10.60	0.80	0.35	22500
25000				11.77	0.98	0.42	25000
27500				12.95	1.16	0.50	27500

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR17

Table 3

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	2" (SDR11)			3" (SDR11)			4" (SDR11)			6" (SDR11)			
10	0.93	0.19	0.08										10
15	1.40	0.41	0.18	0.64	0.06	0.03							15
20	1.86	0.69	0.30	0.86	0.10	0.05							20
30	2.79	1.46	0.63	1.29	0.22	0.10	0.78	0.07	0.03				30
40	3.72	2.49	1.08	1.71	0.38	0.16	1.04	0.11	0.05				40
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	50
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	60
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	70
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	80
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	90
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	100
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	125
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	150
175				7.50	5.81	2.52	4.54	1.71	0.74	2.09	0.26	0.11	175
200				8.57	7.44	3.22	5.18	2.19	0.95	2.39	0.33	0.14	200
250				10.71	11.25	4.87	6.48	3.31	1.43	2.99	0.50	0.22	250
300				12.85	15.77	6.83	7.78	4.64	2.01	3.59	0.71	0.31	300
350				15.00	20.98	9.08	9.07	6.18	2.67	4.19	0.94	0.41	350
400							10.37	7.91	3.43	4.78	1.20	0.52	400
450							11.66	9.84	4.26	5.38	1.50	0.65	450
500							12.96	11.96	5.18	5.98	1.82	0.79	500
550										6.58	2.17	0.94	550
600										7.18	2.55	1.11	600
700										8.37	3.40	1.47	700
800										9.57	4.35	1.88	800
900										10.76	5.41	2.34	900
1000										11.96	6.58	2.85	1000

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR17

Table 3 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	8" (SDR11)			10" (SDR11)			12" (SDR11)			14" (SDR11)			
100	0.71	0.03	0.01										**100**
150	1.06	0.05	0.02	0.68	0.02	0.01							**150**
200	1.41	0.09	0.04	0.91	0.03	0.01	0.65	0.01	0.01				**200**
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	**250**
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	**300**
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	**350**
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	**400**
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	**450**
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	**500**
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	**550**
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	**600**
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	**700**
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	**800**
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	**900**
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	**1000**
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	**1200**
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	**1400**
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	**1600**
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	**1800**
2000				9.08	2.25	0.97	6.46	0.98	0.42	5.36	0.62	0.27	**2000**
2400				10.90	3.15	1.37	7.75	1.38	0.60	6.43	0.87	0.38	**2400**
2800				12.71	4.20	1.82	9.04	1.83	0.79	7.50	1.16	0.50	**2800**
3200				14.53	5.37	2.33	10.33	2.34	1.01	8.57	1.49	0.64	**3200**
3500							11.30	2.77	1.20	9.37	1.76	0.76	**3500**
4000							12.91	3.54	1.53	10.71	2.25	0.97	**4000**
4500										12.05	2.80	1.21	**4500**

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR17

Table 3 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	16" (SDR11)			18" (SDR11)			20" (SDR11)			22" (SDR11)			
300	0.61	0.01	0.00										300
400	0.82	0.02	0.01	0.65	0.01	0.00							400
500	1.02	0.02	0.01	0.81	0.01	0.01	0.66	0.01	0.00				500
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	600
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	700
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	800
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	900
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	1000
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	1200
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	1400
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	1600
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	1800
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	2000
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	2400
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	2800
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	3200
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	3500
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	4000
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	5000
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	5500
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	6000
7000				11.34	1.87	0.81	9.18	1.12	0.48	7.59	0.70	0.30	7000
8000				12.96	2.39	1.03	10.49	1.43	0.62	8.67	0.90	0.39	8000
9000							11.81	1.78	0.77	9.76	1.12	0.48	9000
10000							13.12	2.16	0.94	10.84	1.36	0.59	10000
11000										11.93	1.62	0.70	11000

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR17

Table 3 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	24" (SDR11)			26" (SDR11)			28" (SDR11)			30" (SDR11)			
700	0.64	0.01	0.00										**700**
800	0.73	0.01	0.00	0.62	0.01	0.00							**800**
900	0.82	0.01	0.00	0.70	0.01	0.00	0.60	0.00	0.00				**900**
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	**1000**
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	**1200**
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	**1400**
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	**1600**
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	**1800**
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	**2000**
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	**2400**
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	**2800**
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	**3200**
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	**3500**
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	**4000**
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	**5000**
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	**5500**
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	**6000**
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	**7000**
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	**8000**
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	**9000**
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	**10000**
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	**11000**
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	**12000**
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	**13000**
14000				10.87	1.13	0.49	9.37	0.78	0.34	8.16	0.56	0.24	**14000**
15000				11.64	1.28	0.55	10.04	0.89	0.39	8.75	0.64	0.28	**15000**
17500							11.71	1.19	0.51	10.20	0.85	0.37	**17500**
20000							13.39	1.52	0.66	11.66	1.09	0.47	**20000**
22500										13.12	1.35	0.58	**22500**

Note: Caution should be taken when velocities fall within the shaded levels.

Flow Rate vs. Friction Loss - SDR17

Table 3 - continued

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	32" (SDR11)			36" (SDR11)			
1200	0.61	0.00	0.00				1200
1400	0.72	0.01	0.00	0.57	0.00	0.00	1400
1600	0.82	0.01	0.00	0.65	0.00	0.00	1600
1800	0.92	0.01	0.00	0.73	0.01	0.00	1800
2000	1.02	0.01	0.00	0.81	0.01	0.00	2000
2400	1.23	0.02	0.01	0.97	0.01	0.00	2400
2800	1.43	0.02	0.01	1.13	0.01	0.01	2800
3200	1.64	0.03	0.01	1.30	0.02	0.01	3200
3500	1.79	0.03	0.01	1.42	0.02	0.01	3500
4000	2.05	0.04	0.02	1.62	0.02	0.01	4000
5000	2.56	0.06	0.03	2.02	0.03	0.01	5000
5500	2.82	0.07	0.03	2.23	0.04	0.02	5500
6000	3.07	0.09	0.04	2.43	0.05	0.02	6000
7000	3.59	0.11	0.05	2.83	0.06	0.03	7000
8000	4.10	0.15	0.06	3.24	0.08	0.04	8000
9000	4.61	0.18	0.08	3.64	0.10	0.04	9000
10000	5.12	0.22	0.10	4.05	0.12	0.05	10000
11000	5.64	0.26	0.11	4.45	0.15	0.06	11000
12000	6.15	0.31	0.13	4.86	0.17	0.08	12000
13000	6.66	0.36	0.15	5.26	0.20	0.09	13000
14000	7.17	0.41	0.18	5.67	0.23	0.10	14000
15000	7.69	0.47	0.20	6.07	0.26	0.11	15000
17500	8.97	0.62	0.27	7.09	0.35	0.15	17500
20000	10.25	0.79	0.34	8.10	0.45	0.19	20000
22500	11.53	0.99	0.43	9.11	0.56	0.24	22500
25000	12.81	1.20	0.52	10.12	0.68	0.29	25000
27500				11.14	0.81	0.35	27500
30000				12.15	0.95	0.41	30000

Note: Caution should be taken when velocities fall within the shaded levels.

Friction Loss Through Fittings

Table 4

Fitting or Valve Type	90 Elbow (Molded)	90 Elbow (Fabricated)	45 Elbow (Molded)	45 Elbow (Fabricated)	Tee (Molded)	Tee (Fabricated)	Branch Wye (Fabricated)	Ball Valve, Full Bore, Full Open	For Industry Standard Elastomer Butterfly Valve, Full Open
SDR 11/17									
Nominal Pipe Size (inch)	**Equivalent Length of Pipe (ft.)**								
2	2.6	3.9	1.3	1.9	3.2	4.9	9.7	0.5	6.5
3	3.8	5.7	1.9	2.9	4.8	7.2	14.3	0.7	9.5
4	4.9	7.4	2.5	3.7	6.1	9.2	18.4	0.9	12.3
6	7.2	10.8	3.6	5.4	9.0	13.6	27.1	1.4	18.1
8	9.4	14.1	4.7	7.1	11.8	17.6	35.3	1.8	23.5
10	11.7	17.6	5.9	8.8	14.7	22.0	44.0	2.2	29.3
12	13.9	20.9	7.0	10.4	17.4	26.1	52.2	2.6	34.8
14		22.9		11.5		28.6	57.3	2.9	38.2
16		26.2		13.1		32.7	65.5	3.3	43.6
18		29.5		14.7		36.8	73.6	3.7	49.1
20		32.7		16.4		40.9	81.8	4.1	54.5
22		36.0		18.0		45.0	90.0	4.5	60.0
24		39.3		19.6		49.1	98.2	4.9	65.5
26		42.5		21.3		53.2	106.4	5.3	70.9
28		45.8		22.9		57.3	114.6	5.7	76.4
30		49.1		24.5		61.4	122.7	6.1	81.8
32		52.4		26.2		65.5	130.9	6.5	87.3
36		58.9		29.5		73.6	147.3	7.4	98.2

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 (ft^2)
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

Material: **10" PE100 SDR 11**
Outer Diameter: **10.75 (in)**
Inside Diameter: **8.679 (in)**

Q - Flow Rate (gpm)
A - Section Area Pipe 0.4108 full = **0.2104** ½full (ft^2)
n - Manning Friction Factor **0.009**
R - Hydraulic Radius of pipe **0.1833** (ft)
S - Hydraulic Gradient - Slope **1/8** (in/ft) = 0.0104
Slope **1/4** (in/ft) = 0.0208
Slope **1/2** (in/ft) = 0.0416

$$Q = .2104 \cdot \frac{1.486}{0.009} \cdot (0.1833)^{2/3} \cdot (0.0208)^{1/2}$$

$$Q = 34.74 \cdot 0.323 \cdot 0.144$$

$$Q = 1.62\ (ft^3/sec)$$

$$Q = 727\ (gpm)$$

$$V = \frac{1.486}{0.009} \cdot (0.1833)^{2/3} \cdot \frac{0.144}{12}$$

$$V = 165.1 \cdot 0.323 \cdot 0.012$$

$$V = 0.64\ (ft/sec)$$

Table 5 : Approximate Discharge Rates and Velocities in Sloping Drains Flowing Half-Full

Nominal Pipe Diameter (inch)	SDR 11						SDR 17					
	1/8 (in/ft) Slope		1/4 (in/ft) Slope		1/2 (in/ft) Slope		1/8 (in/ft) Slope		1/4 (in/ft) Slope		1/2 (in/ft) Slope	
	Flowrate (gpm)	Velocity (fps)	Flowrate (gpm)	Velocity (fps)	Flowrate (gpm)	Velocity (fps)	Flowrate (gpm)	Velocity (fps)	Flowrate (gpm)	Velocity (fps)	Flowrate (gpm)	Velocity (fps)
2	9	0.17	13	0.23	18	0.33	11	0.17	16	0.25	22	0.35
3	26	0.21	37	0.30	52	0.43	32	0.23	45	0.32	63	0.45
4	50	0.25	71	0.36	101	0.51	62	0.27	87	0.38	123	0.53
6	142	0.33	200	0.46	283	0.66	173	0.34	245	0.49	346	0.69
8	286	0.39	404	0.55	572	0.78	350	0.41	495	0.58	699	0.82
10	514	0.45	727	0.64	1029	0.91	629	0.48	890	0.67	1258	0.95
12	811	0.51	1147	0.72	1622	1.01	992	0.53	1402	0.75	1983	1.07
14	1040	0.54	1471	0.76	2080	1.08	1272	0.57	1799	0.80	2544	1.14
16	1485	0.59	2100	0.83	2970	1.18	1817	0.62	2569	0.88	3634	1.24
18	2034	0.64	2876	0.90	4067	1.28	2487	0.67	3517	0.95	4974	1.34
20	2693	0.68	3809	0.97	5387	1.37	3294	0.72	4659	1.02	6589	1.44
22	3472	0.73	4911	1.03	6945	1.46	4247	0.77	6006	1.09	8494	1.53
24	4379	0.77	6193	1.09	8758	1.55	5356	0.81	7574	1.15	10712	1.63
26	5421	0.82	7666	1.15	10842	1.63	6631	0.86	9378	1.21	13262	1.72
28	6607	0.86	9343	1.21	13213	1.71	8080	0.90	11426	1.27	16159	1.80
30	7941	0.90	11230	1.27	15881	1.79	9711	0.94	13733	1.33	19422	1.89
32	9432	0.94	13338	1.32	18863	1.87	11536	0.99	16314	1.39	23072	1.97
36	12911	1.01	18259	1.43	25822	2.03	15791	1.07	22332	1.51	31582	2.13

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 **5**).

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.

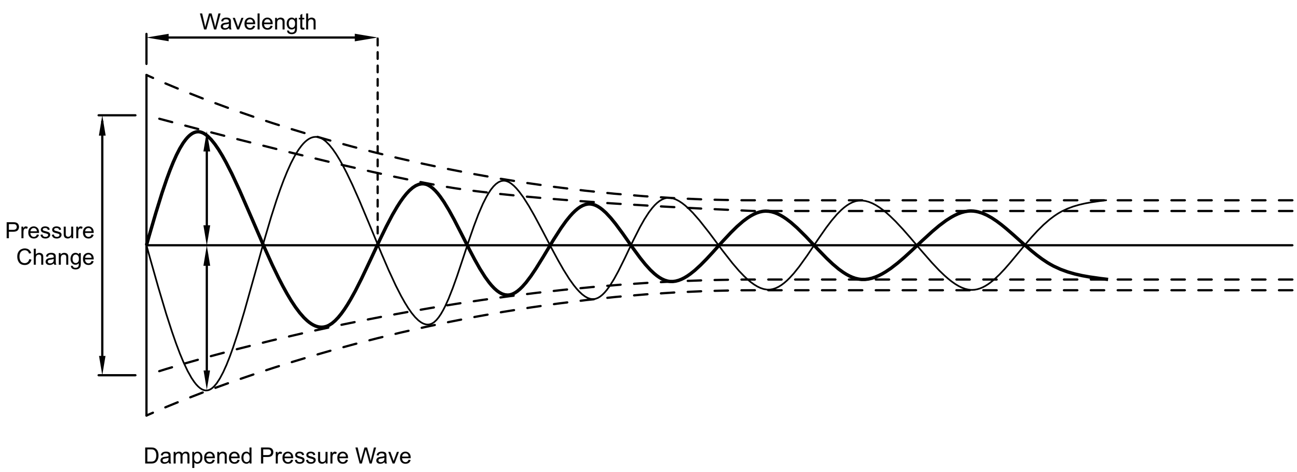


Figure 5

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.

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

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.

e.g. - 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_c - 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/in²), 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).

Pipe Details

System Information		Other Information	
Material:	**6" PE100 SDR 11**	Bulk Water Density **(K)**	**3.19 x 10⁵ (lb/in²)**
Flow Rate:	**300 (gal/min)**	Fluid Density **(δ)**	**1.937 (slugs/ft³)**
Pipeline Length:	**500 (ft)**	Valve Closing Time	**2.0 (sec)**
Operating Pressure:	**50 (lb/in²)**	Water Velocity	**4.0 (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 10⁵** (lb/in²)
- n_i - Conversion Factor **1/144** (ft²/in²)
- δ - Fluid Density **1.937** (slugs/ft³)

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

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

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/in²)
- δ - Fluid Density **1.937** (slugs/ft³)
- V - Fluid Velocity **4** (ft/sec)
- V_w - Velocity of Pressure Wave **4870** (ft/sec)
- n_i - Conversion Factor **1/144** (ft²/in²)

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

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

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/in²)
P_i - Valve Pressure (instantaneous) (lb/in²)
P_s - Standard System Operating Pressure (lb/in²)
In this case, 6" PE100 SDR11 pipe is rated at 200psi.
Therefore, the system design is within safety limits.

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

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

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/in²)
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** (ft²/in²)
δ - Fluid Density **1.937** (slugs/ft³)

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

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

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

Expansion/Contraction

Allowing for Length Changes in PE Pipelines

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 6**) 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.

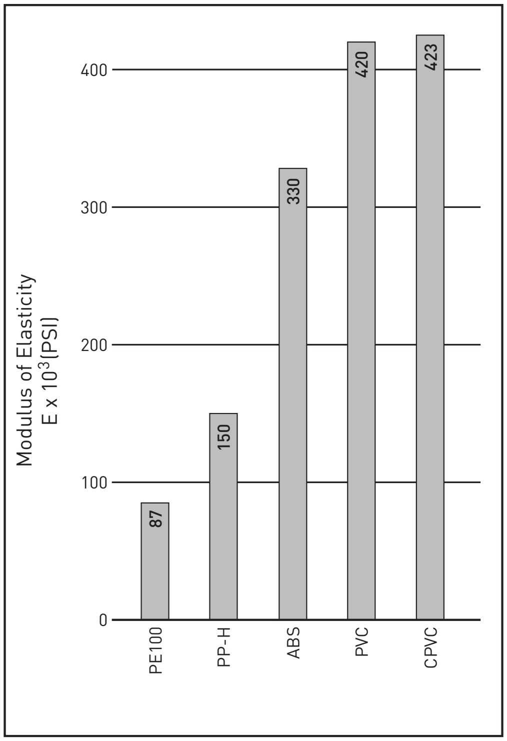
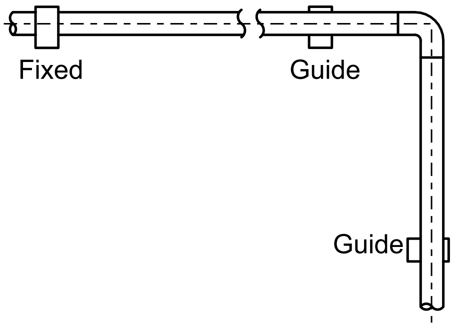


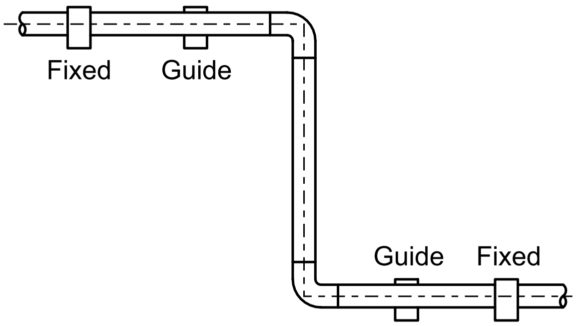
Figure 6

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.



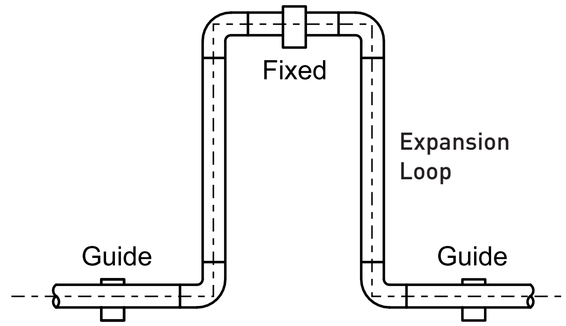
Changes in Direction



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.



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

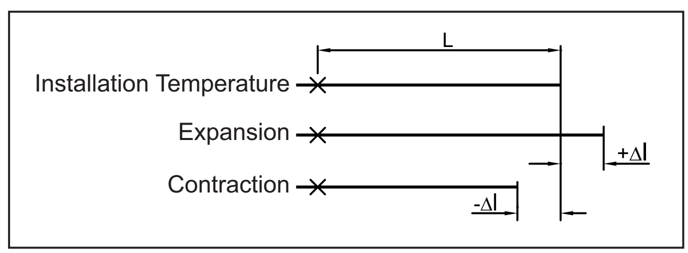
$$\Delta L = L \cdot \Delta T \cdot \delta$$

(inch) = (inch) · (ºF) · (inch/inchºF)

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
δ = 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 the 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: 10" PE100 SDR 11

Difference in Contraction Temperature

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

Difference in Expansion Temperature

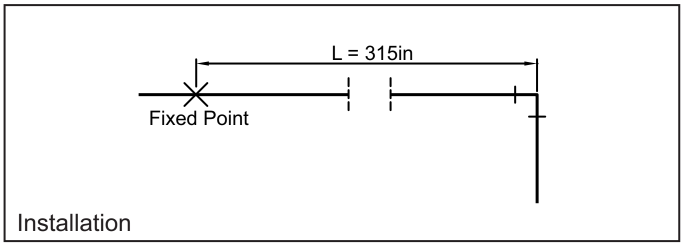
$\Delta T_2 = T_2 - T_v$ = 95°F - 73°F = 22°F

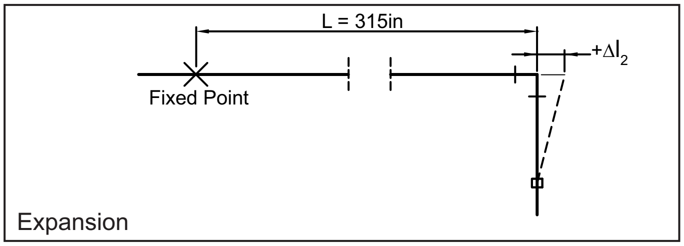
Contraction during service with coolant

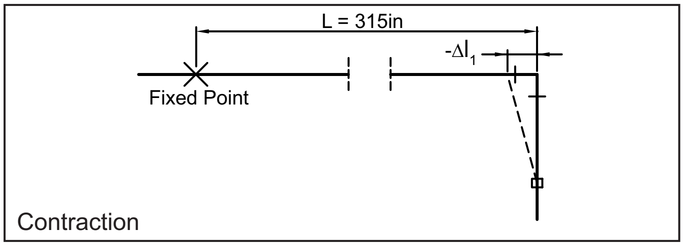
$-\Delta L_1 = L \cdot \Delta T_1 \cdot \delta$ = 315in · 33 · (0.000110) = 1.14in

Expansion during defrosting and cleaning

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







Length Change (ΔL) in Inches

Table 6

Temperature Change in (°F)	Length of Pipe Section (ft): 5	10	15	20	25	30	35	40	45	50	55	60	65	70	80	85	90	95	100
5			0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6
10		0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3
15	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
20	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.8	2.0	2.1	2.2	2.4	2.5
25	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.1	2.3	2.5	2.6	2.8	3.0	3.1
30	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8
35	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1	2.3	2.5	2.8	3.0	3.2	3.5	3.7	3.9	4.2	4.4
40	0.3	0.5	0.8	1.1	1.3	1.6	1.8	2.1	2.4	2.6	2.9	3.2	3.4	3.7	4.0	4.2	4.5	4.8	5.0
45	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.6
50	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	3.3	3.6	4.0	4.3	4.6	5.0	5.3	5.6	5.9	6.3
55	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.4	4.7	5.1	5.4	5.8	6.2	6.5	6.9
60	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.1	5.5	5.9	6.3	6.7	7.1	7.5
65	0.4	0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.9	4.3	4.7	5.1	5.6	6.0	6.4	6.9	7.3	7.7	8.2
70	0.5	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.2	4.6	5.1	5.5	6.0	6.5	6.9	7.4	7.9	8.3	8.8
80	0.5	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.8	5.3	5.8	6.3	6.9	7.4	7.9	8.4	9.0	9.5	10.0
90	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.7	11.3
100	0.7	1.3	2.0	2.6	3.3	4.0	4.6	5.3	5.9	6.6	7.3	7.9	8.6	9.2	9.9	10.6	11.2	11.9	12.5

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)

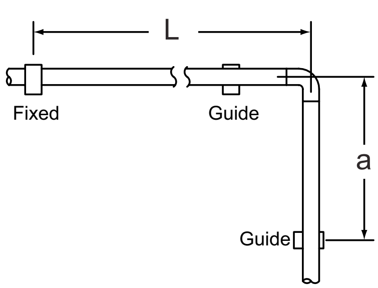
$$a = k\sqrt{\Delta L \cdot d}$$

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

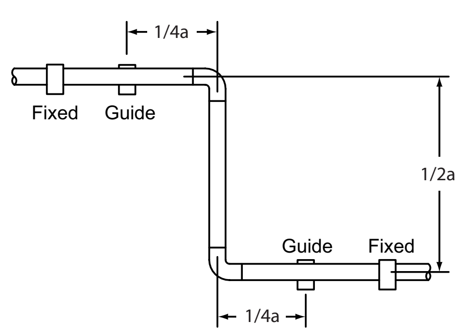
Table 7: Flexible Sections (a) in Inches

	Nominal Pipe Diameter																	
Length Change - ΔL (in)	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22"	24"	26"	28"	30"	32"	36"
0.1	13	15	17	21	24	27	29	31	33	35	37	39	40	42	44	45	47	49
0.2	18	22	25	30	34	38	42	44	47	49	52	55	57	59	62	64	66	70
0.3	22	27	30	37	42	47	51	53	57	60	64	67	70	73	75	78	81	85
0.4	25	31	35	42	48	54	59	62	66	70	74	77	81	84	87	90	93	99
0.5	28	34	39	47	54	60	66	69	74	78	82	86	90	94	97	101	104	110
0.6	31	38	43	52	59	66	72	75	81	85	90	94	99	103	107	110	114	121
0.7	34	41	46	56	64	71	78	81	87	92	97	102	107	111	115	119	123	131
0.8	36	44	49	60	68	76	83	87	93	99	104	109	114	119	123	127	132	140
0.9	38	46	52	63	72	81	88	92	99	105	110	116	121	126	131	135	140	148
1.0	40	49	55	67	76	85	93	97	104	110	116	122	127	133	138	142	147	156
2.0	57	69	78	95	108	121	131	138	147	156	164	172	180	187	195	201	208	221
3.0	69	84	96	116	132	148	161	168	180	191	201	211	221	230	238	247	255	270
4.0	80	97	110	134	153	170	186	195	208	221	233	244	255	265	275	285	294	312
5.0	90	109	123	150	171	191	208	218	233	247	260	273	285	296	308			
6.0	98	119	135	164	187	209	227	238	255	270	285	299	312					
7.0	106	129	146	177	202	226	246	257	275	292	308							
8.0	113	138	156	189	216	241	263	275	294	312								
9.0	120	146	165	201	229	256	279	292	312									
10.0	127	154	174	212	241	270	294	308										

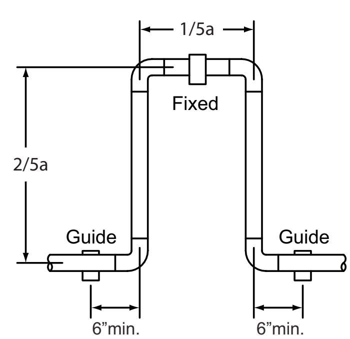
Change of Direction



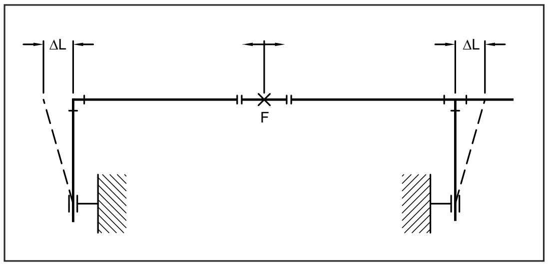
Offset



Expansion

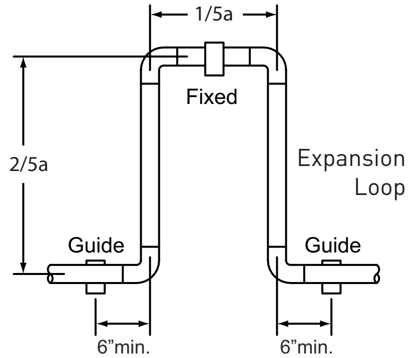


Installation Hints



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 1**), the length change of **1.44in** would require a flexible section length of **a = 36.4in**. A single flexible section on the other hand, would need to be **91.00in.** in length.

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

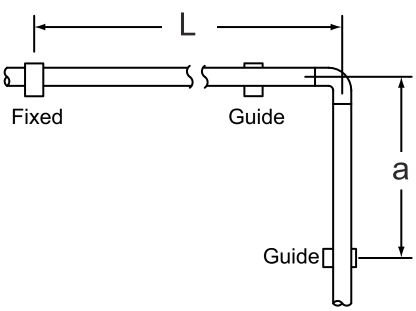
L = **315in.**

d = **10in.** (nominal)

Installation temperature: **73°F**

Max. working temperature: **35°F**

Material: **PE**



1 . Length change

+ΔL = L • ΔT • ∝ = 315 • 38 • (0.000110) = 1.32in.

2. Flexible section required to take up length change of ΔL = 1.32in according to **Table 7**:

a = approx. 98in.

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. 69in. The length change, starting from the zero position, then amounts to

±ΔL/2 = 1.32in/2 = 0.66in.

a = approx. 69in. (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.

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.

The Installation of Pipe Work under Plaster or Embedded in Concrete

Padded Pipe Work

Where pipe work installed under plaster or embedded in concrete changes direction or branches off, the flexible section under consideration must be padded along the length a, which is based on the calculated length change. The accompanying tees or elbows must, of course, also be included in the padding. Only flexible materials, such as glass wool, mineral wool, foam plastic or similar may be used for padding.

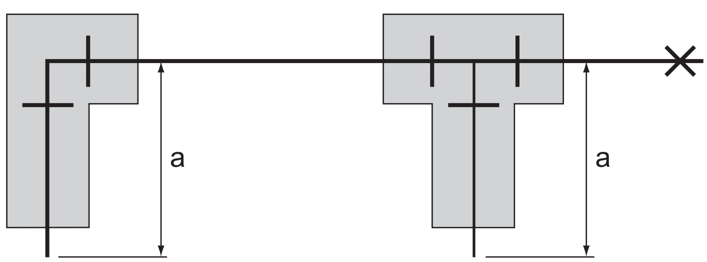


Figure 7

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. 0.25 cm (0.01 inch) 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/cm3 are to be conveyed, the pipe bracket centers given in **Table 8** must be multiplied by the factors given in the second column of **Table 7**, resulting in shorter distances between the supports.

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 PVC, CPVC, PE, 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.

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

Table 8

Nominal Pipe Size (inch)	Pipe Bracket Intervals L (ft.) for pipes SDR11 at Various Temperatures				
	≤65°F	85°F	105°F	125°F	140°F
2	4.6	4.4	4.1	3.9	3.6
3	5.6	5.3	5.0	4.7	4.4
4	6.3	6.0	5.7	5.3	5.0
6	7.5	7.1	6.7	6.3	5.9
8	8.6	8.1	7.7	7.2	6.7
10	9.6	9.1	8.6	8.1	7.6
12	10.3	9.8	9.2	8.6	8.1
14	11.0	10.4	9.8	9.2	8.6
16	11.6	11.0	10.4	9.7	9.1
18	12.2	11.6	11.0	10.3	9.6
20	13.0	12.3	11.6	10.9	10.2
22	13.9	13.1	12.4	11.6	10.9
24	14.4	13.6	12.8	12.1	11.3
26	14.9	14.1	13.3	12.5	11.7
28	15.6	14.8	13.9	13.1	12.2
30	16.1	15.3	14.4	13.5	12.6
32	16.8	15.9	15.0	14.1	13.2
36	17.8	16.9	15.9	14.9	14.0

Nominal Pipe Size (inch)	Pipe Bracket Intervals L (ft.) for pipes SDR17 at Various Temperatures				
	≤65°F	85°F	105°F	125°F	140°F
2	4.2	4.0	3.8	3.6	3.3
3	5.1	4.9	4.6	4.3	4.0
4	5.8	5.5	5.2	4.9	4.6
6	6.9	6.5	6.1	5.8	5.4
8	7.9	7.4	7.1	6.6	6.1
10	8.8	8.3	7.9	7.4	7.0
12	9.4	9.0	8.4	7.9	7.4
14	10.1	9.5	9.0	8.5	7.9
16	10.7	10.1	9.5	9.0	8.4
18	11.2	10.8	10.0	9.5	8.8
20	11.9	11.3	10.6	10.0	9.3
22	12.8	12.1	11.4	10.7	10.0
24	13.3	12.5	11.8	11.1	10.4
26	13.7	13.0	12.3	11.5	10.8
28	14.3	13.6	12.8	12.0	11.2
30	14.8	14.0	13.2	12.4	11.6
32	15.4	14.6	13.8	12.9	12.1
36	16.4	15.5	14.6	13.8	12.9

Note:

General rule of thumb: pipe spacing can be adjusted by dividing the support spacing by the specific gravity.

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

Mechanical Connections

Mechanical Joining of Piping Systems

Flange Connections	Flange adapters for butt fusion Coated Metal Flanges Backing Rings
Unions	Plastics-oriented connections between same plastics Transitions to other plastics Seal: O-ring
Transition Pipe Fittings	Plastic x Metal fittings with rustproof reinforcement ring Stainless Weld x PE Butt Fusion Transition Fittings
Threaded Fittings	Plastic fittings with reinforcement ring and tapered Female NPT threads.

Threaded Connections

The Following Different Types of Threads Are Used

Designation of the thread	According to standard	Typical use	Description
G (Buttress Threads)	ISO 228	Unions	Parallel internal or external pipe thread, where pressure-tight joints are not made on the threads
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

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

Creating Flange Joints

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

Materials

Vinyl Flanges

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

Gasket

A rubber gasket must 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 9)** 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.

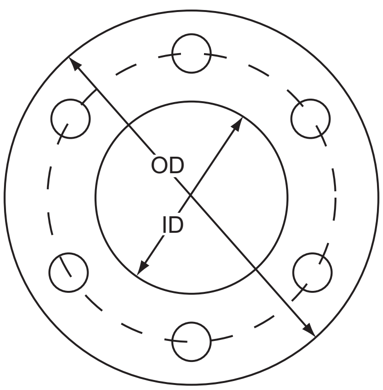


Figure 8

Table 9

Size (in)	O.D. (in)	I.D. (in)	Size (in)	O.D. (in)	I.D. (in)
2	6.00	2.63	**18**	25.00	18.38
3	7.50	3.75	**20**	27.50	20.38
4	9.00	4.75	**22**	29.50	22.38
6	11.00	6.88	**24**	32.00	24.38
8	13.50	8.88	**26**	34.25	26.38
10	16.00	11.00	**28**	36.50	28.38
12	19.00	13.13	**30**	38.75	30.38
14	21.00	14.18	**32**	41.75	32.38
16	23.50	16.19	**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 10
Fastener Specifications

Flange Size (in)	No. of Bolts	Length[1] (in)	Bolt Size (in) and Type	Washer Size (in) and Type[2]
2	4	3.75	5/8" SAE GRD 5	5/8" SAE
3	4	4.50	5/8" SAE GRD 5	5/8" SAE
4	8	4.75	5/8" SAE GRD 5	5/8" SAE
6	8	5.75	3/4" SAE GRD 5	3/4" SAE
8	8	6.00	3/4" SAE GRD 5	3/4" SAE
10	12	7.00	7/8" SAE GRD 5	7/8" SAE
12	12	7.50	7/8" SAE GRD 5	7/8" SAE
14	12	8.00	1" SAE GRD 5	1" SAE
16	16	9.00	1" SAE GRD 5	1" SAE
18	16	10.00	1 1/8" SAE GRD 5	1 1/8" SAE
20	20	11.00	1 1/8" SAE GRD 5	1 1/8" SAE
22	20	13.00	1 1/4" SAE GRD 5	1 1/4" SAE
24	20	13.00	1 1/4" SAE GRD 5	1 1/4" SAE
26	24	14.00	1 1/4" SAE GRD 5	1 1/4" SAE
28	28	14.00	1 1/4" SAE GRD 5	1 1/4" SAE
30	28	15.00	1 1/4" SAE GRD 5	1 1/4" SAE
32	28	13.00	1 1/2" SAE GRD 5	1 1/2" SAE
36	32	15.00	1 1/2" SAE GRD 5	1 1/2" SAE

[1] Suggested bolt length for flange-to-flange connection with 0.125" thick gasket. Adjust bolt length as required for other types of connections.

[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.

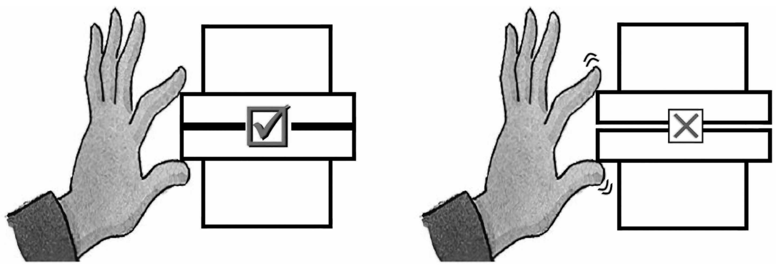


Figure 9

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".

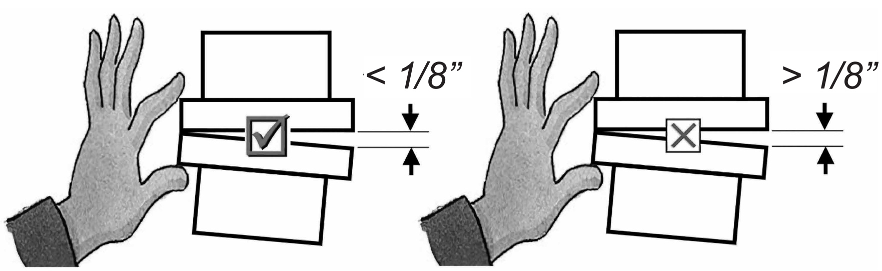


Figure 10

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.

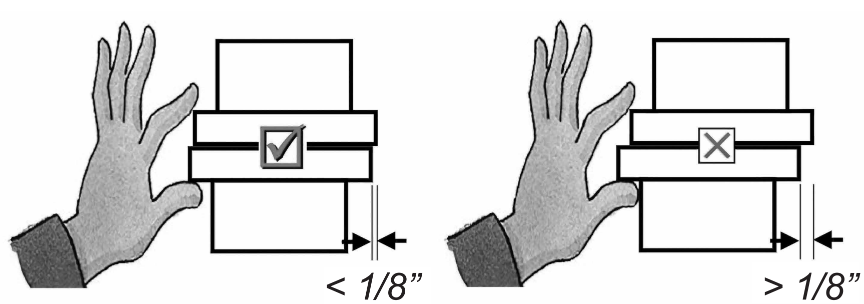


Figure 11

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.

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.

The torque required on each bolt in order to achieve the best seal with minimal mechanical stress has been carefully studied in laboratory and field installations, and is given in **Table 11**.

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.

Table 11
Multiple Pass Bolt Torque

Size (in)	Max. Torque	Torque Sequence (ft-lb, lubed*)				Torque Sequence (ft-lb, unlubed**)			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th
2	22	5	—	—	—	5	10	22	—
3	30	5	12	15	—	15	20	30	—
4	30	10	15	20	—	15	25	30	—
6	44	12	24	30	—	20	32	44	—
8	58	15	35	40	—	30	40	50	58
10	58	25	50	60	—	20	40	60	58
12	75	30	60	72	—	20	50	65	75
14	140	46	92	126	140	35	70	105	140
16	140	46	92	126	140	35	70	105	140
18	140	46	92	126	140	35	70	105	140
20	140	46	92	126	140	35	70	105	140
22	160	53	106	144	160	40	80	120	160
24	180	59	119	162	180	45	90	135	180
26	180	59	119	162	180	45	90	135	180
28	180	59	119	162	180	45	90	135	180
30	180	59	119	162	180	45	90	135	180
32	240	79	158	216	240	60	120	180	240
36	260	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 11** are 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

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 12)

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")

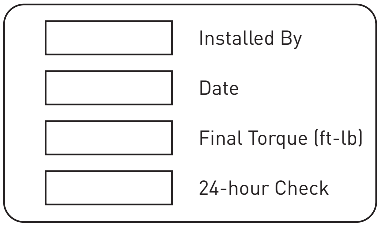


Figure 12

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 1)

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 3/8" through 1½" should be sufficiently sealed after hand-tightening, for the hydrostatic pressure test of the system.

Optional: Further Tightening (2") (see Table 12)

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 12
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 3/8" to 1½" only) (see Table 1)
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

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.

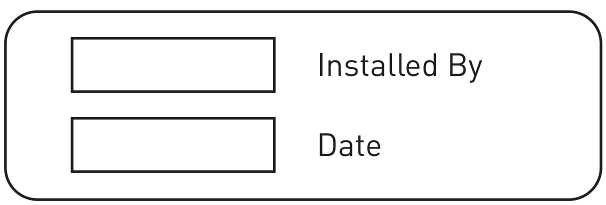


Figure 13

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 13
Threaded Connection Guide

Connection Type	Next Step
Plastic to Plastic	Tighten up to 1/2 turn
Plastic Male to Metal Female	Tighten up to 1/2 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.

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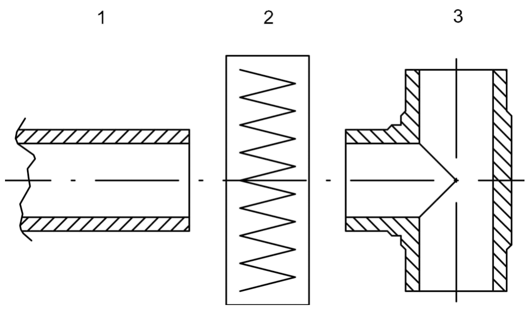
Infrared (IR) Butt Fusion

Infrared (IR) Fusion Joining Method

In infrared (IR) fusion joining the fusion areas of the components being joined (pipes, fittings, valves) are heated to fusion temperature without contact to the heating element and joined by means of mechanical pressure without using additional materials.

The Principle of Fusion Joining



1 Pipe
2 Heating element
3 Fitting

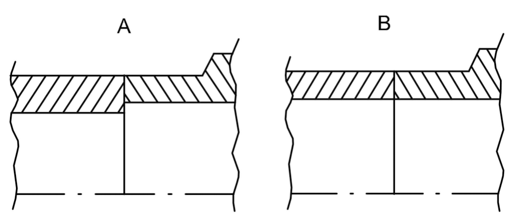
The resulting fusion joints are homogeneous and display the following characteristics:

- Non-contact heating of the joining components eliminates the risk of contamination and inhomogeneities;
- Smaller joining beads due to adjustment of joining pressure path prior to the fusion process itself, i.e. elimination of the equalization process
- Adjustment of the joining pressure path also ensures excellent reproducibility of the fusion joints
- Low-stress fusion joints due to very uniform heating by means of IR radiator

General Requirements

The basic rule is that only similar materials can be fusion joined. For the 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. The components to be joined must have the same wall thicknesses in the fusion area. Maximum permissible wall displacement: 10%.

Only same wall thicknesses in the fusion area



A incorrect
B correct

IR fusion joining must only be performed by personnel trained in the use of this method. Training is provided world-wide by qualified GF IR Plus® welding instructors.

Tools Required

Infrared fusion joining requires a special joining machine in addition to the tools normally used for plastic pipe work construction (pipe cutters, etc.).

GF Supplies Two Types of IR Plus® Fusion Joining Machines

IR 63 Plus®: for fusion joints 1/2" to 2"

IR 225 Plus®: for fusion joints 2" to 8"

General Conditions

Protect the area of the fusion joint from adverse weather conditions, such as rain, snow or wind. The permitted temperature range for IR Plus® fusion joining between +5°C and +40°C. Outside this range, suitable action must be taken to ensure that these conditions are maintained. It must also be ensured that the components being joined are in this temperature range.

Preparing the Fusion Joint and Operating the IR Fusion Joining Machine

In principle, IR fusion joining machines do not require any special preparation, but it should be ensured that the components being joined are clean. Operation of the IR machines is defined exactly in the operating instructions, but we strongly recommend attending a 1-day training course to become a qualified IR welder.

Properties and Characteristics of IR Fusion Joints

Non-Contact Heating

The components being joined are heated uniformly and without contact to the ideal fusion temperature by infrared radiation.

A defined gap between the heating element and the end faces minimizes the risk of contamination of the joining surface. Contamination of the heating element by plastic particles is thus also eliminated.

Reduced Bead Formation

The fusion bead produced during joining is considerably reduced without any loss of quality. Bead forming equalization is eliminated by non-contact softening of the end faces. The minimal, defined bead is only formed during the joining process. The fusion area thus has improved flow dynamics, low clearance volume, and greater throughput area.

Reproducible Joining Processes

The joining path controls the joining pressure and thus the fusion process. The high reproducibility of the joints is assured by the clearly defined and controlled process sequence.

Clear, Simple Operator Guidance

Clear, unambiguous operator guidance via the liquid crystal display leads the user interactively through the fusion process in logical operating steps.

Welding Report/Traceability

The welding parameters for the relevant welding operations can be read out directly via various interfaces on the machine. It is possible to print these out on paper (commercially available printers), on labels or to employ electronic data output (PCMCIA card).

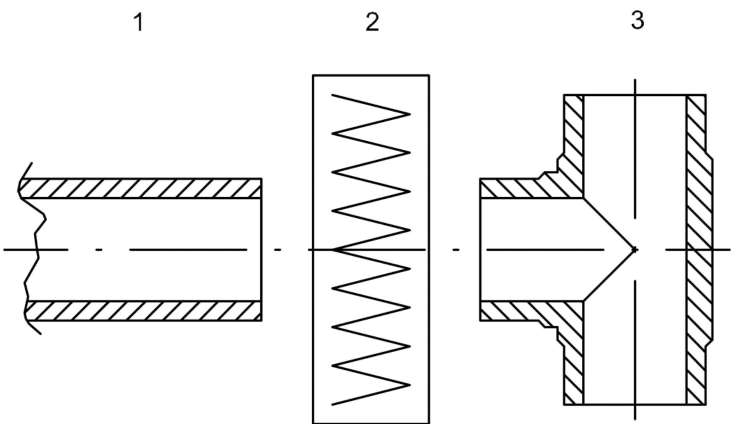
This automatically provides an accurate record with all essential fusion parameters for each individual fusion joint, as required.

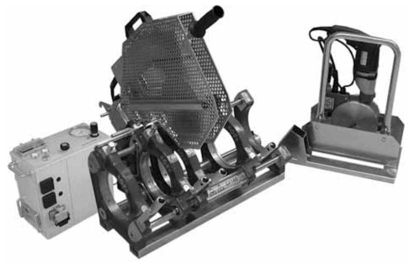
Contact Butt Fusion

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.

The Principle of Fusion Joining



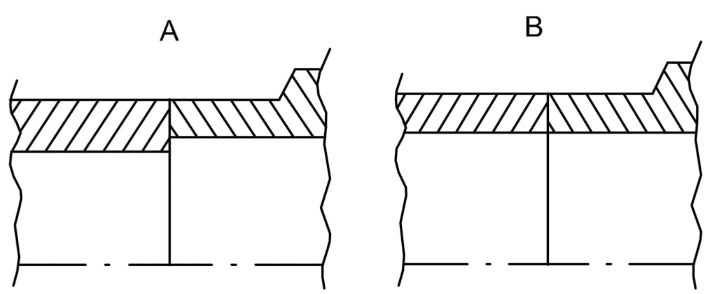


1 Pipe
2 Heating element
3 Fitting

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



A incorrect

B correct

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

Tools Required

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.

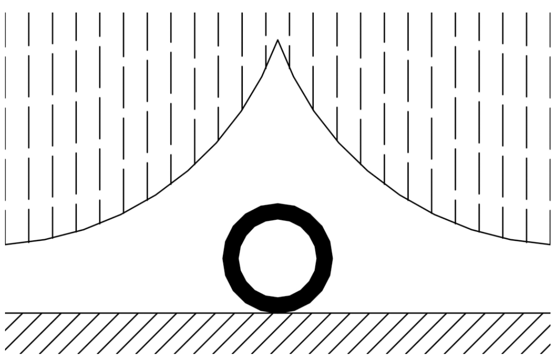
The heating surfaces of the heating element must be flat and parallel. The temperature variation over the working area must not exceed 10°C. The machine should be set up and operated according to the manufacturer's instructions.

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.

General Conditions

Protect the area of the fusion joint from adverse weather conditions, such as rain, snow and wind. At temperatures below +5°C or above +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.

Protect the Fusion Area

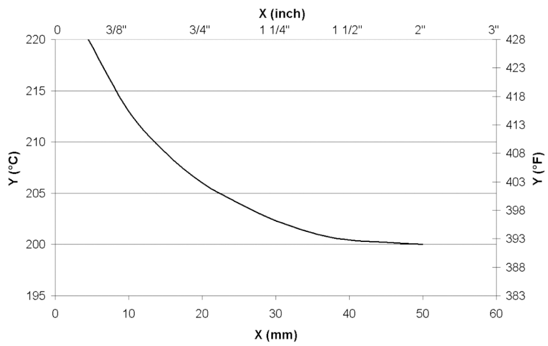


Screening the fusion area can ensure a more even temperature distribution on the entire circumference of a pipe subject to direct sunlight. The pipe ends at the opposite end of the fusion areas should be sealed whenever possible to reduce to a minimum the cooling of the fusion surfaces which can be caused by wind.

Preparation of the Fusion Joint

The quality of the fusion process is governed by the care with which the preparatory work is carried out. This part of the procedure therefore deserves special attention.

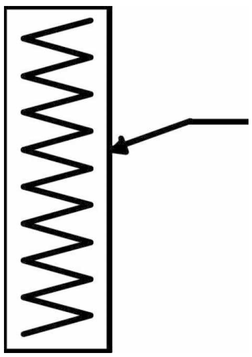
Heating Tool



X Wall thickness in mm

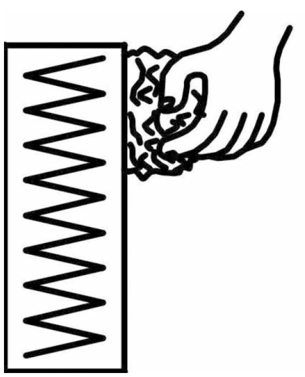
Y Heating tool temperature °C

The fusion temperature should be between 204°C–232°C. In principle, the upper temperature should be aimed at for less thick walls and the lower temperature for thicker walls.



Check the Temperature
To test the thermostat, check temperature before commencing the fusion joining. This is best carried out with the help of a digital thermometer. But only thermometers with a sensor for measuring surface temperature are suitable.

To ensure it is being maintained at the correct level the fusion temperature should be checked from time to time during the joining work. The temperature of the heating element is particularly sensitive to wind.



Clean the Heating Element
Clean the heating element with dry, clean paper before each fusion joint!

Protect the working surface of the heating element from becoming soiled. Clean both faces of the heating element with dry, lint-free paper before each fusion joint. Protect the heating element from wind, damage and soiling during the intervals between making fusion joints.

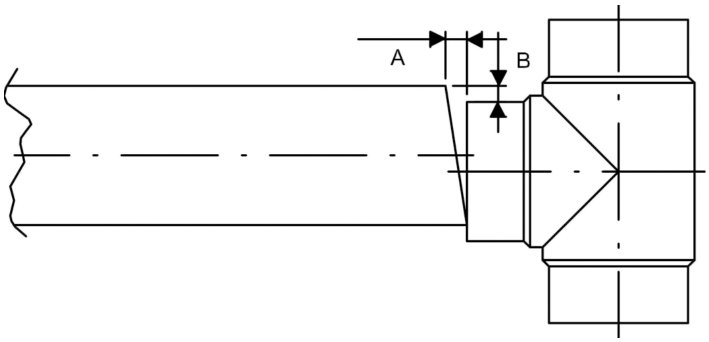
Planing and Subsequent Checking

Before machining the joining surfaces, make sure that the tools and the work pieces are clean and grease-free beyond the actual fusion zone; if necessary, clean with a cleaning fluid.

All the components clamped into the fusion joining machine are planed simultaneously with the planer provided. The shavings should not be thicker than d 0.2mm. This step is completed when there is no un-machined area left on either of the parts to be joined. This is normally the case when no more shavings come off the machined surface.

Remove any shavings which may have fallen into the pipe or fitting with a brush. The fusion surfaces should not be touched by hand under any circumstances. Otherwise they must be cleaned with cleaning fluid.

Once they have been machined, the parts are moved together until they touch. The gap between the two parts must not exceed 0.5 mm at any point.



A max. gap: 0.5 mm

B max. displacement: 10 % of wall thickness

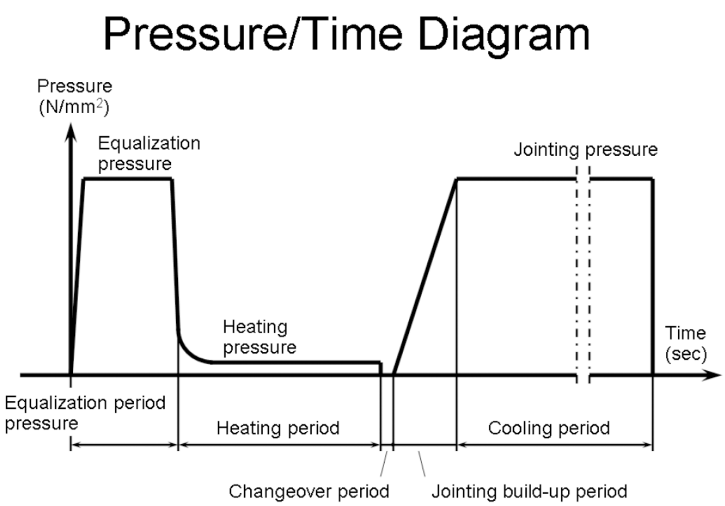
Check the Wall Alignment and Gap

The alignment of the two parts should be checked at the same time. A possible misalignment on the outside must not exceed 10% of the thickness of the wall. If this limit is exceeded, a better clamping position is to be sought, e.g.: by rotating the pipe. In such a case, however, the surface must be re-planed.

Important: The fusion surfaces must be planed immediately prior to the joining.

Setting the Fusion Pressure

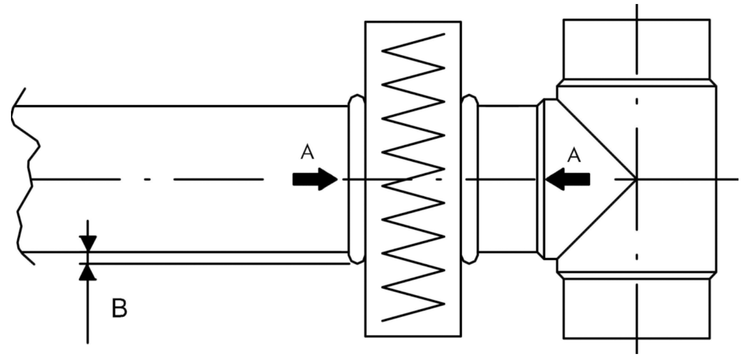
Fusion joining requires different pressures to be applied during equalisation and joining on the one hand and during the heat soak period on the other. Please see the following diagram.



The specific joining pressure required for equalization and fusion can be found in the following table with the heating and cooling periods. The table lists the times for various wall thicknesses. Interpolate for intermediate values.

The force needed for equalization and joining (FA) is given by the product of the fusion area and the specific joining pressure (FA = A * p). The force (FB) required to move the pipe must be added to this. (F_{tot} = FA + FB). This latter force includes the intrinsic resistance of the machine and the resistance of the axially mobile pipe or fitting clamped in it. The resistance of longer pipes should be reduced as far as possible by placing rollers beneath them. The kinetic force (FB) should not exceed the joining force (FA).

Equalize and Heat



A Contact force

B Height of bead (see tabulated values)

Approximate Values for Butt Fusion of PE[1)]

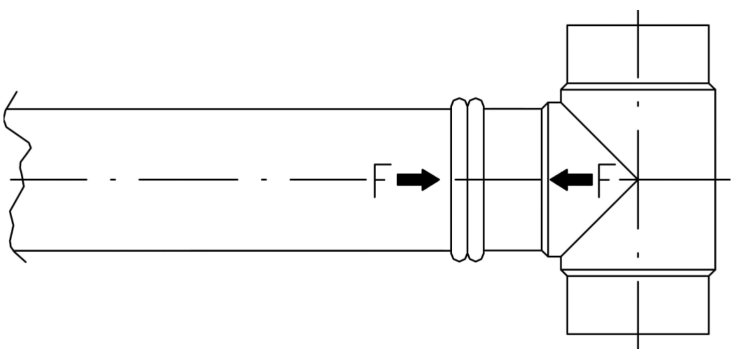
Wall Thickness (in)	Equalisation at p= 22 psi Height of bead (in)	Heating time ²) p= 1.5 psi (sec)	Changeover time max. (sec)	Time to reach full joining (sec)	Cooling time ²) under joining p= 22 psi (min)	Total Fusion Time (approx)
up to 0.18	0.02	up to 45	5	5	6	up to 7 min
0.18 ... 0.28	0.04	45 ... 70	5 ... 6	5 ... 6	6 ... 10	7 min–11 min
0.28 ... 0.47	0.06	70 ... 120	6 ... 8	6 ... 8	10 ... 16	11 min–19 min
0.47 ... 0.75	0.08	120 ... 190	8 ... 11	8 ... 11	16 ... 24	19 min–28 min
0.75 ... 1.02	0.10	190 ... 260	10 ... 12	11 ... 14	24 ... 32	28 min–37 min
1.02 ... or greater	0.12	260 ... 370	12 ... 16	14 ... 19	32 ... 45	37 min–52 min

1) In accordance with DVS 2207-1
2) The times are affected by the pipe wall thickness, the outside temperature and wind strength.

Determine the values to be set for equalization and joining on the basis of the information above, bearing in mind the instructions from the manufacturer of the fusion joining machine before commencing the fusion process.

Fusion Joining Procedure

Once it has attained the fusion temperature, position the heating element in the fusion joining machine. Press the parts to be joined against the heating element with the force required for equalisation until the entire circumference of each of the joining faces rests completely against it and a bead (see the table) has formed. Reduce the equalisation pressure almost to 0 (p ~ 0.01 N/mm²). The heating time listed in the table is measured from this moment.



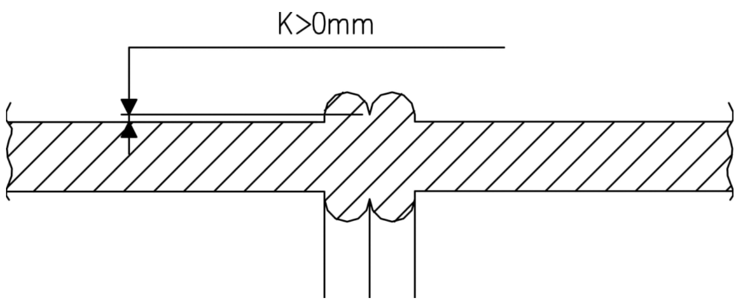
Join and Cool

Leave parts in the fusion joining machine at fusion pressure until the end of the cooling period!

Once the heating period has elapsed, remove the parts from the heating element which should then be removed without touching the joining surfaces and push the parts together immediately. The changeover time must not exceed the value listed in the table. Pay particular attention during joining that the parts be moved together swiftly until the surfaces are about to touch.

Then they should be moved together so that they are in contact along the entire circumference. Next the pressure should be increased rapidly to the present joining pressure within the period of time specified in the table. This pressure must be maintained during the entire cooling period. Adjustment may be necessary, especially shortly after the joining pressure has been attained.

The joined parts must stay in the fusion joining machine under joining pressure until the end of the cooling period specified in the table.



Fusion Check

A bead should form around the entire circumference of the pipe. K in the diagram to the left should always be positive.

Carrying Out the Pressure Test

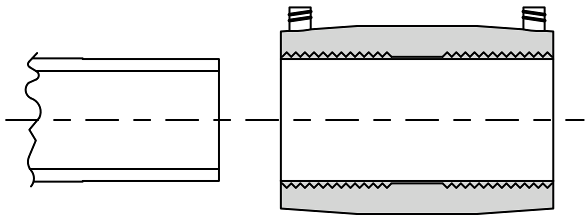
All fusion joints must be allowed to cool completely before pressure testing, i.e.: as a rule wait about 1 hour after the last joint has been completed.

Electrofusion

Electrofusion Joining Method

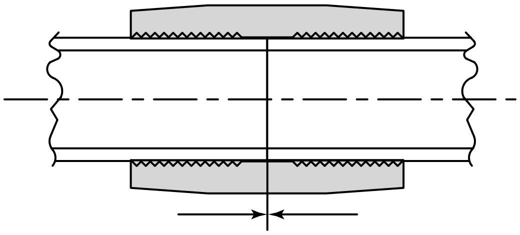
The fusion area of the pipes and socket fittings are heated to fusion temperature and joined by means of an interference fit, without using additional materials. A homogeneous joint between socket and spigot is accomplished. Electrofusion must only be carried out with fusion joining machines by Georg 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.

The Principle of Electrofusion Joining

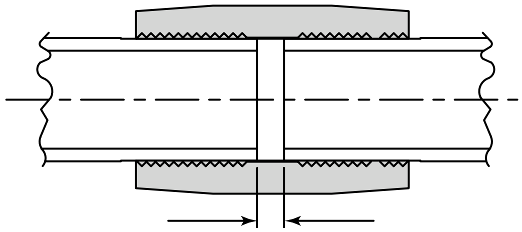


General Requirements

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 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.



Correct



Incorrect

Easy Fuse electrofusion should only be performed by GF trained and certified personnel.

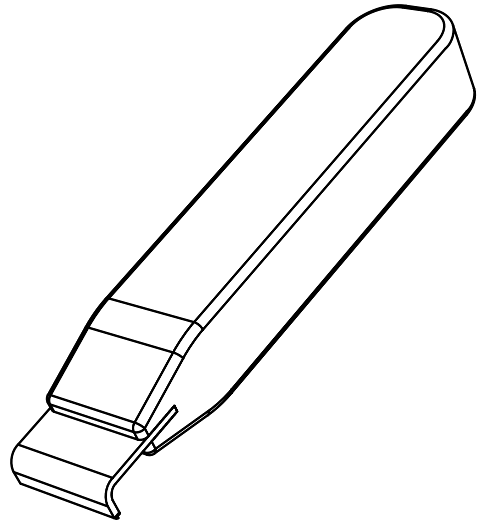
Tools and Preparation

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

The clamping equipment must hold the various parts securely without damaging the surfaces. It must also be able to clamp the pipe without forcing it out of round. A standard plastic scraper, as seen, should be used to prepare the surface of the pipe.

The outer layer of "skin" of the pipe will need to be removed to expose a clean, virgin pipe material for fusion. Abrasive materials such as sandpaper, emery cloth or files should not be used in place of a scraping tool.

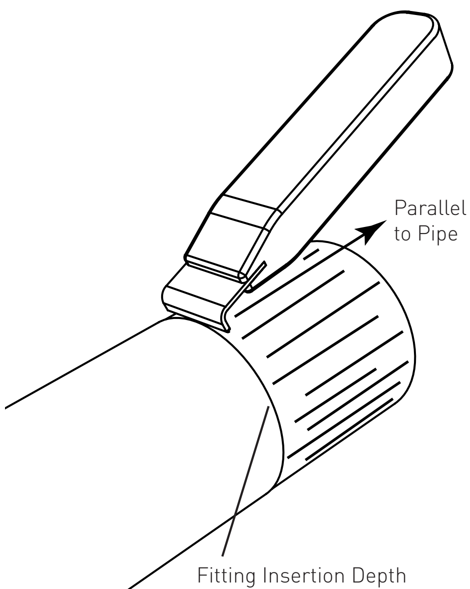
Note: Abrasive materials have proven to be an ineffective means to properly prepare the surface of the pipe for electrofusion. It is also recommended that metal type files not be used, as these type of tools do not cleanly remove the desired material from the surface of the pipe.



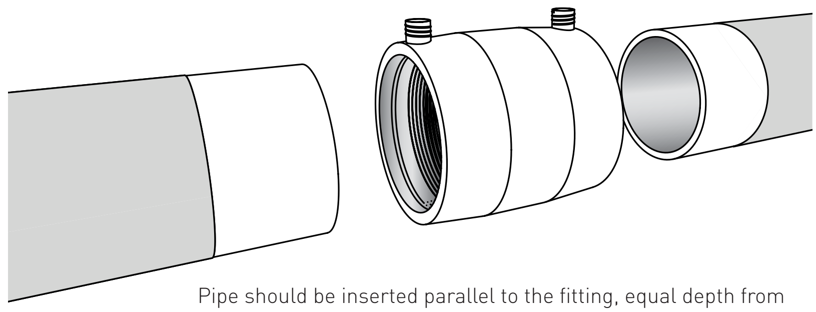
Approved Scraper

To Properly Remove the Outer Layer of Material from the Pipe

The pipe end should be marked to identify the insertion depth. Once the pipe is clearly marked the scraper should be applied in a parallel motion to the pipe.



Fitting Insertion Depth should be clearly marked on pipe prior to scraping



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

Fusion Process

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

GF electrofusion fittings are supplied with Easy Fuse Auto-programming ID resistors. The ID resistors send the proper signal to the Easy Fuse processor, automatically setting the fusion parameters, i.e. voltage and cycle time. 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

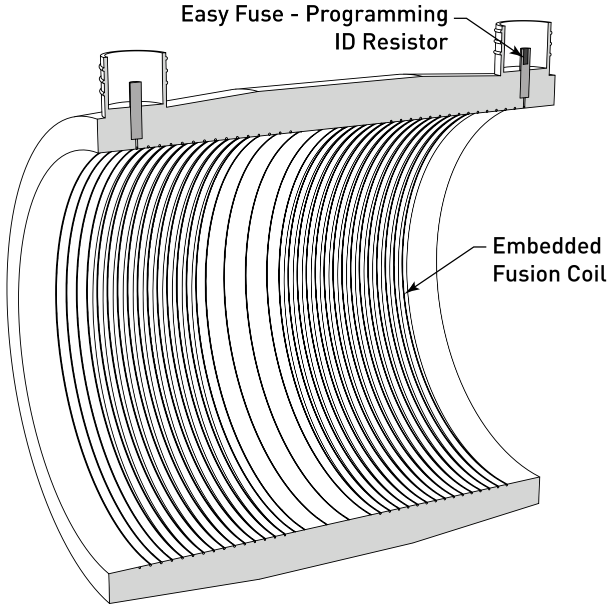
All electrofusion couplings require the pipe to be restrained or sufficiently supported on each side of the pipe to:

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!

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