GF Piping Systems

Technical Handbook for Pressure Piping Systems

PROGEF® Standard Polypropylene
PROGEF® Natural Polypropylene
PPro-Seal™ Natural Polypropylene
SYGEF® Standard Polyvinylidene Fluoride
SYGEF® Plus Polyvinylidene Fluoride

Table of Contents

Overview Polypropylene Piping Systems . . . 5
General Information . . . 5
PROGEF Standard Polypropylene (PP-H) . . . 5
PROGEF Natural Polypropylene (PP-R) . . . 5
PPro-Seal Natural Polypropylene (PP-R) . . . 5
Mechanical Properties . . . 6
Chemical, Weathering, and Abrasion Resistance . . . 6
Thermal Properties . . . 6
Combustion Behavior . . . 6
Electrical Properties . . . 6
Complete System of Pipe, Valves and Fittings . . . 7
Reliable Fusion Joining . . . 7
General Properties Polypropylene . . . 7
Material Data . . . 7
Overview SYGEF® Polyvinylidene Fluoride (PVDF) Piping Systems . . . 8
General Information . . . 8
Mechanical Properties . . . 8
Chemical, Weathering, and Abrasion Resistance . . . 8
Thermal Properties . . . 8
Flammability and Fire Testing . . . 9
Electrical Properties . . . 9
Physiological Properties . . . 9
Extractables . . . 10
Discoloration Phenomena . . . 10
Manufacturing . . . 10
Compliance with Life Science Standards . . . 11
Raw Materials . . . 11
Manufacturing (Pipe) . . . 11
Manufacturing (Fabricated Products) . . . 12
Traceability of Machined Components . . . 12
Delivery, Storage and Handling . . . 12
General Properties SYGEF® Polyvinylidene Fluoride (PVDF) . . . 13
Material Data . . . 13
Specifications PVDF and PP . . . 14
Pressure/Temperature . . . 14
Dimensional Pipe Size . . . 16
Calculating Pipe Size . . . 17
Friction Loss Characteristics . . . 17
Hazen and Williams Formula . . . 17
C Factors . . . 17
Pressure Loss of Fittings . . . 17
Flow Rate vs. Friction Loss . . . 18
PROGEF Standard Polypropylene (PP) . . . 18
PROGEF Natural Polypropylene (PP) . . . 20
PPro-Seal Natural Polypropylene (PP) . . . 22
PPro-Seal Natural Polypropylene . . . 22
SYGEF Polyvinylidene Fluoride (PVDF), PN 16 . . . 23
SYGEF Polyvinylidene Fluoride (PVDF), PN 10 . . . 25
Gravity Drain Systems . . . 27
Flow Rate for Gravity Drain Systems . . . 27
Approximate Discharge Rates and Velocities in Sloping Drains Flowing Half-Full . . . 28
Surge Pressure (Water Hammer) . . . 29

Expansion/Contraction 31
Allowing for Length Changes in PP and PVDF Pipelines 31
Calculation and Positioning of Flexible Sections 31
Determining the Length Change (ΔL) (Example 1) 32
Length Change (ΔL) in Inches 33
Determining the Length of the Flexible Section (a) 34
Installation 36
The Installation of Pipe Work under Plaster or Embedded in Concrete 36
Pipe Bracket Support Centers and Fixation of Plastic Pipelines 36
Mechanical Connections 39
Threaded Connections 39
Flanged Connections 39
Creating Union Joints 42
Fusion Joining 44
Socket Fusion 44
Contact (Conventional) Butt Fusion 45
IR Plus® Infrared Butt Fusion Joining 46
BCF® Plus (Bead and Crevice Free) Fusion Joining 47
Electrofusion Joining 47
Pressure Testing 48
Sterilization and Sanitization Methods 51
Autoclave Sterilization 51
In-Line Steam 51
Hot Water Sanitization 51
Ozone Sanitization 51
Chemical Sanitization 51

Overview Polypropylene Piping Systems

General Information

Polypropylene is a thermoplastic belonging to the polyolefin group. It is a semi-crystalline material. Its density is lower than that of other well-known thermoplastics. Its mechanical characteristics, its chemical resistance, and especially its relatively high heat deflection temperature have made polypropylene one of the most important materials used in piping installations today.

PP is formed by the polymerisation of propylene (C_3H_6) using Ziegler-Natta catalysts.

There are three different types which are conventionally supplied for piping installations:
- Isotactic PP Homopolymeride (PP-H)
- PP block co-polymeride (PP-B)
- PP random co-polymeride (PP-R)

Because of its high internal pressure resistance, PP-H is preferred for industrial applications. On the other hand, PP-R is used predominantly in sanitary applications because of its low e-modulus (flexible piping) and its high internal pressure resistance at high temperatures. PP-B is mainly used for sewage piping systems because of its high impact strength, especially at low temperatures and its low thermal endurance.

PROGEF Standard Polypropylene (PP-H)

Most of the grades are offered with nucleating agents (crystallization seeds), because PP crystallizes at least 10 times slower than PE. This way, we achieve lower internal stress and a finer structure. We differentiate between α and β nucleation.

Nucleation is realized by merely adding ppm (parts per million) of nucleating agents. PP is a non-polar material whose surface hardly swells or dissolves. Cementing is not possible without special surface treatment. On the other hand, PP welds very well. Pressure piping systems can use heating element socket welding, heating element butt welding or the no-contact infrared (IR-Plus®) fusion technology developed by GF.

Internal pressure resistance is ensured through long-term testing in accordance with EN ISO 15494 and with the value of MRS 10 MPa (minimum required strength).

The PP-H resin used by GF for PROGEF Standard PP industrial piping systems is characterized by

Advantages
- good chemical resistance
- high internal pressure resistance
- high impact strength
- high thermal ageing and thermal forming resistance
- high stress fracture resistance
- outstanding weldability
- homogeneous, fine structure

PROGEF Natural Polypropylene (PP-R)

Specially for applications related to the BCF® Plus (bead and crevice-free) welding technology, such as the life science/pharmaceutical industry, GF offers the PROGEF® Natural PP system in addition to our PROGEF Standard PP system.

For such requirements, the welding technology plays a decisive role. With BCF® Plus welding technology, beads and dead zones are eliminated. This prevents micro-organisms from accumulating, thus improving water quality.

For less demanding purity requirements and all other industrial applications, especially those involving aggressive media, high impact and temperature stress, GF recommends PROGEF Standard PP, which has optimal characteristics.

The material used for the PROGEF Natural system is an unpigmented random copolymer, particularly distinguished by the following characteristics:

Advantages
- excellent resistance against certain disinfectants and chemicals (mainly alkaline solutions)
- translucence
- very high surface finish quality
- good weldability (BCF® Plus and IR Plus® weldable)
- high temperature resistance

PPro-Seal Natural Polypropylene (PP-R)

Specifically for applications such as lab grade DI water, reverse osmosis and chemical distribution systems where electrofusion or threaded joining is appropriate.

The material used for the PPro-Seal Natural system is an unpigmented random copolymer, particularly distinguished by the following characteristics:

Advantages
- excellent resistance against certain disinfectants and chemicals (mainly alkaline solutions)
- translucence
- very high surface finish quality
- electrofusion (same fusion machine that Fuseal® PP & Fuseal 25/50™ PVDF use)
- high temperature resistance

Mechanical Properties

PP-H has the highest crystallinity and therefore the highest hardness, tensile strength and stiffness, so the pipes hardly sag and a greater distance between supports is possible. PP-R has a very good long-term creep strength at higher temperatures, such as, for example, 80°C at continuous stress.

Unlike PE, PP is not as impact-resistant below 0°C. Because of this, GF recommends ABS or PE for low temperature applications.

The long-term behavior for internal pressure resistance is provided by the hydrostatic strength curve based on the EN ISO 15494 standard. The application limits for pipes and fittings, as shown in the pressure-temperature diagram, can be derived from these curves.

Chemical, Weathering, and Abrasion Resistance

Due to its non-polar nature, polypropylene shows a high resistance against chemical attack.

The resistance of PP is nevertheless lower than that of PE because of its tertiary C atoms.

PP is resistant against many acids, alkaline solutions, solvents, alcohol and water. Fats and oils swell PP slightly. PP is not resistant to oxidizing acids, ketones, petrol, benzene, halogens, aromatic hydrocarbons, chlorinated hydrocarbons and contact with copper.

For detailed information, please refer to the detailed list of chemical resistance from GF or contact your local GF subsidiary.

If polypropylene is exposed to direct sunlight over a long period of time, it will, like most natural and plastic materials, be damaged by the short-wave UV portion of sunlight together with oxygen in the air, causing photo-oxidation.

PP fittings and valves are highly heat stabilized. As per approvals, polypropylene has no special additive against the effects of UV radiation. The same applies to PP piping. Piping which is exposed to UV light should therefore be protected. This is achieved by covering the pipes, e.g. with insulation or also by painting the piping system with a UV absorbing paint.

Thermal Properties

In general polypropylene can be used at temperatures from 0°C to +80°C (32°F to 176°F). Below –10°C, the outstanding impact strength of the material is reduced. On the other hand, the stiffness is even higher at low temperatures. Please consult the pressure-temperature diagram for your maximum working temperature. For temperatures below 0°C it must be ensured, as for every other material, that the medium does not freeze, consequently damaging the piping system.

As with all thermoplastics, PP shows a higher thermal expansion than metal. As long as this is taken into account during the planning of the installation, there should be no problems in this regard.

The thermal conductivity is lower than metal. Because of the resulting insulation properties, a PP piping system is notably more economical in comparison to a system made of a metal like copper.

Combustion Behavior

Polypropylene is a flammable plastic. The oxygen index amounts to 19%. (Materials that burn with less than 21% of oxygen in the air are considered to be flammable).

PP drips and continues to burn without soot after removing the flame. Basically, toxic substances are released by all burning processes. Carbon monoxide is generally the combustion product most dangerous to humans. When PP burns, primarily carbon dioxide, carbon monoxide and water are by-products of combustion.

The following classifications in accordance with differing combustion standards are used:

- According to UL94, PP is classified as HB (Horizontal Burning) and according to DIN 53438-1 as K2. According to DIN 4102-1 and EN 13501-1, PP is listed as B2 (normally flammable).
- According to ASTM D 1929, the self-ignition temperature is 360°C.
- Suitable fire-fighting agents are water, foam or carbon dioxide.

Electrical Properties

Since PP is a non-polar hydrocarbon polymer, it is an outstanding insulator. These properties, however, can be worsened considerably as a result of pollution, effects of oxidizing media or weathering.

The dielectric characteristics are essentially independent of temperature and frequency.

The specific volume resistance is > 10^{16} Ωcm; the dielectric strength is 75 kV/mm.

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

Complete System of Pipe, Valves and Fittings

GF's Polypropylene piping system easily transitions between PE, PVC, and PVDF, and is available with pipes, fittings and valves in sizes from 20 mm to 500 mm (metric), ½" to 2" (ASTM).

This system includes all commonly required pressure pipe fittings, including threaded adaptors and flanges for ease of mating to equipment or other piping materials. A large portfolio of ball, check, diaphragm, butterfly, pressure reduction, and pressure relief valves are also available from GF. Please refer to the GF Valve Technical Handbook for more details.

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.

Five different fusion methods for GF's Polypropylene Piping Systems are available and commonly used in today's demanding applications. These include conventional socket fusion, electrofusion, conventional contact butt fusion, IR Plus® butt fusion and BCF® (Bead and Crevice Free) fusion.

General Properties Polypropylene

Material Data

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

Mechanical

Properties	Unit	PROGEF Standard PP-H	PROGEF Natural PP-R	PPro-Seal Natural PP-R	ASTM Test
Density	lb/in³	0.0325	0.0325	0.0327	ASTM D792
Tensile Strength @ 73°F (Yield)	PSI	4,500	3,625	4,350	ASTM D638
Tensile Strength @ 73°F (Break)	PSI	5,600	4,500	5,000	ASTM D638
Modules of Elasticity Tensile @ 73°F	PSI	188,500	130,500	150,000	ASTM D638
Compressive Strength @ 73°F	PSI	6,500	5,500	5,500	ASTM D695
Flexural Modulus @ 73°F	PSI	181,250	130,500	130,000	ASTM D790
Izod Impact @ 73°F	Ft-Lbs/In of Notch	11.3	8.0	8.0	ASTM D256
Relative Hardness @ 73°F	Shore	70	70	70	ASTM D2240

Thermodynamics

Properties	Unit	PROGEF Standard	PROGEF Natural	PPro-Seal Natural	ASTM Test
Melt Index	gm/10min	0.25	0.30-0.40	0.40-0.80	ASTM D1238
Melting Point	°F	320	316	316	ASTM D789
Coefficient of Thermal Linear Expansion per °F	in/in/°F	0.89×10^{-4} for T≤121°F 1.0×10^{-4} for T>121°F		0.61×10^{-4}	ASTM D696
Thermal Conductivity	BTU-in/ft²/hr/°F	1.6	1.6	1.2	ASTM D177
Maximum Operating Temperature	°F	176	176	176	
Heat Distortion Temperature @ 264 PSI	°F	125	125	130	ASTM D648

Other

Properties	Unit	PROGEF Standard	PROGEF Natural	PPro-Seal Natural	ASTM Test
Water Absorption	%	<0.1%	<0.1%	<0.03%	ASTM D570
Poisson's Ratio @ 73°F		0.38	0.38	0.38	
Industry Standard Color		7032	Neutral	Neutral	RAL 9005
Food and Drug Association (FDA)		YES	YES	YES	CFR 21.177.1520
United States Pharmacopeia (USP)		YES	YES	YES	USP 25 Class VI

Note: This data is based on information compiled from multiple sources.

Overview SYGEF® Polyvinylidene Fluoride (PVDF) Piping Systems

General Information

Polyvinylidene Fluoride (PVDF) is a semi-crystalline thermoplastic having outstanding mechanical, physical and chemical properties. These result from the chemical structure of PVDF. Polyvinylidene Fluoride belongs to the class of fluorinated polymers whose best-known representative is polytetrafluoroethylene (PTFE). PTFE is characterized by a superb heat resistance and the best chemical resistance of all polymers; a big disadvantage is that it is not melt processable, e.g., into fittings. PVDF, on the other hand, combines various advantages of PTFE with good workability into structural parts. The fluorine content in PVDF amounts to 59% by weight.

PVDF from GF is characterized by a very good mechanical behavior and high temperature resistance. Because of the exceptionally wide pressure/temperature range in which PVDF can be used, it has opened, in connection with the specific characteristics of this material, completely new areas of application in plastic piping fabrication. These include applications in the semi-conductor, chemical and pharmaceutical industry, electroplating, paper and cellulose processing, the automotive industry and water treatment. Pipes, fittings and valves of PVDF are uncolored and opaque (milky, translucent).

By avoiding the addition of any additives, the outstanding characteristics of the material remain to the fullest extent, especially concerning the chemical resistance and physiological harmlessness.

Advantages

- outstanding mechanical properties, even at high temperatures
- excellent chemical resistance
- no electrochemical corrosion
- long service life, even under intensely corrosive conditions
- outstanding resistance against Sunlight and Y-radiation
- very pure material without additives, stabilizers or plasticizers
- inhospitable to microbial growth
- physiologically harmless
- secure jointing by high-quality welding technology
- produced with smooth inner surfaces
- very low heat conductivity
- excellent flame retardant properties

Mechanical Properties

PVDF has a high tensile strength and stiffness. The impact strength is still good at temperatures around 32°F (0°C). PVDF's advantages are particularly prevalent at higher temperatures. This is due to the high fluorine content which causes strong interactions between the PVDF chains. This, in turn, displaces the softening and the loss of properties to higher temperatures. This also has an effect on the long-term creep strength.

PVDF has the highest long-term creep strength of all the polymers used for GF piping systems. The long-term behavior for internal pressure resistance is provided by the hydrostatic strength curve based on the DVS 2205-1 Guidelines, Supplement 4 (see also the Pressure/Temperature section). The application limits for pipes and fittings, as shown in the pressure and temperature diagram, can be determined from these curves.

Chemical, Weathering, and Abrasion Resistance

PVDF is resistant to most inorganic solvents and additionally to aliphatic and aromatic hydrocarbons, organic acids, alcohol and halogenated solvents. PVDF is also not attacked by dry and moist halogens with the exception of fluorine. PVDF is not resistant against strong basic amines, alkalis, and alkaline metals. Strong polar solvents, such as ketones and esters and organic acids can cause PVDF to swell somewhat.

For detailed information, please refer to the detailed list of chemical resistance from GF or contact your GF subsidiary.

Outstanding resistance against UV light as well as gamma radiation permits, among other applications, the use of PVDF piping outdoors. No loss of properties occurs. Abrasion resistance is considerable and approximately comparable to that of polyamide.

Thermal Properties

PVDF shows its outstanding properties in a temperature range from -4°F (-20°C) to 284°F (140°C). This allows using the material in a wide range of applications. Especially at high temperatures, PVDF provides maximum security. Its high crystalline melting point at around 343°F (173°C) speaks for itself.

Please consult the pressure-temperature diagrams for your operational temperature. For temperatures below 32°F (0°C), the media must be prevented from freezing to avoid damaging the piping (as for other piping materials).

With a thermal coefficient of linear expansion of $0.67–1.00\times10^{-4}$ in/in°F (coefficient depends on temperature), PVDF lies clearly above that of metals. Because of this, its thermal expansion must be taken into account during the planning of the piping system. As for all polymers, PVDF is a good thermal insulator because its heat conductivity of 1.3 BTU-in/ft^2/hr/°F is very low. (For comparison, the value for steel is 1733 BTU-in/ft^2/hr/°F).

Flammability and Fire Testing

Combustion Behavior

PVDF displays an exceptionally good combustion behavior without the addition of fire protection additives. Material decomposition begins at 716°F (380°C). The oxygen index amounts to 44%. (Materials that burn with less than 21% of oxygen in the air are considered to be flammable).

PVDF thus also falls in the best flammability class V0 according to UL94, and in the building materials class B1 (difficult to ignite) according to DIN 4102-1.

SYGEF® PVDF products show such excellent fire safety behavior that they are accepted and listed by Factory Mutual for use in clean rooms (FM 4910).

Comparative oxygen indices	
Material	**% Oxygen**
PMMA	17.3
PE	17.4
PP	17.4
PIB	17.7
PS	18.1
PC	27.0
PA 6.6	29.0
ETFE	30.0
SYGEF	43.7
PVC	45
PTFE	95

Installation within Designated Return Air Plenums

SYGEF Standard 25/50 PVDF, available in sizes 20mm to 75mm, is officially certified for building air plenum installations according to UL 723 ASTM E-84 25/50. This standard is intended to help protect occupants' safety in the event of a fire. It is a measure of smoke generation and flame spread in the event of a fire. Please contact your local GF sales representative for more information.

Fire Testing

Since the combustion of PVDF produces hydrogen fluoride, which forms a corrosive acid in connection with water, immediate cleaning of areas susceptible to corrosion with water containing detergent is necessary after a fire. Additional combustion products are carbon monoxide and carbon dioxide. Concerning the choice of fire-fighting agents, sand or powder-type extinguishing agents are recommended because the use of water may result in the development of corrosive acids. Test method according to ASTM D635 The end of a test specimen is held horizontally, for 30 seconds, in the flame of a Bunsen burner, the narrow side of the specimen being inclined at an angle of 45°.

PVDF stops burning immediately if the flame is removed. By way of comparison, unplasticised PVC also stops burning immediately, while self-extinguishing polyester continues to burn for 2 seconds after the source of ignition has been removed.

The HOOKER HLT 15 flame test This method of test is much more stringent than the ASTM D635 test. The test permits the classification of non-flammable products into various categories.

A test specimen prepared according to ASTM D635 is clamped vertically and is then periodically exposed to the Bunsen flame, using the following rhythm:

The test specimen must have stopped burning at any rate before the flame is applied again.

SYGEF will withstand four contact cycles with the flame. After the fifth contact it melts, but without burning.

ISO R 181 test according to SCHRAMM

A flat test specimen in horizontal position is pressed for 3 min. against a rod heated to 1742°F (950°C). The loss in weight p in mg is then determined, together with the longitudinal shrinkage L in cm and assessed according to the following equation: Lg = 100,000 pL in degrees SCHRAMM

Duration	**Operation**
5 seconds	1st contact with flame
10 seconds	Flame removed
7 seconds	2nd contact with flame
14 seconds	Flame removed
10 seconds	3rd contact with flame
20 seconds	Flame removed
15 seconds	4th contact with flame
30 seconds	Flame removed
25 seconds	5th contact with flame
50 seconds	Flame removed

For SYGEF, the result is 2.2 degrees SCHRAMM. By way of comparison, unplasticised PVC shows 2.2 degrees SCHRAMM also, and self-extinguishing polyester 2.5 degrees SCHRAMM

Electrical Properties

PVDF is a good electrical insulator. Because of the possible electrostatic charges, caution is recommended when using PVDF in applications where combustion or explosion dangers exist. The specific volume resistance is >10^{14} Ωcm; the specific surface resistance is 10^{14} Ω.

Physiological Properties

PVDF is physiologically non-toxic as long as it is used below the maximum temperature of 302°F (150°C). During welding, good ventilation is required or alternately the released gases must be extracted.

PVDF can be used in the USA in accordance with the relevant regulations of the Food and Drug Administration (FDA) for food packaging and items that come into contact with food. The Federal Health Ministry of Germany generally recommends that plastic items containing fluorine be thoroughly rinsed or boiled before their first use—a common procedure usual for other materials too.

Extractables

PVDF is a pure resin. Unlike other plastics, SYGEF PVDF does not contain additives, stabilizers, antioxidants or extrusion/injection molding aides. It is considered to be chemically inert and is not water soluble. SYGEF Plus HP Grade PVDF pipes and fittings are comprised of only PVDF while SYGEF Plus HP Grade Valves also contain PTFE diaphragms. Testing shows that PVDF is not detectable in water.

SYGEF Plus HP Grade PVDF yields no polymeric extractables at any temperature. At elevated temperatures, fluoride is a detectable ionic extractable in trace amounts yielding water quality well within USP specifications for production of DI, USP and WFI. Testing with hot deionized water shows that trace elements are detectable at extremely low levels as surface contaminants. They virtually disappear after the system is adequately flushed. Dynamic testing under flowing conditions also indicated that the amount of extractables challenge the detection limits of modern analytical test equipment.

Additionally, SYGEF Plus HP Grade PVDF piping system components comply with the recommendations of SEMI F57 Guidelines for extractable levels of metallic and ionic contaminants as well as TOC for polymer components. These levels are far below those seen with traditional metal piping systems used widely in the pharmaceutical industry.

Discoloration Phenomena

PVDF exhibits a more intense degree of color change due to heat history and chemical effects when compared to other thermoplastics. Because PVDF is absent of additives, changes in coloration are exhibited far more readily than otherwise expected.

Coloration changes can vary from beige to dark brown. It is important to recognize that even a major discoloration (brown) does not always relate to a degradation of the polymer. Such discoloration is common for PVDF materials operating in hot ultrapure water systems at 158°F (70°C) to 176°F (80°C) and is the result of minor double bonding of carbon along the PVDF linear molecule chain.

According to a 1993 report by a PVDF raw material supplier, the theoretical effects of such discoloration of PVDF are outlined as follows:

- PVDF becomes completely black when only (1) in (1000) of PVDF monomer (-CH2-CF2-) transform to a (-CH=CF-) molecule
- In a 3.2 ft length of 2 in (63 mm) pipe there are about 2 ft^2. of surface area
- When the discoloration affects .03937 in of the surface (entire pipe appears black), this volume is 11 in^3.
- PVDF has a density of ~ 0.06 lb/in^3, therefore, 11 in^3. Weights ~ 0.7 lb.
- Since 59% of the (-CH2-CF2-) monomer is F2, the loss of 1 atom of F per 1000 results in 2.0×10^{-4} lbs F being removed from the 3.2 ft of pipe material; (0.7 lb × 59%/2 × 1/1000) = 2.0×10^{-4} lbs
- There are 6.02 $\times10^{23}$ atoms per 0.04 lb F; hence, 2.0×10^{-4} lbs is equivalent to 2.98 × 10^{21} atoms
- If a 2 in (63 mm) pipe has a velocity of 5 ft/sec., then the flow is approximately 61 gallons/min.
- Because brown discoloration occurs within 2 weeks time in a hot UPW system, the amount of H^2O passing through this 3.2 ft of pipe is about 0.17×10^6 ft^3.
- Therefore, this 0.094 g is diluted to levels challenging detection capabilities even when the PVDF appears black 2.0×10^{-4} lbs/0.17×10^6 ft^3 = ~ 19 ppt
- If a conservative factor of 1000 is used to demonstrate the difference between the first signs of discoloration (brown) and the 1 per 1000 rule (black) the value is easily < 0.019 ppt Fire Rated Construction

Manufacturing

Complete System of Pipe, Fittings and Valves

The production hall for SYGEF Plus HP (PVDF) pipes, fittings and valves shall be maintained at Class 10,000 Cleanroom (ISO Class 7) or better as defined by the current ISO Standard 14644-1. Specific class levels are assigned for each level of production as described later in this section.

SYGEF (PVDF) pipe shall be a Standard Dimensions Ratio (SDR) series which defines the outer pipe diameter, wall thickness and tolerances. GF produces pipe and fittings rated for 232 psi (16 bar) from ⅜" (16 mm) to 8" (225 mm) and 150 psi (10 bar) from 3" (90 mm) to 18" (450 mm) when measured at 68°F (20°C).

Flanged connections have ANSI 150# bolt pattern. All mechanical connections for sample ports, instrumentation or venting have either sanitary or approved ANSI threaded NPT connections.

All SYGEF Plus HP (PVDF) valves have a minimum pressure rating of 150 psi (10 bar) at 68°F (23°C). High purity PVDF valves in sizes through 2" (63 mm) are Type 514/515 Diaphragm Valves as manufactured by GF. Additionally, Type 519 Zero-Static Lateral Valves are available up to 4" (110 mm) along the run. All diaphragm valves are weir style with PTFE diaphragm seals backed with EPDM or FPM.

Compliance with Microelectronics Standards

Compliance with industry standards is very important to GF Piping Systems. This is especially the case in the field of high purity where SYGEF Plus HP Grade (PVDF) piping system components are required to convey ultrapure water (UPW) and high purity chemicals with qualities as characterized within SEMI documentation. Disregard for this requirement would impart serious yield losses to the high tech end-users of piping systems.

For example, SEMI F63 defines the UPW quality used in today's sub-100 nanometer semiconductor factories. SEMI F57 outlines the critical characteristics and performance criteria of polymer raw materials and components. SEMI F40 gives the necessary steps for testing these raw materials and components.

To insure that manufacturing conditions and final product meet or exceed the requirements of SEMI F57 guidelines for extractable levels of metallic, ionic and organic (TOC) contaminants standardized testing regimes have been adopted within GF's high purity facility. This strict compliance to SEMI F57 demands routine sampling of production pipes, fittings and valves, which are submitted to certified laboratories for testing using SEMI F40 protocol. Databases with Cpk (process capability) indices are maintained and monitored for early warning indications of potential problems in either raw material purity or production induced changes.

The leached levels seen in SYGEF Plus HP (PVDF) continue to provide demanding customers with satisfactory results. At the same time, they are far below those found coming from traditional metal piping systems, which are widely used in the pharmaceutical industry.

Compliance with Life Science Standards

SYGEF Plus HP (PVDF) Piping Systems have been installed for use in Deionized (DI) Water, USP Water, and WFI systems and are well suited to these applications. This material can be sanitized using hot water, steam, ozonation or chemicals and does not require passivation for the life of the system. It can also be steam sterilized. Additionally, since SYGEF Plus HP (PVDF) piping components are produced and packaged in a high purity environment, no Clean In Place (CIP) procedures are required at startup, provided that installation occurs in a controlled environment.

SYGEF Plus HP (PVDF) meets the requirements of ASME BPE (Bioprocessing Equipment) Standard, Section PM and Section SF.

Recent changes in the USP XXIII call for water to pass the Total Organic Carbon (TOC) test with limits of ≤ 500 ppb. Historically, the users of PVDF systems have focused on the much more rigorous TOC requirements of the microelectronics industry. These systems typically pass using on-line monitoring equipment at limits of ≤ 5 ppb, 100 times more stringent than the current USP XXIII requirement. Of significant importance, these results have been achieved with virtually no unscheduled down time.

SYGEF Plus HP (PVDF) has measurably smoother surfaces than those found in common grades of stainless steel used in pharmaceutical systems. Piping system components are made from a pure fluoropolymer resin, containing no metals such as iron, copper or nickel. This inert pipe cannot experience rouging or pitting corrosion. Additionally the BCF welding process provides smooth weld surfaces, far superior to the results produced by welding on stainless steel. In stainless steel systems, microscopic pitting from corrosion of the pipe surface, as well as welding beads create rough surfaces which can harbor microorganisms. This smoother surface, combined with the smoother BCF weld result, presents fewer opportunities on the piping system surface for bacteria to adhere and proliferate. Thus, it requires less frequent sanitization and less production down time.

Raw Materials

SYGEF Plus HP (PVDF) pipe, fittings and valves shall be manufactured from natural, unpigmented, virgin polyvinylidene fluoride (PVDF) homopolymer conforming to the standards of ASTM D3222. All raw material utilized for SYGEF Plus HP (PVDF) production shall be specially controlled regarding procurement, shipment, handling and storage prior to production to minimize contact with extraneous contamination.

PVDF raw materials shall be handled in a clean room environment to prevent contamination. The raw material shall be gravity fed into the processing equipment. Pneumatic conveyance of the raw material is prohibited. PVDF raw material shall meet the testing requirements for impurities per SEMI F57.

Manufacturing (Pipe)

Environment

SYGEF Plus HP (PVDF) pipe shall be extruded in a dedicated high purity PVDF production area which is located in an ISO 14644-1 Class 7 (U.S. Fed. Standard 209E Class 10,000) or better environment. All pipes shall be extruded on dedicated production equipment used exclusively for the production of high purity PVDF. Pipe dimensions and tolerances shall be continually monitored with QC sampling at designated time intervals compliant with Good Manufacturing Practices.

Stress Relieving

Extrusion stresses shall be relieved by use of a continuous in-line annealing oven. Stress relief shall be measured and relate to a maximum 0.4% dimensional change when tested according to ISO 10931-2, ISO 10931-2, and max internal stress of 2.5 N/mm^2.

Pipe Identification

SYGEF Plus HP (PVDF) pipe shall be identified on the pipe outer surface (on top) with the production lot, pipe diameter and wall thickness. Pipe identification shall be accomplished by use of heat embossed lettering and without the use of any ink on the pipe surface. After packaging, each pipe length shall have a label adhered to the outside of the outer polyethylene bag. The label shall denote production lot, pipe diameter, wall thickness and surface quality.

Surface Finish

SYGEF Plus HP (PVDF) pipe shall have samples taken which are measured for mean roughness of the interior pipe surface.

Using ISO 4287/4288, SYGEF Plus HP (PVDF) pipe, shall have profilometer mean roughness values compliant with SEMI F57 or better.

Pipe interior shall also be visually inspected for defects on a lighted table prior to fitting with protective polyethylene end caps and double bagged in heat sealed polyethylene liners immediately after production within the cleanroom.

	SYGEF Standard	SYGEF Plus
Surface finish Compliant to Semi F57	Inner surface Ra < 0.5 µm (20µin) for injection moulded and extruded components	Inner surface (PN10/SDR33): • d ≤ 225 Ra ≤ 0.2 µm (8µin) • d = 250 Ra ≤ 0.3 µm (12µin) • d280–315 Ra ≤ 0.4 µm (16µin) • d355–450 Ra ≤ 0.65 µm (26µin) • for injection moulded and extruded components

Manufacturing (Fittings/Valves)

Environment

All high purity PVDF fittings and valves shall be manufactured on dedicated equipment in clean production cells that are Class 100 (ISO Class 5) or better. Any machined valve components shall be performed with no coolant other than filtered air.

Cleaning

Fittings and valves (diaphragm) shall be washed in a Class 100 Cleanroom (ISO Class 5), using DI water with nonionic, phosphate free surfactant solution. After cleaning, the components shall be rinsed with hot (176°F/80°C) UPW water, flushed with ambient UPW water, both meeting SEMI F63-00-0701 requirements, and heat dried with HEPA filtered air or filtered nitrogen.

Identification

All high purity PVDF fittings and valves shall be molded with permanent identification to allow tractability to production lot and raw material batch.

In addition, all high purity PVDF fitting and valve labels shall have an identification code or numbering scheme on the packaging that permits traceability back to the lot and batch cleaning of fittings or valves.

Packaging

After cleaning, fittings and valves shall be immediately and individually heat sealed in PA6/PE double bags while in the cleanroom. Valves shall be assembled in a Class 100 (ISO Class 5) environment. No external markings or labeling shall be permitted except on the outer bag. The production label shall denote production lot, dimension and logistical information.

Manufacturing (Fabricated Products)

Production of PVDF fabricated items are to be done under a minimum Class 10,000 cleanroom as defined in the current Federal Standard. Machine components made from semi-finished PVDF block and rod used in this fabrication of parts or sub-assemblies shall be inspected, cleaned and packaged similar to fittings and valves. Final inspection is made prior to packaging by 100% visual inspection of every weld. Pressure test for welded assemblies as required.

Traceability of Machined Components

Welding of sub-components shall only be done by manufacturers certified technicians. All factory welds shall be labeled using the manufacturers fusion machine printouts from actual welds. All finished parts and assemblies shall be permanently marked with a traceable number which links incoming material, production dates, machines used and welding personnel.

Delivery, Storage and Handling

Any material that becomes damaged and/or contaminated in transit handling or storage shall not be used. It must be rejected by the quality control representative and returned to the manufacturer/distributor.

All material and equipment shall be handled and stored in an indoor location throughout the progress of the job in such a manner as to prevent damage and/or contamination. Room shall be maintained dry and dust free. Room shall be kept at a temperature between 60°F (15°C) and 85°F (30°C).

Piping, fittings, and valves shall be stored in their original factory sealed poly bags. Use nylon or polypropylene rope or soft strand for slings and tie-downs used to let, load, or transport pipe bundles. Do not stack pipe higher than 2 feet.

All fabricated material shall be used within 48 hours of being removed from the storage site. All high-purity PVDF piping system components shall be inspected and approved by fabricator and installer upon arrival into the fabrication clean room and before spool fabrication begins.

Fabricated spool pieces shall be supported and padded to prevent damage during transport.

All pipe fitting ends of fabricated spool pieces shall be double bagged and sealed. Bags shall be secured with cap or cleanroom tape a minimum 6 inches away from pipe end. Cleanroom tape directly over pipe or fitting end is not acceptable.

General Properties SYGEF® Polyvinylidene Fluoride (PVDF)

Material Data

The following table lists typical physical properties of PVDF (Polyvinylidene Flouride) thermoplastic materials. Variations may exist depending on specific compounds and product.

Mechanical

Properties	Unit	SYGEF Plus HP/Standard PVDF	ASTM Test
Density	lb/in^3	0.0643	ASTM D792
Tensile Strength @ 73°F (Yield)	PSI	≥ 7,250	ASTM D638
Tensile Strength @ 73°F (Break)	PSI	≥ 6,500	ASTM D638
Modules of Elasticity Tensile @ 73°F	PSI	≥ 246,560	ASTM D638
Compressive Strength @ 73°F	PSI	12,500	ASTM D695
Flexural Modulus @ 73°F	PSI	267,500	ASTM D790
Izod Impact @ 73°F	ft-lbs/in of notch	≥ 3.8	ASTM D256
Relative Hardness @ 73°F	Durometer “D”	78	ASTM D2240

Thermodynamics

Properties	Unit	SYGEF	ASTM Test
Melt Index	gm/10 min	1.10	ASTM D1238
Melting Point	°F	≥ 336	ASTM D789
Coefficient of Thermal Linear Expansion per °F	in/in/°F	0.67...1.00 ($\times 10^{-4}$)	ASTM D696
Thermal Conductivity	BTU-in/ft^2/hr/°F	1.3	ASTM D177
Specific Heat	CAL/g/°C	0.32	DSC
Maximum Operating Temperature	°F	284	
Heat Distortion Temperature @ 264 PSI	°F	≥ 220	ASTM D648

Other

Properties	Unit	SYGEF	ASTM Test
Water Absorption	%	≤ 0.04	ASTM D570
Limited Oxygen Index (LOI)	%	≥ 43	
Industry Standard Color		Opaque	RAL 9005
Food and Drug Association (FDA)		YES	CFR21.177.1520
United States Pharmacopeia (USP)		YES	USP 25 Class VI
SEMI		YES	F57
Factory Mutual		YES	FM4910

Note: This data is based on information compiled from multiple sources.

Specifications PVDF and PP

Pressure/Temperature

Long-Term Stress

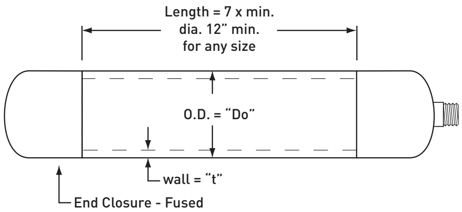
To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends (Figure 1) and subjected to various internal pressures, to produce circumferential stresses that will predict failure in a few minutes to 50 years. The test is run according to ASTM D1598, "Standard Test 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 Test setup for determining long-term stress



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 PROGEF Standard (PP-H) Polypropylene

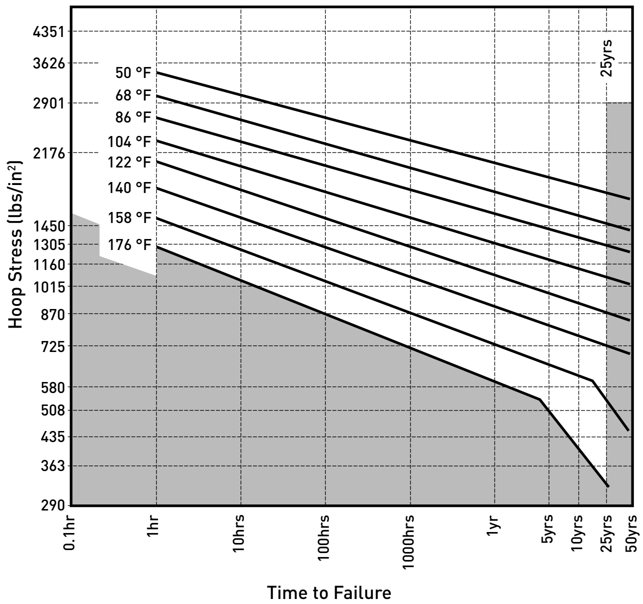


Figure 3 PROGEF Natural (PP-R) Polypropylene

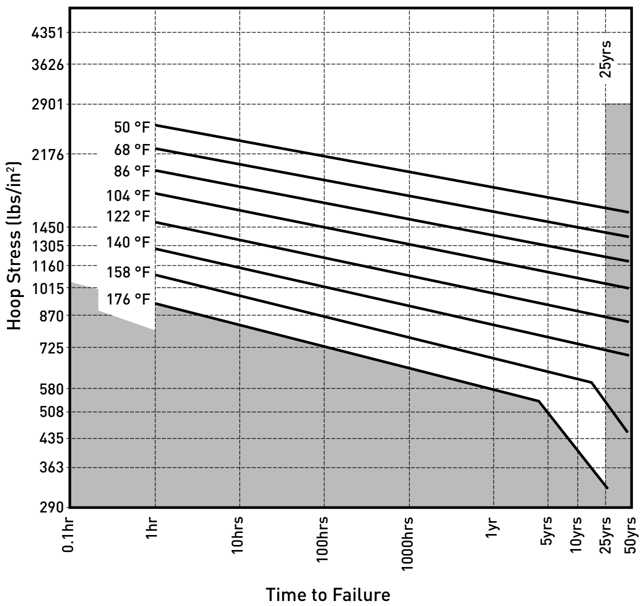


Figure 4 PPro-Seal Natural (PP-R) Polypropylene

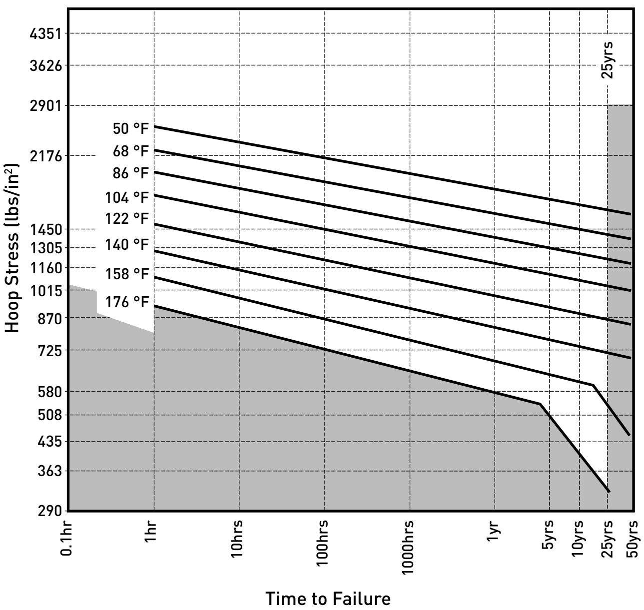
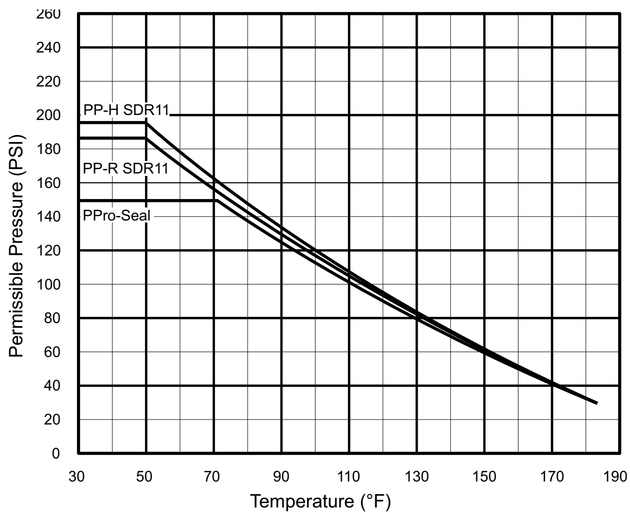


Figure 5 Working Temperature and Pressures for PROGEF Standard (PP-H), PROGEF Natural (PP-R) and PPro-Seal (PP-R)

Based on 25-year service life. Service Factor C=2.0



+GF+

Figure 6 Regression Curve Stress/Time to failure for SYGEF PVDF

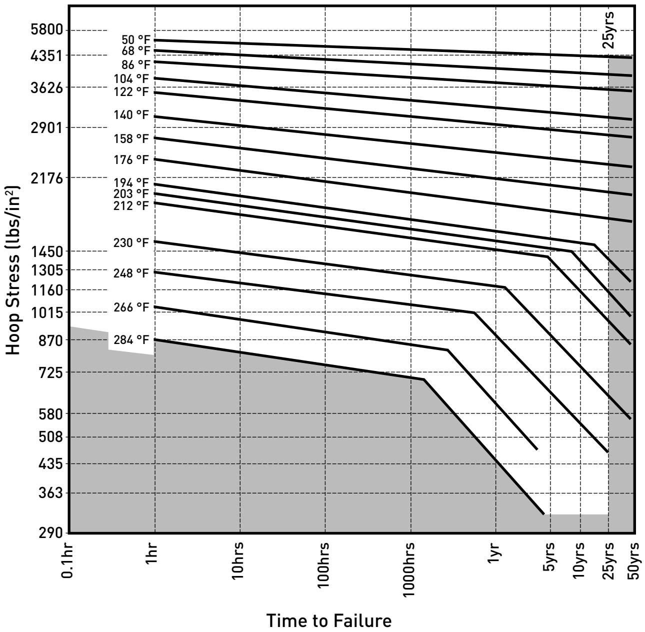
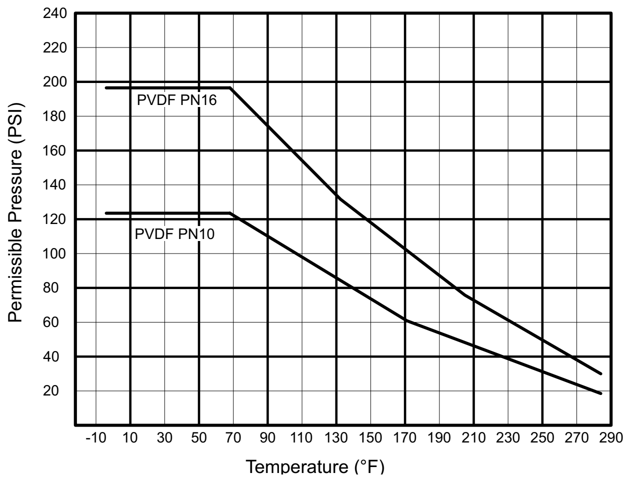


Figure 7 Working Temperature and Pressures for SYGEF PVDF

Based on 25-year service life. Service Factor C=2.0



Dimensional Pipe Size

Pipe Size Comparison: Polypropylene Piping Systems

Nominal Size	Outer Diameter			Wall Thickness			Inner Diameter		
	PROGEF Standard	PROGEF Natural	PPro-Seal	PROGEF Standard	PROGEF Natural	PPro-Seal	PROGEF Standard	PROGEF Natural	PPro-Seal
½" (20 mm)	20.0 mm	20.0 mm	0.840 in	1.9 mm	1.9 mm	0.147 in	16.2 mm	16.2 mm	0.546 in
¾" (25 mm)	25.0 mm	25.0 mm	1.050 in	2.3 mm	2.3 mm	0.154 in	20.4 mm	20.4 mm	0.742 in
1" (32 mm)	32.0 mm	32.0 mm	1.315 in	2.9 mm	2.9 mm	0.179 in	26.2 mm	26.2 mm	0.957 in
1¼" (40 mm)	40.0 mm	40.0 mm	—	3.7 mm	3.7 mm	—	32.6 mm	32.6 mm	—
1½" (50 mm)	50.0 mm	50.0 mm	1.900 in	4.6 mm	4.6 mm	0.200 in	40.8 mm	40.8 mm	1.500 in
2" (63 mm)	63.0 mm	63.0 mm	2.375 in	5.8 mm	5.8 mm	0.218 in	51.4 mm	51.4 mm	1.939 in
2½" (75 mm)	75.0 mm	—	—	6.8 mm		—	61.4 mm	—	—
3" (90 mm)	90.0 mm	90.0 mm		8.2 mm	5.1 mm		73.6 mm	79.8 mm	
4" (110 mm)	110.0 mm	—	—	10.0 mm	—	—	90.0 mm	—	—
6" (160 mm)	160.0 mm	—	—	14.6 mm	—	—	130.8 mm	—	—
8" (200 mm)	200.0 mm	—	—	18.2 mm	—	—	163.6 mm	—	—
9" (225 mm)	225.0 mm	—	—	20.5 mm	—	—	184.0 mm	—	—
10" (250 mm)	250.0 mm	—	—	22.7 mm	—	—	204.6 mm	—	—
12" (315 mm)	315.0 mm	—	—	28.6 mm	—	—	257.8 mm	—	—
14" (355 mm)	355.0 mm	—	—	32.2 mm	—	—	290.6 mm	—	—
16" (400 mm)	400.0 mm	—	—	36.3 mm	—	—	327.4 mm	—	—
18" (450 mm)	450.0 mm	—	—	40.9 mm	—	—	368.2 mm	—	—
20" (500 mm)	500.0 mm	—	—	45.4 mm	—	—	409.2 mm	—	—

Pipe Size Comparison: PVDF Piping Systems

Nominal Size	Outer Diameter		Wall Thickness		Inner Diameter	
	SYGEF PVDF PN16	SYGEF PVDF PN10	SYGEF PVDF PN16	SYGEF PVDF PN10	SYGEF PVDF PN16	SYGEF PVDF PN10
⅜" (16 mm)	16.0 mm	—	1.9 mm	—	12.2 mm	—
½" (20 mm)	20.0 mm	—	1.9 mm	—	16.2 mm	—
¾"- (25 mm)	25.0 mm	—	1.9 mm	—	21.2 mm	—
1" (32 mm)	32.0 mm	—	2.4 mm	—	27.2 mm	—
1¼" (40 mm)	40.0 mm	—	2.4 mm	—	35.2 mm	—
1½" (50 mm)	50.0 mm	—	3.0 mm	—	44.0 mm	—
2" (63 mm)	63.0 mm	—	3.0 mm	—	57.0 mm	—
2½" (75 mm)	75.0 mm	—	3.6 mm	—	67.8 mm	—
3" (90 mm)	90.0 mm	90.0 mm	4.3 mm	2.8 mm	81.4 mm	84.4 mm
4" (110 mm)	110.0 mm	110.0 mm	5.3 mm	3.4 mm	99.4 mm	103.2 mm
6" (160 mm)	160.0 mm	160.0 mm	7.7 mm	4.9 mm	144.6 mm	150.2 mm
8" (200 mm)	200.0 mm	200.0 mm	9.6 mm	6.2 mm	180.8 mm	187.6 mm
9" (225 mm)	225.0 mm	225.0 mm	10.8 mm	6.9 mm	203.4 mm	211.2 mm
10" (250 mm)	—	250.0 mm	—	7.7 mm	—	234.6 mm
12" (315 mm)	—	315.0 mm	—	9.7 mm	—	295.6 mm
14" (355 mm)	—	355.0 mm	—	10.8 mm	—	333.4 mm
16" (400 mm)	—	400.0 mm	—	12.1 mm	—	375.8 mm
18" (450 mm)	—	450.0 mm	—	13.6 mm	—	422.8 mm

Note: All dimensions are nominal. Please refer to detailed GF specifications and applicable standards for tolerances.

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 acceptable velocity in pipes is typically 7.0 ±3.0 (ft/sec), with a maximum velocity of 10.0 (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.

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 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 plastic 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.

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 (in)
Q = Fluid Flow (gal/min)

C = Constant for Plastic Pipes (conservative - 150)

Hazen and Williams Formula

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

Step 1: Solve for V

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

Step 2: Solve for ΔH

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

Step 3: Solve for ΔP

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

Pressure Loss of Fittings

Pressure loss due to fittings depends on the type. In general it can be calculated from the following formula:

$$L_e = K_r \times \frac{(V^2)}{2 \times g}$$

where

L_e = Head loss in equivalent feet of pipe
K_r = resistance coefficient (dimensionless, depends on fitting type)
g = Gravitational constant 32 ft/sec^2
V = Flow velocity in ft/sec

K_r

Sweep 90	Sharp 90	45 Elbow	Tee	Reducer	Increaser
0.4	1.2	0.3	1.3	1.0	0.5

The pressure loss due to all fittings in the piping system is the sum of each L_e. For example, the pressure loss due to ten sweep 90 elbows in a system flowing at 5 ft/sec is approximately:

$$L_e = (10 \times 0.4) \times \frac{5^2}{2 \times 32} = 1.6 \text{ ft pipe equivalent}$$

Flow Rate vs. Friction Loss

PROGEF Standard Polypropylene (PP)

PROGEF Standard Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	20 mm			25 mm			32 mm			40 mm			
0.75	0.75	0.51	0.22										**0.75**
1	1.00	0.88	0.38	0.63	0.29	0.12							**1**
2	2.01	3.17	1.37	1.27	1.03	0.45	0.77	0.31	0.13				**2**
3	3.01	6.71	2.90	1.90	2.19	0.95	1.15	0.65	0.28	0.74	0.22	0.10	**3**
4	4.02	11.43	4.95	2.53	3.72	1.61	1.54	1.10	0.48	0.99	0.38	0.16	**4**
5	5.02	17.28	7.48	3.17	5.63	2.44	1.92	1.67	0.72	1.24	0.58	0.25	**5**
6	6.03	24.22	10.48	3.80	7.89	3.42	2.30	2.34	1.01	1.49	0.81	0.35	**6**
7	7.03	32.22	13.95	4.43	10.50	4.54	2.69	3.11	1.34	1.74	1.07	0.46	**7**
8	8.03	41.26	17.86	5.07	13.44	5.82	3.07	3.98	1.72	1.98	1.37	0.59	**8**
9	9.04	51.32	22.22	5.70	16.72	7.24	3.46	4.95	2.14	2.23	1.71	0.74	**9**
10	10.04	62.38	27.00	6.33	20.32	8.80	3.84	6.01	2.60	2.48	2.08	0.90	**10**
15	15.07	132.17	57.22	9.50	43.06	18.64	5.76	12.74	5.52	3.72	4.40	1.90	**15**
20				12.67	73.35	31.75	7.68	21.71	9.40	4.96	7.50	3.25	**20**
30				19.00	155.43	67.29	11.52	46.00	19.92	7.44	15.88	6.88	**30**
40							15.36	78.38	33.93	9.92	27.06	11.72	**40**
50										12.40	40.91	17.71	**50**
60										14.88	57.34	24.82	**60**

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

PROGEF Standard Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	50 mm			63 mm			75 mm			90 mm			
5	0.79	0.19	0.08										**5**
10	1.58	0.70	0.30	1.00	0.23	0.10							**10**
15	2.38	1.48	0.64	1.50	0.48	0.21	1.05	0.20	0.09				**15**
20	3.17	2.52	1.09	2.00	0.82	0.35	1.40	0.34	0.15	0.97	0.14	0.06	**20**
25	3.96	3.80	1.65	2.49	1.24	0.54	1.75	0.52	0.23	1.22	0.22	0.09	**25**
30	4.75	5.33	2.31	2.99	1.73	0.75	2.10	0.73	0.32	1.46	0.30	0.13	**30**
35	5.54	7.09	3.07	3.49	2.31	1.00	2.45	0.97	0.42	1.70	0.40	0.17	**35**
40	6.33	9.08	3.93	3.99	2.95	1.28	2.80	1.24	0.54	1.95	0.51	0.22	**40**
45	7.13	11.30	4.89	4.49	3.67	1.59	3.15	1.55	0.67	2.19	0.64	0.28	**45**
50	7.92	13.73	5.94	4.99	4.46	1.93	3.50	1.88	0.81	2.43	0.78	0.34	**50**
55	8.71	16.38	7.09	5.49	5.33	2.31	3.85	2.24	0.97	2.68	0.93	0.40	**55**
60	9.50	19.25	8.33	5.99	6.26	2.71	4.20	2.63	1.14	2.92	1.09	0.47	**60**
65	10.29	22.32	9.66	6.48	7.26	3.14	4.54	3.06	1.32	3.16	1.27	0.55	**65**
70	11.08	25.61	11.09	6.98	8.32	3.60	4.89	3.51	1.52	3.41	1.45	0.63	**70**
75				7.48	9.46	4.09	5.24	3.98	1.72	3.65	1.65	0.71	**75**
80				7.98	10.66	4.61	5.59	4.49	1.94	3.89	1.86	0.80	**80**
95				9.48	14.65	6.34	6.64	6.17	2.67	4.62	2.55	1.11	**95**
100				9.98	16.11	6.98	6.99	6.79	2.94	4.87	2.81	1.22	**100**
125				12.47	24.36	10.55	8.74	10.26	4.44	6.08	4.25	1.84	**125**
150				14.97	34.15	14.78	10.49	14.38	6.22	7.30	5.95	2.58	**150**
175							12.24	19.13	8.28	8.52	7.92	3.43	**175**
200										9.73	10.14	4.39	**200**
225										10.95	12.61	5.46	**225**
250										12.16	15.33	6.64	**250**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

PROGEF Standard Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	110 mm			160 mm			200 mm			225 mm			
20	0.65	0.05	0.02										**20**
25	0.81	0.08	0.04										**25**
30	0.98	0.11	0.05										**30**
35	1.14	0.15	0.07	0.54	0.02	0.01							**35**
40	1.30	0.19	0.08	0.62	0.03	0.01							**40**
45	1.46	0.24	0.10	0.69	0.04	0.02							**45**
50	1.63	0.29	0.13	0.77	0.05	0.02	0.49	0.02	0.01				**50**
75	2.44	0.62	0.27	1.16	0.10	0.04	0.74	0.03	0.01	0.58	0.02	0.01	**75**
100	3.25	1.06	0.46	1.54	0.17	0.07	0.98	0.06	0.02	0.78	0.03	0.01	**100**
125	4.07	1.60	0.69	1.93	0.26	0.11	1.23	0.09	0.04	0.97	0.05	0.02	**125**
150	4.88	2.24	0.97	2.31	0.36	0.16	1.48	0.12	0.05	1.17	0.07	0.03	**150**
200	6.51	3.81	1.65	3.08	0.62	0.27	1.97	0.21	0.09	1.56	0.12	0.05	**200**
250	8.14	5.76	2.49	3.85	0.93	0.40	2.46	0.31	0.14	1.95	0.18	0.08	**250**
300	9.76	8.08	3.50	4.62	1.31	0.57	2.95	0.44	0.19	2.34	0.25	0.11	**300**
350	11.39	10.74	4.65	5.39	1.74	0.75	3.45	0.59	0.25	2.72	0.33	0.14	**350**
400	13.02	13.76	5.96	6.16	2.23	0.97	3.94	0.75	0.33	3.11	0.42	0.18	**400**
500				7.70	3.37	1.46	4.92	1.14	0.49	3.89	0.64	0.28	**500**
600				9.24	4.73	2.05	5.91	1.59	0.69	4.67	0.90	0.39	**600**
700				10.78	6.29	2.72	6.89	2.12	0.92	5.45	1.20	0.52	**700**
800				12.33	8.06	3.49	7.88	2.71	1.17	6.23	1.53	0.66	**800**
900							8.86	3.37	1.46	7.01	1.90	0.82	**900**
1000							9.85	4.10	1.77	7.79	2.31	1.00	**1000**
1250							12.31	6.20	2.68	9.73	3.50	1.51	**1250**
1500							14.77	8.69	3.76	11.68	4.90	2.12	**1500**
1750										13.62	6.52	2.82	**1750**

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

PROGEF Standard Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	250 mm			315 mm			355 mm			400 mm			
100	0.63	0.02	0.01										**100**
150	0.94	0.04	0.02	0.59	0.01	0.01							**150**
200	1.26	0.07	0.03	0.79	0.02	0.01	0.62	0.01	0.01				**200**
250	1.57	0.11	0.05	0.99	0.03	0.01	0.78	0.02	0.01	0.61	0.01	0.00	**250**
300	1.89	0.15	0.06	1.19	0.05	0.02	0.94	0.03	0.01	0.74	0.02	0.01	**300**
350	2.20	0.20	0.09	1.39	0.06	0.03	1.09	0.04	0.02	0.86	0.02	0.01	**350**
400	2.52	0.25	0.11	1.59	0.08	0.04	1.25	0.05	0.02	0.98	0.03	0.01	**400**
500	3.15	0.38	0.17	1.98	0.12	0.05	1.56	0.07	0.03	1.23	0.04	0.02	**500**
750	4.72	0.81	0.35	2.97	0.26	0.11	2.34	0.15	0.06	1.84	0.08	0.04	**750**
1000	6.30	1.38	0.60	3.97	0.45	0.19	3.12	0.25	0.11	2.46	0.14	0.06	**1000**
1250	7.87	2.09	0.90	4.96	0.68	0.29	3.90	0.38	0.16	3.07	0.21	0.09	**1250**
1300	8.19	2.25	0.97	5.16	0.73	0.32	4.06	0.41	0.18	3.20	0.23	0.10	**1300**
1350	8.50	2.41	1.04	5.35	0.78	0.34	4.21	0.44	0.19	3.32	0.24	0.11	**1350**
1400	8.82	2.58	1.11	5.55	0.84	0.36	4.37	0.47	0.20	3.44	0.26	0.11	**1400**
1500	9.44	2.93	1.27	5.95	0.95	0.41	4.68	0.53	0.23	3.69	0.30	0.13	**1500**
1750	11.02	3.89	1.69	6.94	1.26	0.55	5.46	0.71	0.31	4.30	0.40	0.17	**1750**
2000	12.59	4.99	2.16	7.93	1.62	0.70	6.24	0.90	0.39	4.92	0.51	0.22	**2000**
2500				9.92	2.45	1.06	7.80	1.37	0.59	6.15	0.77	0.33	**2500**
3000				11.90	3.43	1.49	9.36	1.92	0.83	7.38	1.07	0.46	**3000**
3500				13.88	4.56	1.98	10.92	2.55	1.10	8.61	1.43	0.62	**3500**
4000							12.49	3.26	1.41	9.84	1.83	0.79	**4000**
4500										11.07	2.27	0.98	**4500**
5000										12.30	2.76	1.20	**5000**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

PROGEF Standard Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	450 mm			500 mm			
350	0.68	0.01	0.00				**350**
400	0.78	0.01	0.01	0.63	0.01	0.00	**400**
450	0.87	0.02	0.01	0.71	0.01	0.00	**450**
500	0.97	0.02	0.01	0.79	0.01	0.01	**500**
750	1.46	0.05	0.02	1.18	0.03	0.01	**750**
1000	1.94	0.08	0.03	1.57	0.05	0.02	**1000**
1250	2.43	0.12	0.05	1.97	0.07	0.03	**1250**
1500	2.92	0.17	0.07	2.36	0.10	0.04	**1500**
1750	3.40	0.22	0.10	2.75	0.13	0.06	**1750**
2000	3.89	0.29	0.12	3.15	0.17	0.07	**2000**
2500	4.86	0.43	0.19	3.94	0.26	0.11	**2500**
3000	5.83	0.61	0.26	4.72	0.36	0.16	**3000**
3500	6.80	0.81	0.35	5.51	0.48	0.21	**3500**
4000	7.78	1.03	0.45	6.30	0.62	0.27	**4000**
4500	8.75	1.28	0.56	7.08	0.77	0.33	**4500**
5000	9.72	1.56	0.68	7.87	0.93	0.40	**5000**
5500	10.69	1.86	0.81	8.66	1.11	0.48	**5500**
6000	11.67	2.19	0.95	9.44	1.31	0.57	**6000**
6500				10.23	1.52	0.66	**6500**
7000				11.02	1.74	0.75	**7000**

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

PROGEF Natural Polypropylene (PP)

PROGEF Natural Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	20 mm			25 mm			32 mm			40 mm			
0.75	0.75	0.51	0.22										**0.75**
1	1.00	0.88	0.38	0.63	0.29	0.12							**1**
2	2.01	3.17	1.37	1.27	1.03	0.45	0.77	0.31	0.13				**2**
3	3.01	6.71	2.90	1.90	2.19	0.95	1.15	0.65	0.28	0.74	0.22	0.10	**3**
4	4.02	11.43	4.95	2.53	3.72	1.61	1.54	1.10	0.48	0.99	0.38	0.16	**4**
5	5.02	17.28	7.48	3.17	5.63	2.44	1.92	1.67	0.72	1.24	0.58	0.25	**5**
6	6.03	24.22	10.48	3.80	7.89	3.42	2.30	2.34	1.01	1.49	0.81	0.35	**6**
7	7.03	32.22	13.95	4.43	10.50	4.54	2.69	3.11	1.34	1.74	1.07	0.46	**7**
8	8.03	41.26	17.86	5.07	13.44	5.82	3.07	3.98	1.72	1.98	1.37	0.59	**8**
9	9.04	51.32	22.22	5.70	16.72	7.24	3.46	4.95	2.14	2.23	1.71	0.74	**9**
10	10.04	62.38	27.00	6.33	20.32	8.80	3.84	6.01	2.60	2.48	2.08	0.90	**10**
15	15.07	132.17	57.22	9.50	43.06	18.64	5.76	12.74	5.52	3.72	4.40	1.90	**15**
20				12.67	73.35	31.75	7.68	21.71	9.40	4.96	7.50	3.25	**20**
30				19.00	155.43	67.29	11.52	46.00	19.92	7.44	15.88	6.88	**30**
40							15.36	78.38	33.93	9.92	27.06	11.72	**40**
50										12.40	40.91	17.71	**50**
60										14.88	57.34	24.82	**60**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

PROGEF Natural Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	50 mm			63 mm			90 mm			
5	0.79	0.19	0.08							**5**
10	1.58	0.70	0.30	1.00	0.23	0.10				**10**
15	2.38	1.48	0.64	1.50	0.48	0.21	0.62	0.06		**15**
20	3.17	2.52	1.09	2.00	0.82	0.35	0.83	0.10	0.04	**20**
25	3.96	3.80	1.65	2.49	1.24	0.54	1.03	0.15	0.06	**25**
30	4.75	5.33	2.31	2.99	1.73	0.75	1.24	0.20	0.09	**30**
35	5.54	7.09	3.07	3.49	2.31	1.00	1.45	0.27	0.12	**35**
40	6.33	9.08	3.93	3.99	2.95	1.28	1.66	0.35	0.15	**40**
45	7.13	11.30	4.89	4.49	3.67	1.59	1.86	0.43	0.19	**45**
50	7.92	13.73	5.94	4.99	4.46	1.93	2.07	0.53	0.23	**50**
55	8.71	16.38	7.09	5.49	5.33	2.31	2.28	0.63	0.27	**55**
60	9.50	19.25	8.33	5.99	6.26	2.71	2.48	0.74	0.32	**60**
65	10.29	22.32	9.66	6.48	7.26	3.14	2.69	0.85	0.37	**65**
70	11.08	25.61	11.09	6.98	8.32	3.60	2.90	0.98	0.42	**70**
75				7.48	9.46	4.09	3.10	1.11	0.48	**75**
80				7.98	10.66	4.61	3.31	1.25	0.54	**80**
95				9.48	14.65	6.34	3.93	1.72	0.75	**95**
100				9.98	16.11	6.98	4.14	1.90	0.82	**100**
110				10.97	19.23	8.32	4.55	2.26	0.98	**110**
125				12.47	24.36	10.55	5.17	2.87	1.24	**125**
150							6.21	4.02	1.74	**150**
175							7.24	5.34	2.31	**175**
200							8.28	6.84	2.96	**200**
225							9.31	8.51	3.68	**225**
250							10.35	10.34	4.48	**250**
275							11.38	12.34	5.34	**275**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

PPro-Seal Natural Polypropylene (PP)

PPro-Seal Natural Polypropylene

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
		½"			¾"			1"			1½"			2"		
0.5	0.69	0.52	0.22													**0.5**
0.75	1.03	1.10	0.47													**0.75**
1	1.37	1.87	0.81	0.74	0.42	0.18										**1**
2	2.74	6.74	2.92	1.48	1.52	0.66	0.89	0.44	0.19							**2**
3	4.11	14.29	6.19	2.23	3.21	1.39	1.34	0.93	0.40							**3**
4	5.48	24.34	10.54	2.97	5.47	2.37	1.78	1.59	0.69	0.73	0.18	0.08				**4**
5	6.85	36.80	15.93	3.71	8.27	3.58	2.23	2.40	1.04	0.91	0.27	0.12				**5**
6	8.22	51.58	22.33	4.45	11.60	5.02	2.68	3.36	1.46	1.09	0.38	0.16				**6**
7	9.59	68.63	29.71	5.19	15.43	6.68	3.12	4.47	1.94	1.27	0.50	0.22	0.76	0.14	0.06	**7**
8	10.96	87.88	38.04	5.94	19.76	8.55	3.57	5.73	2.48	1.45	0.64	0.28	0.87	0.18	0.08	**8**
9	12.33	109.30	47.32	6.68	24.58	10.64	4.01	7.13	3.08	1.63	0.80	0.35	0.98	0.23	0.10	**9**
10				7.42	29.87	12.93	4.46	8.66	3.75	1.82	0.97	0.42	1.09	0.28	0.12	**10**
12.5				9.28	45.16	19.55	5.58	13.09	5.67	2.27	1.47	0.64	1.36	0.42	0.18	**12.5**
15				11.13	63.29	27.40	6.69	18.35	7.94	2.72	2.06	0.89	1.63	0.59	0.26	**15**
17.5				12.99	84.21	36.45	7.81	24.42	10.57	3.18	2.74	1.19	1.90	0.79	0.34	**17.5**
20							8.92	31.27	13.54	3.63	3.51	1.52	2.17	1.01	0.44	**20**
22.5							10.04	38.89	16.83	4.09	4.37	1.89	2.45	1.25	0.54	**22.5**
25							11.15	47.27	20.46	4.54	5.31	2.30	2.72	1.52	0.66	**25**
30										5.45	7.44	3.22	3.26	2.13	0.92	**30**
40										7.26	12.67	5.49	4.35	3.63	1.57	**40**
50										9.08	19.16	8.29	5.43	5.50	2.38	**50**
60										10.89	26.86	11.63	6.52	7.70	3.33	**60**
70										12.71	35.73	15.47	7.61	10.25	4.44	**70**
80													8.69	13.12	5.68	**80**
90													9.78	16.32	7.07	**90**
100													10.87	19.84	8.59	**100**
110													11.95	23.67	10.25	**110**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

+GF+

SYGEF Polyvinylidene Fluoride (PVDF), PN 16

SYGEF PVDF (PN16)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	16 mm			20 mm			25 mm			32 mm			
0.5	0.89	0.97	0.42										**0.5**
0.75	1.33	2.05	0.89										**0.75**
1	1.77	3.49	1.51	1.00	0.88	0.38							**1**
2	3.54	12.58	5.45	2.01	3.17	1.37	1.17	0.86	0.37				**2**
3	5.31	26.66	11.54	3.01	6.71	2.90	1.76	1.81	0.78	1.07	0.54	0.23	**3**
4	7.08	45.42	19.66	4.02	11.43	4.95	2.35	3.09	1.34	1.43	0.92	0.40	**4**
5	8.85	68.66	29.72	5.02	17.28	7.48	2.93	4.67	2.02	1.78	1.39	0.60	**5**
6	10.63	96.24	41.66	6.03	24.22	10.48	3.52	6.54	2.83	2.14	1.95	0.84	**6**
7	12.40	128.04	55.43	7.03	32.22	13.95	4.11	8.70	3.77	2.49	2.59	1.12	**7**
8				8.03	41.26	17.86	4.69	11.15	4.83	2.85	3.32	1.44	**8**
9				9.04	51.32	22.22	5.28	13.86	6.00	3.21	4.12	1.79	**9**
10				10.04	62.38	27.00	5.86	16.85	7.29	3.56	5.01	2.17	**10**
11				11.05	74.42	32.22	6.45	20.10	8.70	3.92	5.98	2.59	**11**
12							7.04	23.62	10.22	4.28	7.03	3.04	**12**
13							7.62	27.39	11.86	4.63	8.15	3.53	**13**
14							8.21	31.42	13.60	4.99	9.35	4.05	**14**
15							8.80	35.71	15.46	5.34	10.62	4.60	**15**
17.5							10.26	47.50	20.56	6.23	14.13	6.12	**17.5**
20							11.73	60.83	26.33	7.13	18.09	7.83	**20**
25										8.91	27.35	11.84	**25**
30										10.69	38.34	16.60	**30**
35										12.47	51.01	22.08	**35**
40													**40**

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

SYGEF PVDF (PN16)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	40 mm			50 mm			63 mm			75 mm			
1	0.21	0.02	0.01										**1**
2.5	0.53	0.11	0.05										**2.5**
5	1.06	0.40	0.17	0.68	0.13	0.06							**5**
10	2.13	1.43	0.62	1.36	0.48	0.21	0.81	0.14	0.06				**10**
15	3.19	3.03	1.31	2.04	1.02	0.44	1.22	0.29	0.13	0.86	0.12	0.05	**15**
20	4.25	5.16	2.23	2.72	1.74	0.75	1.62	0.49	0.21	1.15	0.21	0.09	**20**
25	5.32	7.80	3.38	3.40	2.63	1.14	2.03	0.75	0.32	1.43	0.32	0.14	**25**
30	6.38	10.94	4.73	4.08	3.69	1.60	2.43	1.05	0.45	1.72	0.45	0.20	**30**
35	7.45	14.55	6.30	4.77	4.91	2.13	2.84	1.39	0.60	2.01	0.60	0.26	**35**
40	8.51	18.63	8.07	5.45	6.29	2.72	3.25	1.79	0.77	2.29	0.77	0.33	**40**
45	9.57	23.17	10.03	6.13	7.82	3.39	3.65	2.22	0.96	2.58	0.95	0.41	**45**
50	10.64	28.16	12.19	6.81	9.51	4.12	4.06	2.70	1.17	2.87	1.16	0.50	**50**
55	11.70	33.60	14.55	7.49	11.35	4.91	4.46	3.22	1.39	3.15	1.38	0.60	**55**
60				8.17	13.33	5.77	4.87	3.78	1.64	3.44	1.63	0.70	**60**
65				8.85	15.46	6.69	5.27	4.39	1.90	3.73	1.89	0.82	**65**
70				9.53	17.73	7.68	5.68	5.03	2.18	4.01	2.16	0.94	**70**
75				10.21	20.15	8.72	6.08	5.72	2.48	4.30	2.46	1.06	**75**
80				10.89	22.71	9.83	6.49	6.45	2.79	4.59	2.77	1.20	**80**
95							7.71	8.86	3.84	5.45	3.81	1.65	**95**
100							8.11	9.74	4.22	5.73	4.19	1.81	**100**
125							10.14	14.73	6.38	7.17	6.33	2.74	**125**
150							12.17	20.65	8.94	8.60	8.88	3.84	**150**
175										10.03	11.81	5.11	**175**
200										11.47	15.12	6.55	**200**
225													**225**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

SYGEF PVDF (PN16)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	90 mm			110 mm			160 mm			200 mm			225 mm			
20	0.80	0.09	0.04													**20**
25	0.99	0.13	0.06													**25**
30	1.19	0.19	0.08	0.80	0.07	0.03										**30**
35	1.39	0.25	0.11	0.93	0.09	0.04										**35**
40	1.59	0.32	0.14	1.07	0.12	0.05										**40**
45	1.79	0.39	0.17	1.20	0.15	0.06										**45**
50	1.99	0.48	0.21	1.33	0.18	0.08	0.63	0.03	0.01							**50**
75	2.98	1.01	0.44	2.00	0.38	0.17	0.95	0.06	0.03	0.60	0.02	0.01				**75**
100	3.98	1.72	0.75	2.67	0.65	0.28	1.26	0.11	0.05	0.81	0.04	0.02	0.64	0.02	0.01	**100**
125	4.97	2.60	1.13	3.33	0.98	0.43	1.58	0.16	0.07	1.01	0.05	0.02	0.80	0.03	1.01	**125**
150	5.97	3.65	1.58	4.00	1.38	0.60	1.89	0.22	0.10	1.21	0.08	0.03	0.96	0.04	0.02	**150**
175	6.96	4.85	2.10	4.67	1.84	0.79	2.21	0.30	0.13	1.41	0.10	0.04	1.11	0.06	0.02	**175**
200	7.96	6.21	2.69	5.34	2.35	1.02	2.52	0.38	0.16	1.61	0.13	0.06	1.27	0.07	0.03	**200**
225	8.95	7.73	3.35	6.00	2.92	1.27	2.84	0.47	0.20	1.81	0.16	0.07	1.43	0.09	0.04	**225**
250	9.95	9.39	4.07	6.67	3.55	1.54	3.15	0.57	0.25	2.02	0.19	0.08	1.59	0.11	0.05	**250**
275	10.94	11.21	4.85	7.34	4.24	1.84	3.47	0.68	0.30	2.22	0.23	0.10	1.75	0.13	0.06	**275**
300	11.93	13.16	5.70	8.00	4.98	2.16	3.78	0.80	0.35	2.42	0.27	0.12	1.91	0.15	0.07	**300**
325				8.67	5.78	2.50	4.10	0.93	0.40	2.62	0.31	0.14	2.07	0.18	0.08	**325**
350				9.34	6.63	2.87	4.41	1.07	0.46	2.82	0.36	0.16	2.23	0.20	0.09	**350**
400				10.67	8.48	3.67	5.04	1.37	0.59	3.23	0.46	0.20	2.55	0.26	0.11	**400**
450				12.00	10.55	4.57	5.67	1.70	0.74	3.63	0.57	0.25	2.87	0.32	0.14	**450**
500							6.30	2.07	0.90	4.03	0.70	0.30	3.19	0.39	0.17	**500**
600							7.56	2.90	1.26	4.84	0.98	0.42	3.82	0.55	0.24	**600**
700							8.82	3.86	1.67	5.64	1.30	0.56	4.46	0.73	0.32	**700**
800							10.08	4.94	2.14	6.45	1.67	0.72	5.10	0.94	0.41	**800**
900							11.35	6.15	2.66	7.26	2.07	0.90	5.73	1.17	0.51	**900**
1000										8.06	2.52	1.09	6.37	1.42	0.62	**1000**
1150										9.27	3.27	1.41	7.33	1.84	0.80	**1150**
1200										9.68	3.53	1.53	7.65	1.99	0.86	**1200**
1300										10.48	4.10	1.77	8.28	2.31	1.00	**1300**
1400										11.29	4.70	2.03	8.92	2.65	1.15	**1400**
1450													9.24	2.83	1.22	**1450**
1600													10.19	3.39	1.47	**1600**
1750													11.15	4.01	1.73	**1750**
1900																**1900**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

SYGEF Polyvinylidene Fluoride (PVDF), PN 10

SYGEF PVDF (PN10)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	90 mm			110 mm			160 mm			200 mm			
20	0.74	0.07	0.03										**20**
25	0.93	0.11	0.05										**25**
30	1.11	0.16	0.07	0.74	0.06	0.03							**30**
40	1.48	0.26	0.11	0.99	0.10	0.04							**40**
50	1.85	0.40	0.17	1.24	0.15	0.07	0.58	0.02	0.01	0.37	0.01	0.00	**50**
75	2.78	0.85	0.37	1.86	0.32	0.14	0.88	0.05	0.02	0.56	0.02	0.01	**75**
100	3.70	1.44	0.62	2.47	0.54	0.23	1.17	0.09	0.04	0.75	0.03	0.01	**100**
125	4.63	2.18	0.94	3.09	0.82	0.35	1.46	0.13	0.06	0.94	0.04	0.02	**125**
150	5.55	3.06	1.32	3.71	1.15	0.50	1.75	0.19	0.08	1.12	0.06	0.03	**150**
175	6.48	4.07	1.76	4.33	1.53	0.66	2.04	0.25	0.11	1.31	0.08	0.04	**175**
200	7.40	5.21	2.26	4.95	1.96	0.85	2.34	0.32	0.14	1.50	0.11	0.05	**200**
225	8.33	6.48	2.80	5.57	2.44	1.05	2.63	0.39	0.17	1.69	0.13	0.06	**225**
250	9.25	7.88	3.41	6.19	2.96	1.28	2.92	0.48	0.21	1.87	0.16	0.07	**250**
275	10.18	9.40	4.07	6.81	3.53	1.53	3.21	0.57	0.25	2.06	0.19	0.08	**275**
300	11.10	11.04	4.78	7.42	4.15	1.80	3.51	0.67	0.29	2.25	0.23	0.10	**300**
325				8.04	4.81	2.08	3.80	0.78	0.34	2.43	0.26	0.11	**325**
400				9.90	7.07	3.06	4.67	1.14	0.49	3.00	0.39	0.17	**400**
450				11.14	8.79	3.81	5.26	1.42	0.61	3.37	0.48	0.21	**450**
500							5.84	1.72	0.75	3.74	0.58	0.25	**500**
600							7.01	2.41	1.04	4.49	0.82	0.35	**600**
700							8.18	3.21	1.39	5.24	1.09	0.47	**700**
800							9.35	4.11	1.78	5.99	1.39	0.60	**800**
1000							11.68	6.21	2.69	7.49	2.11	0.91	**1000**
1200										8.99	2.95	1.28	**1200**
1400										10.49	3.93	1.70	**1400**
1600										11.98	5.03	2.18	**1600**
1800													**1800**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

SYGEF PVDF (PN10)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	225 mm			250 mm			315 mm			315 mm			
100	0.59	0.02	0.01										**100**
150	0.89	0.04	0.02	0.72	0.02	0.01							**150**
200	1.18	0.06	0.03	0.96	0.04	0.02							**200**
250	1.48	0.09	0.04	1.20	0.05	0.02	0.75	0.02	0.01				**250**
300	1.77	0.13	0.06	1.44	0.08	0.03	0.90	0.02	0.01	0.71	0.01	0.01	**300**
350	2.07	0.17	0.07	1.68	0.10	0.04	1.06	0.03	0.01	0.83	0.02	0.01	**350**
400	2.36	0.22	0.09	1.92	0.13	0.06	1.21	0.04	0.02	0.95	0.02	0.01	**400**
500	2.95	0.33	0.14	2.39	0.20	0.09	1.51	0.06	0.03	1.19	0.04	0.02	**500**
750	4.43	0.69	0.30	3.59	0.42	0.18	2.26	0.14	0.06	1.78	0.08	0.03	**750**
1000	5.91	1.18	0.51	4.79	0.71	0.31	3.02	0.23	0.10	2.37	0.13	0.06	**1000**
1250	7.39	1.79	0.77	5.99	1.07	0.46	3.77	0.35	0.15	2.96	0.19	0.08	**1250**
1300	7.68	1.92	0.83	6.23	1.15	0.50	3.92	0.37	0.16	3.08	0.21	0.09	**1300**
1350	7.98	2.06	0.89	6.47	1.24	0.54	4.07	0.40	0.17	3.20	0.22	0.10	**1350**
1400	8.27	2.21	0.96	6.70	1.32	0.57	4.22	0.43	0.19	3.32	0.24	0.10	**1400**
1500	8.86	2.51	1.09	7.18	1.50	0.65	4.52	0.49	0.21	3.56	0.27	0.12	**1500**
1750	10.34	3.34	1.44	8.38	2.00	0.87	5.28	0.65	0.28	4.15	0.36	0.16	**1750**
2000	11.82	4.27	1.85	9.58	2.56	1.11	6.03	0.83	0.36	4.74	0.46	0.20	**2000**
2250				10.78	3.19	1.38	6.79	1.04	0.45	5.34	0.58	0.25	**2250**
2500				11.97	3.87	1.68	7.54	1.26	0.54	5.93	0.70	0.30	**2500**
2750							8.30	1.50	0.65	6.52	0.84	0.36	**2750**
3000							9.05	1.76	0.76	7.11	0.98	0.43	**3000**
3500							10.56	2.35	1.02	8.30	1.31	0.57	**3500**
4000							12.07	3.00	1.30	9.49	1.67	0.72	**4000**
4500										10.67	2.08	0.90	**4500**
5000										11.86	2.53	1.09	**5000**
5500													**5500**

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

SYGEF PVDF (PN10)

Flow Rate (GPM)	V	ΔH	ΔP	V	ΔH	ΔP	Flow Rate (GPM)
	400 mm			450 mm			
400	0.75	0.01	0.01				**400**
500	0.93	0.02	0.01	0.74	0.01	0.00	**500**
750	1.40	0.04	0.02	1.11	0.02	0.01	**750**
1000	1.87	0.07	0.03	1.47	0.04	0.02	**1000**
1250	2.33	0.11	0.05	1.84	0.06	0.03	**1250**
1300	2.43	0.12	0.05	1.92	0.07	0.03	**1300**
1350	2.52	0.12	0.05	1.99	0.07	0.03	**1350**
1400	2.61	0.13	0.06	2.06	0.08	0.03	**1400**
1500	2.80	0.15	0.07	2.21	0.09	0.04	**1500**
1750	3.27	0.20	0.09	2.58	0.11	0.05	**1750**
2000	3.73	0.26	0.11	2.95	0.15	0.06	**2000**
2250	4.20	0.32	0.14	3.32	0.18	0.08	**2250**
2500	4.67	0.39	0.17	3.69	0.22	0.10	**2500**
2750	5.13	0.47	0.20	4.05	0.26	0.11	**2750**
3000	5.60	0.55	0.24	4.42	0.31	0.13	**3000**
3500	6.53	0.73	0.32	5.16	0.41	0.18	**3500**
4000	7.47	0.93	0.40	5.90	0.53	0.23	**4000**
4500	8.40	1.16	0.50	6.64	0.65	0.28	**4500**
5000	9.33	1.41	0.61	7.37	0.80	0.34	**5000**
5500	10.27	1.69	0.73	8.11	0.95	0.41	**5500**
6000	11.20	1.98	0.86	8.85	1.12	0.48	**6000**
6500				9.58	1.29	0.56	**6500**
7000				10.32	1.48	0.64	**7000**
7500				11.06	1.69	0.73	**7500**
8000							**8000**

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

V = Velocity (ft/sec)
ΔH = Head Loss (ft water/100 ft pipe)
ΔP = Pressure Loss (lb/in^2/100 ft pipe)

+GF+

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 OD(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: 160 mm PROGEF Standard (PP-H)
Outer Diameter: 160.0 (mm)
Inside Diameter: 130.8 (mm)

Q - Flow Rate (gpm)
A - Section Area Pipe 0.1446 full = **0.0723** ½full (ft^2)
n - Manning Friction Factor **0.009**
R - Hydraulic Radius of pipe **0.1073** (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

$$Q = .0723 \cdot \frac{1.486}{0.009} \cdot (0.1073)^{2/3} \cdot (0.0208)^{1/2}$$

$$Q = 11.94 \cdot 0.226 \cdot 0.144$$

$$Q = 0.389 \text{ (ft}^3\text{/sec)}$$

$$Q = 174.4 \text{ (gpm)}$$

$$V = \frac{1.486}{0.009} \cdot (0.1073)^{2/3} \cdot \frac{0.144}{12}$$

$$V = 165.1 \cdot 0.226 \cdot 0.012$$

$$V = 0.45 \text{ (ft/sec)}$$

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

PROGEF Standard/Natural Polypropylene

	1/8 (in/ft) Slope		1/4 (in/ft) Slope		1/2 (in/ft) Slope	
Nominal Pipe Diameter (mm)	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**
20	0.5	0.08	0.7	0.11	0.9	0.16
25	0.9	0.09	1.2	0.13	1.7	0.18
32	1.7	0.11	2.4	0.15	3.4	0.22
40	3.0	0.13	4.3	0.18	6.1	0.25
50	5.5	0.15	7.8	0.21	11.0	0.29
63	10.2	0.17	14.5	0.24	20.4	0.34
75	16.4	0.19	23.2	0.27	32.8	0.38
90	26.6	0.22	37.7	0.31	53.3	0.43
110	45.5	0.25	64.4	0.35	91.1	0.49
160	123.4	0.32	174.5	0.45	246.8	0.63
200	224.1	0.37	316.9	0.52	448.2	0.74
225	306.6	0.40	433.6	0.56	613.1	0.80
250	406.9	0.43	575.4	0.60	813.7	0.85
315	753.5	0.50	1065.7	0.70	1507.1	1.00
355	1037.1	0.54	1466.6	0.76	2074.1	1.08
400	1425.3	0.58	2015.6	0.83	2850.5	1.17
450	1949.4	0.63	2756.9	0.89	3898.9	1.26
500	2583.3	0.68	3653.4	0.96	5166.7	1.36

PPro-Seal Natural Polypropylene

	1/8 (in/ft) Slope		1/4 (in/ft) Slope		1/2 (in/ft) Slope	
Nominal Pipe Diameter (inch)	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**
½	0.3	0.07	0.4	0.10	0.6	0.14
¾	0.7	0.09	1.0	0.12	1.4	0.17
1	1.4	0.10	2.0	0.15	2.8	0.21
1½	4.6	0.14	6.5	0.20	9.2	0.28
2	9.1	0.17	12.9	0.23	18.2	0.33

SYGEF PVDF

	PN16						PN10					
	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	
Nominal Pipe Diameter	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**	**Flow rate (gpm)**	**Velocity (fps)**
16 mm	0.2	0.07	0.3	0.09	0.4	0.13						
20 mm	0.5	0.08	0.7	0.11	0.9	0.16						
25 mm	1.0	0.09	1.4	0.13	1.9	0.19						
32 mm	1.9	0.11	2.6	0.16	3.7	0.22						
40 mm	3.7	0.13	5.3	0.19	7.5	0.26						
50 mm	6.8	0.15	9.6	0.22	13.5	0.31						
63 mm	13.5	0.18	19.0	0.26	26.9	0.36						
75 mm	21.4	0.20	30.3	0.29	42.8	0.41						
90 mm	34.8	0.23	49.3	0.33	69.7	0.46	38.4	0.24	54.3	0.33	76.7	0.47
110 mm	59.3	0.26	83.9	0.37	118.7	0.53	65.6	0.27	92.8	0.38	131.2	0.54
160 mm	161.2	0.34	228.0	0.48	322.5	0.68	178.4	0.35	252.3	0.49	356.9	0.69
200 mm	292.6	0.39	413.7	0.56	585.1	0.79	322.8	0.40	456.6	0.57	645.7	0.81
225 mm	401.6	0.43	567.9	0.60	803.1	0.85	442.8	0.44	626.2	0.62	885.6	0.87
250 mm							586.0	0.47	828.7	0.66	1172.0	0.94
315 mm							1085.3	0.55	1534.9	0.77	2170.7	1.09
355 mm							1496.0	0.59	2115.7	0.84	2992.0	1.18
400 mm							2058.6	0.64	2911.3	0.91	4117.2	1.28
450 mm							2818.7	0.69	3986.2	0.98	5637.4	1.39

Surge Pressure (Water Hammer)

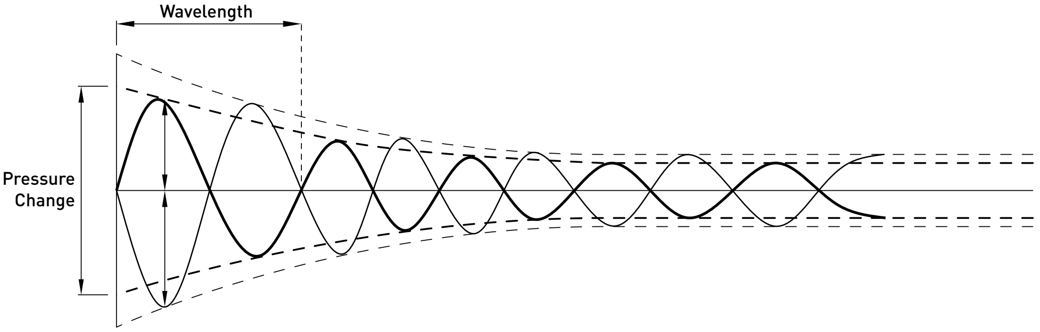
Surge pressure, or water hammer, is a term used to describe dynamic surges caused by pressure changes in a piping system. They occur whenever there is a deviation from the steady state, i.e.; when the velocity of the fluid is increased or decreased, and may be transient or oscillating. Waves of positive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

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

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

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 8 Dampened Pressure Wave



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

Step 1

Determine the velocity of the pressure wave in pipes.

v_w velocity of pressure wave (m/s)
K bulk modulus of elasticity of fluid (Pa)
ρ fluid density (kg/m^3)
E modulus of elasticity of pipe wall (Pa)
d_i pipe inner diameter (mm)
e pipe wall thickness (mm)

$$v_w = \sqrt{\frac{K}{\rho \times n_i \left(1 + \frac{K \times d_i}{e \times E}\right)}}$$

Step 2

Critical time for valve closure.

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

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

Step 3

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

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)

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

Special Consideration

Calculate the Maximum Instantaneous System Pressure.

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)

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

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 150 psi. If P_{max} exceeds 300 psi (150 psi × 2 safety factor), then precaution must be implemented in case of maximum pressure wave (i.e. water hammer) to prevent possible pipe failure.

Step 4

Determine the Maximum System Pressure Increase with Gradual Valve Closure

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

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

Example Problem

A water pipeline from a storage tank is connected to a master valve, which is hydraulically actuated with an electrical remote control. The piping system flow rate is 300 (gal/min) with a velocity of 4 (ft./sec); thus requiring a 160 mm nominal pipeline. The operating pressure of the system will be 50 (lb/in^2), the valve will be 500 (ft.) from the storage tank and the valve closing time is 2.0 (sec). Determine the critical time of closure for the valve, and the internal system pressure should the valve be instantaneously or suddenly closed vs. gradually closing the valve (10 times slower).

Pipe Details

System Information

Material:	160 mm PROGEF Standard (PP-H)
Flow Rate:	300 (gal/min)
Pipeline Length:	500 (ft)
Operating Pressure:	50 (lb/in^2)

Other Information

Bulk Water Density (K):	3.19×10^5 (lb/in^2)
Fluid Density (δ):	1.937 ($slugs/ft^3$)
Valve Closing Time:	2.0 (sec)
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 (m/s)
K bulk modulus of elasticity of fluid (Pa)
ρ fluid density (kg/m^3)
E modulus of elasticity of pipe wall (Pa)
di pipe inner diameter (mm)
e pipe wall thickness (mm)

$$v_w = \sqrt{\frac{K}{\rho \times n_i \left(1 + \frac{K \times d_i}{e \times E}\right)}} = 1211 \text{ (ft/sec)}$$

Step 2: Critical Valve Closure Time

Determine the Critical Closure Time

t_c = Critical Closure Time (sec)
V_w = Velocity of Pressure Wave 1211 (ft/sec)
L = Upstream Pipe Length 500 (ft)

$$t_c = \frac{2L}{V_w} = \frac{2 \times 500}{1211} = 0.83 \text{ (sec)}$$

Step 3: Maximum Pressure Increase

Determine the Maximum Pressure Increase; Assume: Valve Closure Time < Critical Closure Time t_c and Fluid Velocity goes to 0.

P_i = Maximum Pressure Increase (lb/in^2)
δ = Fluid Density 1.937 ($slugs/ft^3$)
V = Fluid Velocity 4 (ft/sec)
V_w = Velocity of Pressure Wave 1211 (ft/sec)
n_i = Conversion Factor 1/144 (ft^2/in^2)

$$P_i = \delta \cdot V \cdot V_w \, n_i = \frac{1.937 \times 4 \times 1211}{144} = 65 \text{ (lb/in}^2\text{)}$$

Consideration: Maximum Instantaneous System Pressure

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

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

$$P_{max} = P_i + P_s = 65 + 50 = 115 \text{ (lb/in}^2\text{)}$$

In this case, 160 mm PROGEF Standard Polypropylene pipe is rated at 150 psi. Therefore, the system design is within safety limits (300 psi max).

Step 4 - Maximum Change in Pressure with Gradual Valve Closure

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

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

$$P_g = \frac{2 \cdot \delta \cdot L \cdot V \cdot n_i}{t_v} = \frac{2 \cdot 1.937 \cdot 500 \cdot 4 \cdot \frac{1}{144}}{2} = 26.9 \text{ (lb/in}^2\text{)}$$

+GF+

Expansion/Contraction

Allowing for Length Changes in PP and PVDF Pipelines

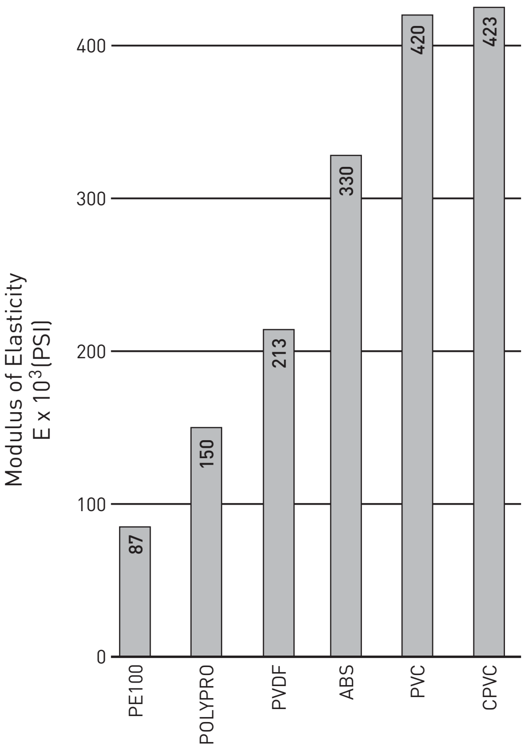
Variations in temperature cause greater length changes in thermoplastic materials than in metals. In the case of above ground, wall or duct mounted pipe work, particularly where subjected to varying working temperatures, it is necessary to make suitable provision for length changes in order to prevent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

Calculation and Positioning of Flexible Sections

It is possible to take advantage of the very low modulus of elasticity of PP and PVDF 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.

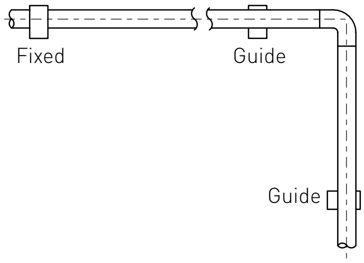
There are two primary methods of controlling or compensating for thermal expansion of plastic piping systems: taking advantage of offsets and changes of direction in the piping and expansion loops.



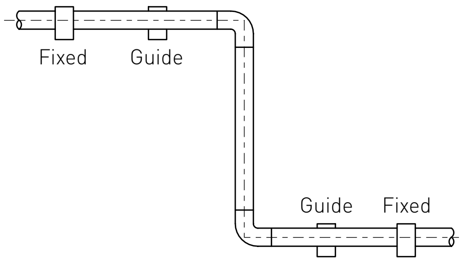
Type 1: Offsets/Changes in Direction

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



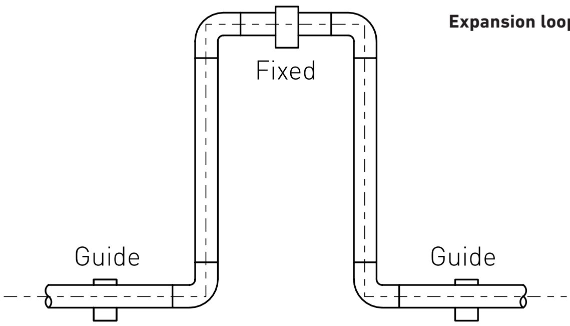
Offsets



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.

Expansion loop



Determining the Length Change (ΔL) (Example 1)

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

$\Delta L = L \cdot \Delta T \cdot \alpha$

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

ΔL = Length change in inches

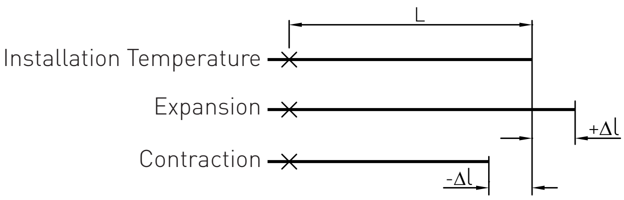
L = Length in inches of the pipe or pipe section where the length change is to be determined

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

α = Coefficient of linear thermal expansion 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 = 315 inch

Installation temperature: T_v = 73°F
Temperature of the coolant: T_1= 40°F
Temperature when defrosting and cleaning: T_2= 95°F
Material: 250 mm PROGEF Standard (PPH)

Difference in Contraction Temperature

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

Difference in Expansion Temperature

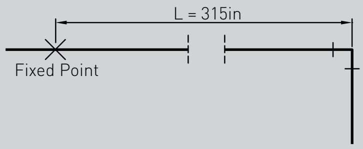
$\Delta T_2 = T_2 - T_v = 95°F - 73°F = 22°F$

Contraction during service with coolant

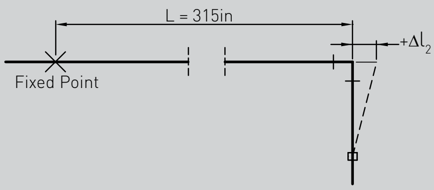
$-\Delta L_1 = L \times \Delta T_1 \times \alpha = 315 \text{ in} \times 33 \times (0.000089) = 0.93 \text{ in}$

Expansion during defrosting and cleaning

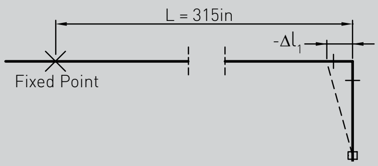
$+\Delta L_2 = L \times \Delta T_2 \cdot \alpha = 315 \text{ in} \times 22 \times (0.000089) = 0.62 \text{ in}$



Installation



Expansion



Length Change (ΔL) in Inches

Note: Use the first PP table for temperature changes occurring in a range below 121°F and the second PP table for changes in the range above 121°F. Use both PP tables if the temperature crosses this boundary: e.g. 20 ft of pipe that changes from 131°F to 116°F = 0.2 in + 0.1 in = 0.3 in length change.

PROGEF Standard/Natural

Length of pipe section (feet) Temperature ≤121°F

Temperature change (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5			0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5
10		0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1
15	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.6
20	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
25	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	1.9	2.0	2.1	2.3	2.4	2.5	2.7
30	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.8	1.9	2.1	2.2	2.4	2.6	2.7	2.9	3.0	3.2
35	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.7
40	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.1	4.3
45	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.8	4.1	4.3	4.6	4.8
50	0.3	0.5	0.8	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0	4.3	4.5	4.8	5.1	5.3
55	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.3	5.6	5.9
60	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.4	5.8	6.1	6.4
65	0.3	0.7	1.0	1.4	1.7	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.9	5.2	5.6	5.9	6.2	6.6	6.9
70	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	3.7	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.7	7.1	7.5
75	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.2	7.6	8.0
80	0.4	0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1	5.6	6.0	6.4	6.8	7.3	7.7	8.1	8.5
85	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.6	4.1	4.5	5.0	5.4	5.9	6.4	6.8	7.3	7.7	8.2	8.6	9.1
90	0.5	1.0	1.4	1.9	2.4	2.9	3.4	3.8	4.3	4.8	5.3	5.8	6.2	6.7	7.2	7.7	8.2	8.7	9.1	9.6
95	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.6	10.1
100	0.5	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0	8.5	9.1	9.6	10.1	10.7

PROGEF Standard/Natural

Length of pipe section (feet) Temperature >121°F

Temperature change (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5			0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6
10		0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.2
15	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.8
20	0.1	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.4
25	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0
30	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.5	2.7	2.9	3.1	3.2	3.4	3.6
35	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.8	4.0	4.2
40	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.8	4.1	4.3	4.6	4.8
45	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.4	2.7	3.0	3.2	3.5	3.8	4.1	4.3	4.6	4.9	5.1	5.4
50	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	5.1	5.4	5.7	6.0
55	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	6.6

SYGEF

Length of pipe section (feet)

Temperature change (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5			0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5
10		0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9
15	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4
20	0.1	0.2	0.3	0.4	0.5	0.6	0.7	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
25	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.2	2.3
30	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.7	2.8
35	0.2	0.3	0.5	0.7	0.8	1.0	1.1	1.3	1.5	1.6	1.8	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.1	3.3
40	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.7
45	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.8	4.0	4.2
50	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.3	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.4	4.7
55	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.3	2.6	2.8	3.1	3.3	3.6	3.9	4.1	4.4	4.6	4.9	5.1
60	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.1	3.4	3.7	3.9	4.2	4.5	4.8	5.1	5.3	5.6
65	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1
70	0.3	0.7	1.0	1.3	1.6	2.0	2.3	2.6	2.9	3.3	3.6	3.9	4.3	4.6	4.9	5.2	5.6	5.9	6.2	6.6
80	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	3.7	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.7	7.1	7.5
90	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.4	3.8	4.2	4.6	5.1	5.5	5.9	6.3	6.7	7.2	7.6	8.0	8.4
100	0.5	0.9	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.6	7.0	7.5	8.0	8.4	8.9	9.4

Determining the Length of the Flexible Section (a)

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, The table below 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, inches
k = Constant (k=30 for PP and k=21.7 for PVDF)
ΔL = Change in length, inches
d = Outside diameter of pipe, inches

Flexible Sections (a) in Inches

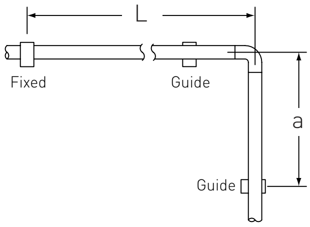
PP-H / PP-N — **PROGEF Standard/Natural Nominal Pipe Diameter (mm)**

Length Change - ΔL (inch)	20	25	32	40	50	63	75	90	110	160	200	225	250	315	355	400	450	500
0.1	8	9	11	12	13	15	16	18	20	24	27	28	30	33	35	38	40	42
0.2	12	13	15	17	19	21	23	25	28	34	38	40	42	47	50	53	56	60
0.3	15	16	18	21	23	26	28	31	34	41	46	49	52	58	61	65	69	73
0.4	17	19	21	24	27	30	33	36	39	48	53	56	60	67	71	75	80	84
0.5	19	21	24	27	30	33	36	40	44	53	60	63	67	75	79	84	89	94
0.6	21	23	26	29	33	37	40	44	48	58	65	69	73	82	87	92	98	103
0.7	22	25	28	31	35	40	43	47	52	63	70	75	79	88	94	100	106	111
0.8	24	27	30	34	38	42	46	51	56	67	75	80	84	94	100	106	113	119
0.9	25	28	32	36	40	45	49	54	59	71	80	85	89	100	106	113	120	126
1.0	27	30	34	38	42	47	52	56	62	75	84	89	94	106	112	119	126	133
2.0	38	42	48	53	60	67	73	80	88	106	119	126	133	149	159	168	179	188
3.0	46	52	58	65	73	82	89	98	108	130	146	155	163	183	194	206	219	231
4.0	53	60	67	75	84	94	103	113	125	151	168	179	188	211	224	238	253	266
5.0	60	67	75	84	94	106	115	126	140	168	188	200	210	236	251	266	282	298
6.0	65	73	82	92	103	116	126	138	153	184	206	219	231	259	275	292	309	326
7.0	70	79	89	100	111	125	137	149	165	199	223	236	249	280	297	315	334	352
8.0	75	84	95	106	119	134	146	160	177	213	238	253	266	299	317	337	357	376
9.0	80	89	101	113	126	142	155	169	187	226	253	268	282	317	336	357	379	399
10.0	84	94	106	119	133	149	163	179	197	238	266	282	298	334	355	376	399	421

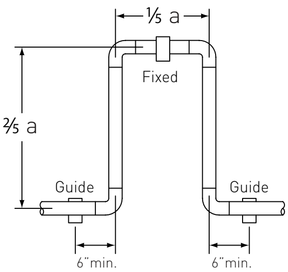
PP-N — **PPro-Seal Nominal Pipe Diameter (inch)**

Length Change - ΔL (inch)	½	¾	1	1½	2
0.1	9	10	11	13	15
0.2	12	14	15	18	21
0.3	15	17	19	23	25
0.4	17	19	22	26	29
0.5	19	22	24	29	33
0.6	21	24	27	32	36
0.7	23	26	29	35	39
0.8	25	27	31	37	41
0.9	26	29	33	39	44
1.0	27	31	34	41	46
2.0	39	43	49	58	65
3.0	48	53	60	72	80
4.0	55	61	69	83	92
5.0	61	69	77	92	103
6.0	67	75	84	101	113
7.0	73	81	91	109	122
8.0	78	87	97	117	131
9.0	82	92	103	124	139
10.0	87	97	109	131	146

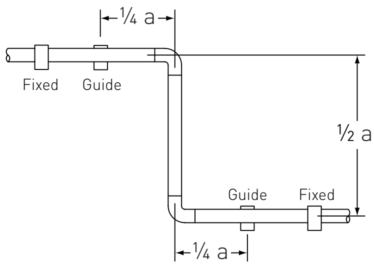
Change of direction



Expansion



Offset



Flexible Sections (a) in Inches where ΔT≤20°F

Values shown are minimum values.

PVDF	SYGEF Pipe Diameter (mm)																
Length Change - ΔL (inch)	20	25	32	40	50	63	75	90	110	160	200	225	250	315	355	400	450
0.1	6	7	8	9	10	11	12	13	14	17	19	20	22	24	26	27	29
0.2	9	10	11	12	14	15	17	18	20	24	27	29	30	34	36	39	41
0.3	11	12	13	15	17	19	20	22	25	30	33	35	37	42	44	47	50
0.4	12	14	15	17	19	22	24	26	29	34	39	41	43	48	51	54	58
0.5	14	15	17	19	22	24	26	29	32	39	43	46	48	54	57	61	65
0.6	15	17	19	21	24	26	29	32	35	42	47	50	53	59	63	67	71
0.7	16	18	20	23	25	29	31	34	38	46	51	54	57	64	68	72	76
0.8	17	19	22	24	27	31	33	37	40	49	54	58	61	68	73	77	82
0.9	18	20	23	26	29	32	35	39	43	52	58	61	65	72	77	82	87
1.0	19	22	24	27	30	34	37	41	45	54	61	65	68	76	81	86	91
2.0	27	30	34	39	43	48	53	58	64	77	86	91	96	108	115	122	129
3.0	33	37	42	47	53	59	65	71	78	94	105	112	118	132	141	149	158
4.0	39	43	49	54	61	68	75	82	90	109	122	129	136	153	162	172	183
5.0	43	48	54	61	68	76	83	91	101	122	136	144	152	171	181	193	204
6.0	47	53	60	67	75	84	91	100	111	133	149	158	167	187	199	211	224
7.0	51	57	64	72	81	90	99	108	119	144	161	171	180	202	215	228	242
8.0	54	61	69	77	86	97	106	116	128	154	172	183	193	216	229	244	258
9.0	58	65	73	82	91	103	112	123	135	163	183	194	204	229	243	258	274
10.0	61	68	77	86	96	108	118	129	143	172	193	204	215	242	257	272	289

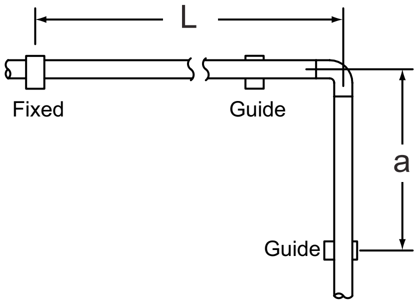
Installation Hints

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. To eliminate bilateral expansion, thrust blocks are recommended at intersections.

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 = 315 inch
d = 250 mm (nominal)
Installation temperature: 73°F
Max. working temperature: 35°F
Material: PP-H

1. Length change
   +ΔL = L • ΔT • ~ = 315 • 38 • (0.000089) = 1.07 inch
2. Flexible section required to take up length change of ΔL = 1.07 inch according to the tables above:
   a = approx. 94 inch
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. 1500 mm (59 inch). The length change, starting from the zero position, then amounts to
   ±ΔL/2 = 1.07 inch/2 = 0.50 inch
   a = approx. 67 inch (per tables above)

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 directly and properly supported. The actuating force is thus transmitted directly, and not through the pipeline. When valves are installed as fixed points, the length changes described previously will start from the valve and must be controlled.

GF has developed a better way to support valves: the Stress Less Valve Support. These support brackets allow the valve to move in line with the pipe, forward and backward, as the pipe expands and contracts. StressLess Valve Supports eliminate stress concentrations at valve locations and mitigate the risk of early leaks in the life of the piping system.

For safe mounting of plastic valves, many GF valves are equipped with metal threaded inserts for direct mounted installation.

Vibration Dampeners

There are two principal ways to control stress caused by vibration. Observe the stability of the system during initial operation and either add restraints or supports as required to reduce effects of equipment vibration, or where necessary, use restraint fittings 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 also be included in the padding. Only flexible materials, such as glass wool, mineral wool, foam plastic or similar may be used for padding.

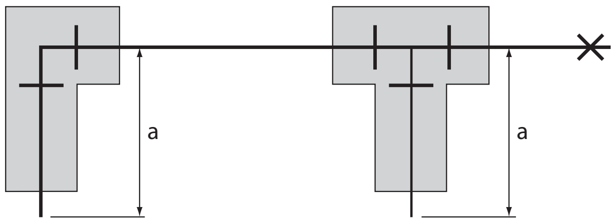


Figure 9 Support pipe in flexible sections

Pipe Bracket Support Centers and Fixation of Plastic Pipelines

General Pipe Supports and Brackets

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 on the next page 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/cm^3 are to be conveyed, pipe spacing can be adjusted by dividing the support spacing by the specific gravity.

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. GF 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. GF pipe brackets are suitable for PVC, CPVC, PE, PP, and PVDF pipes.

GF has developed the Stress Less Pipe Guides product line, the first such clamps especially designed to eliminate stress transfer to pipe due to thermal expansion or seismic events. They have an engineered, designed gap of 3mm between the clamp insert and pipe OD. Excessive force can never be exerted on the pipe regardless of tightening of bolts by the installer.

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/ft³)

Pipe Size (mm)	Pipe Bracket Intervals L (ft.) for PROGEF Standard					
	≤65°F	85°F	105°F	125°F	140°F	176°F
20	2.3	2.2	2.1	2.1	2.0	1.8
25	2.6	2.5	2.5	2.4	2.3	2.1
32	3.1	3.0	3.0	2.9	2.8	2.5
40	3.6	3.5	3.4	3.3	3.1	2.9
50	4.1	4.0	3.9	3.8	3.6	3.3
63	4.8	4.7	4.6	4.4	4.3	3.9
75	5.1	4.9	4.8	4.6	4.4	4.1
90	5.4	5.2	5.1	4.9	4.8	4.4
160	7.4	7.2	6.9	6.6	6.2	5.6
200	8.2	7.9	7.5	7.2	6.9	6.2
225	8.7	8.4	8.0	7.7	7.4	6.6
250	9.2	8.9	8.5	8.2	7.9	7.1
315	10.3	10.0	9.7	9.4	8.9	8.0
355	11.0	10.7	10.3	10.0	9.5	8.7
400	11.6	11.3	11.0	10.7	10.2	9.4
450	12.3	12.0	11.6	11.3	10.8	10.0
500	13.0	12.6	12.3	12.0	11.5	10.7

Pipe Size (mm)	Pipe Bracket Intervals L (ft.) for PROGEF Natural					
	≤65°F	85°F	105°F	125°F	140°F	176°F
20	1.7	1.6	1.6	1.6	1.5	1.4
25	2.0	1.9	1.9	1.8	1.7	1.6
32	2.4	2.3	2.2	2.1	2.1	1.9
40	2.7	2.6	2.6	2.5	2.4	2.1
50	3.1	3.0	3.0	2.9	2.4	2.5
63	3.6	3.5	3.4	3.4	3.3	3.1
90	4.1	3.9	3.8	3.8	3.6	3.3

Pipe Size (inch)	Pipe Bracket Intervals L (ft.) for PPro-Seal					
½	3.8	3.8	3.7	3.5	3.0	2.8
¾	4.0	4.0	3.9	3.8	3.5	3.0
1	4.5	4.5	4.3	4.0	3.8	3.3
1½	5.0	5.0	4.8	4.8	4.3	3.8
2	5.5	5.5	5.3	5.0	4.5	4.0

Pipe Size (mm)	Size (inch)	Pipe Bracket Intervals L (ft.) for SYGEF PVDF						
		≤65°F	104°F	140°F	176°F	212°F	248°F	284°F
20	½	2.8	2.5	2.3	2.0	1.6	1.5	1.3
25	¾	3.1	2.8	2.5	2.2	2.0	1.6	1.5
32	1	3.6	3.3	3.0	2.6	2.3	2.0	1.6
40	1¼	3.9	3.6	3.3	3.0	2.5	2.1	1.8
50	1½	4.6	4.3	3.8	3.3	3.0	2.5	2.0
63	2	4.6	4.3	3.9	3.6	3.1	2.6	2.1
75	2½	4.9	4.6	4.3	3.9	3.4	2.8	2.3
90	3	5.2	4.9	4.6	4.3	3.6	3.1	2.8
110	4	5.9	5.6	5.1	4.8	4.1	3.6	3.1
160	6	7.1	6.7	6.1	5.6	5.1	4.4	3.8
200	8	7.9	7.4	6.9	6.2	5.6	4.9	4.3
225	9	8.4	7.9	7.2	6.9	5.9	5.2	4.6
250	10	8.7	8.2	7.5	7.2	6.2	5.6	4.9
315	12	9.8	9.4	8.5	8.2	7.1	6.2	5.4
355	14	10.7	9.6	8.7	7.8	7.0	6.3	5.7
400	16	11.6	10.4	9.4	8.5	7.6	6.8	6.2
450	18	12.8	11.5	10.4	9.3	8.4	7.6	6.8

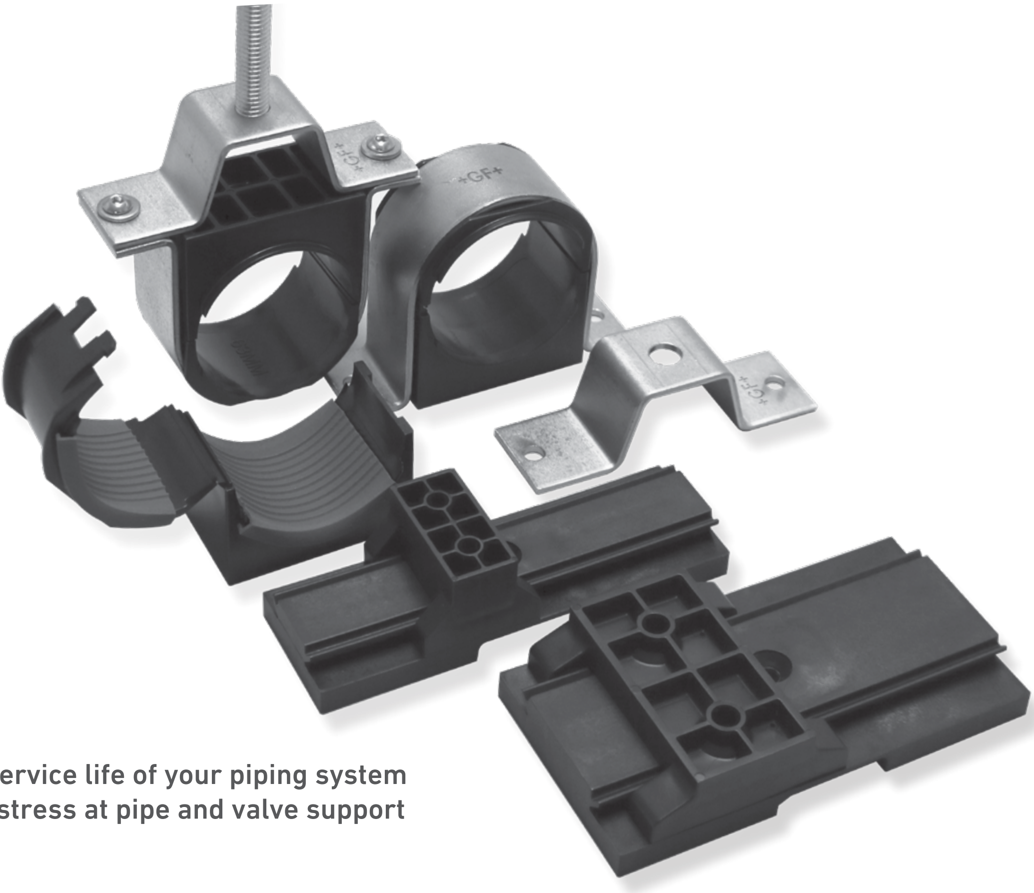
Note: Pipe spacing can be adjusted by dividing the support spacing by the specific gravity.
Example: 63 mm pipe carrying media with a specific gravity of 1.6 – 4.6 ft divided by 1.6 = approx. 2.8 ft centers.

Shear Force of Restraint Fittings (Fixation Brackets)

Pipe Size (mm)	Size (inch)	Shear Force in lbs		
		68°F	104°F	140°F
20	**½**	1798	1506	1214
25	**¾**	2158	1798	1461
32	**1**	2697	2248	1798
40	**1¼**	3147	2698	2023
50	**1½**	3821	3147	2473
63	**2**	4496	3821	2922
75	**2½**	8317	6969	5620
90	**3**	9442	7868	6294
110	**4**	11015	9217	7418

Stress Less®

Pipe and Valve Support System



Patented

Maximize the service life of your piping system by eliminating stress at pipe and valve support locations.

Stress Less® Pipe Supports

Soft touch. Inserts are low friction, molded HDPE. Piping can easily slide with absolute minimal stress and wear during each thermal expansion cycle. Piping can never touch metal.

Engineered for control. Support inserts have a designed 3mm gap around the OD of the clamped piping. This simplifies the system design: no need to account for load accelerations during seismic or water hammer events.

Strong and user friendly. The support insert fits precisely within the steel hoop, which has two functions. First, it provides the necessary strength to support the weight of the piping in normal conditions (for example, 10 times the weight of the pipe when filled with media) and even during a very strong earthquake (subjected to seismic accelerations over 5G). Second, the installer tightens down only the steel hoop and cannot overtighten the support against the pipe.

Firm grip. Optionally, we offer pipe supports with an elastomer insert for vertically installed pipe.

Stress Less® Valve Supports

GF Piping Systems introduces a new and unique product that allows valves to move in two directions as the pipe expands and contracts, all in a controlled manner and while properly supported.

Controlled movement. The support base and slide components are made of low friction PP. Valves can slide with virtually no resistance. Range of travel is ±3 inches (6 inches total).

Practical. Designed to keep centerlines of piping in double strut configuration aligned. Smaller valve support base is taller than the larger valve support.

Designed to securely and easily mount all of the following GF valves, in any material, manual and actuated.

- Type 546 ball valves
- Type 523 ball valves
- Type 543 horizontal 3-way valves
- 5-Series diaphragm valves

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
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 fulfill these requirements.

A robust and effective seal can only be achieved if sufficient compressive forces are transmitted to the flange 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. 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 plastic 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

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

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

Gasket

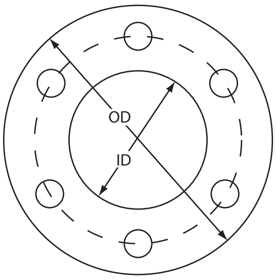
A rubber gasket must be used between the flange faces in order to ensure a good seal. GF recommends a 0.125" thick, full-face gasket with Shore A scale hardness of 70±5, and the bolt torque values (see following pages) are based on this specification. For other hardness requirements, contact GF Technical 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.

GF has developed a gasket with exceptional high purity performance and ease of installation: the SYGEF HP Gasket. This gasket is made of EPDM with a TFM (modified PTFE) covering in the wetted media stream. The TFM adds no coloring contamination and has extremely low leach-out characteristics. The gasket's materials and geometry also afford precise, repeatable and low torque installation.

ANSI Class 150 Flat Flange Gasket Dimensions

Size inch (mm)	O.D. inch	SYGEF I.D. inch	PROGEF I.D. inch	PPro-Seal I.D. inch
½ (20)	3.50	0.59	1.10	0.88
¾ (25)	3.86	0.79	1.34	1.10
1 (32)	4.25	1.02	1.65	1.38
1¼ (40)	4.61	1.34	2.01	—
1½ (50)	5.00	1.69	2.44	1.93
2 (63)	5.98	2.20	3.07	2.44
2½ (75)	7.01	2.60	3.62	—
3 (90)	7.48	3.07	4.33	—
4 (110)	9.02	3.94	5.24	—
6 (160)	10.98	5.94	7.05	—
8 (200)	13.50	8.15	9.30	—
8 (225)	13.50	8.15	9.42	—
10 (250)	16.00	9.84	11.35	—
12 (315)	19.00	11.81	13.31	—
14 (355)	21.00	12.87	14.80	—
16 (400)	23.50	15.39	16.93	—
18 (450)	27.00	16.77		

Full face (flat) flange gaskets are only recommended for 150 psi operating pressure systems up to 6" size. Maximum recommended operating pressure is 90 psi for flat gaskets 8" and larger. For higher operating pressure systems size 8" and larger, profile gaskets are recommended.



Fasteners

It is critical to avoid excessive compression stress on a plastic 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.

Fastener Specifications: SYGEF PVDF, PROGEF PP, PPro-Seal PP

Flange Size inch (mm)	No. of Bolts	Bolt Size (in) and Type	Washer Size (in) and Type
½ (20)	4	½ 13-UNC	½ SAE
¾ (25)	4	½ 13-UNC	½ SAE
1 (32)	4	½ 13-UNC	½ SAE
1¼ (40)	4	½ 13-UNC	½ SAE
1½ (50)	4	½ 13-UNC	½ SAE
2 (63)	4	⅝ 11-UNC	⅝ SAE
2½ (75)	4	⅝ 11-UNC	⅝ SAE
3 (90)	4	⅝ 11-UNC	⅝ SAE
4 (110)	8	⅝ 11-UNC	⅝ SAE
6 (160)	8	¾ 10-UNC	¾ F436
8/9 (200/225)	8	¾ 10-UNC	¾ F436
10 (250)	12	1 8-UNC	1 F436
12 (315)	12	1 8-UNC	1 F436
14 (355)	12	1 8-UNC	1 F436
16 (400)	16	1 8-UNC	1 F436
18 (450)	16	1⅛ 7-UNC	1⅛ F436
20 (500)	20	1⅛ 7-UNC	1⅛ F436

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

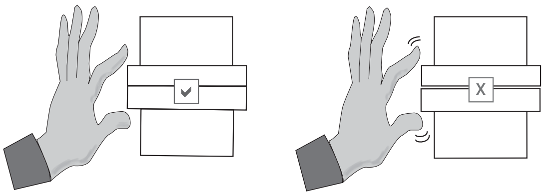
Compared to metals, plastics are relatively flexible and deform slightly under stress. Therefore, not only must bolt torque be controlled in order to avoid cracking the flange, but continuing to tighten the bolts beyond the recommended torque levels may actually make the seal worse, not better.

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

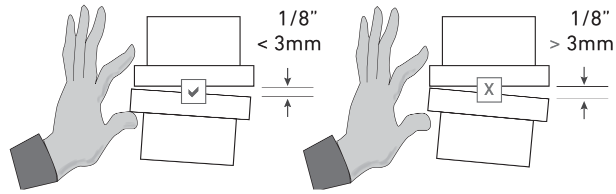
Experienced installers may be tempted to forgo the use of a torque wrench, relying instead on "feel." GF does not endorse this practice. Job-site studies have shown that experienced installers are only slightly better than new trainees at estimating bolt torque by feel. A torque wrench is always recommended.

Checking System Alignment

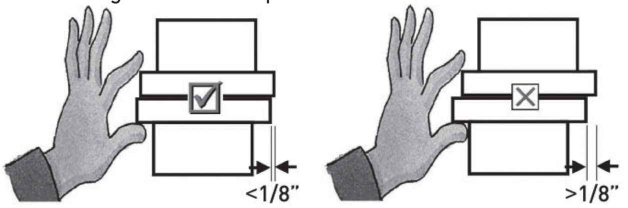
Before assembling the flange, be sure that the two parts of the system being joined are properly aligned. GF has developed a "pinch test" that allows the installer to assess system alignment quickly and easily with minimal tools. First check the gap between the flange faces by pinching the two mating 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.



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 ⅛".



To assess high-low misalignment, pull the flange faces flush together. If the faces are concentric within ⅛", then the high-low misalignment is acceptable.

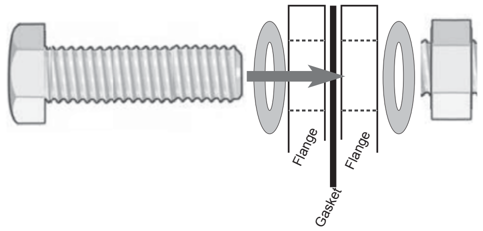


If the gap between the mating components can not be closed by pinching them with one hand, or if the angle or high-low misalignment between them is too large, then using the bolts to force the components together will result in excessive stress and possible failure during or after installation. In this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

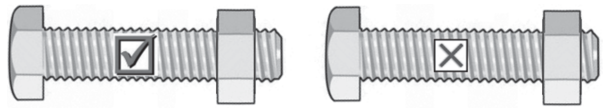
Inserting the Bolts

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

Insert bolts through washers and bolts holes as shown:



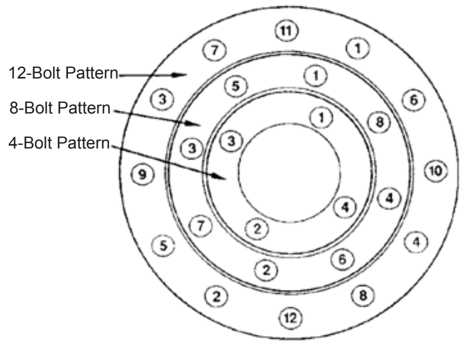
Tighten all nuts by hand. As you tighten each nut, the nuts on the other bolts will loosen slightly. Continue to handtighten all of the nuts until none remain loose. Now the flange assembly will remain in place as you prepare to fully tighten it. Again, when hand-tightened, at least two threads beyond the nut should be exposed in order to ensure permanent engagement. If less than two threads are exposed, disassemble the flange and use longer bolts.



Tightening the Bolts

Plastic flanges require gradual, even bolt tightening. 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 cracking or 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 the table on the next page.

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.

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.

Recommended Multiple Pass Bolt Torque: SYGEF, PROGEF and PPro-Seal Flanges

Flange size (inch)	DN	ANSI 150 bolt pattern	Flat gasket, lubed [ft-lb]*				Flat gasket, unlubed [ft-lb]**				SYGEF Plus Gasket [ft-lb]				Profile gasket, lubed [ft-lb]*				Profile gasket, unlubed [ft-lb]**			
			1st	2nd	3rd	4th***	1st	2nd	3rd	4th***	1st	2nd	3rd	4th***	1st	2nd	3rd	4th***	1st	2nd	3rd	4th***
½	15	4	4	7			5	9							5				4	7		
¾	20	4	5	9			6	12			5	10			4	7			5	9		
1	25	4	5	11			7	14			6	12			5	9			6	12		
1¼	32	4	7	14			9	18			7	15			5	10			7	13		
1½	40	4	7	16			7	14	21		8	19			7	13			8	17		
2	50	4	7	14	28	-	12	25	36		10	25			10	19			12	25		
2½	65	4	10	20	30	43	15	30	45	56	12	28			10	21			13	27		
3	80	4	11	22	33	47	15	30	45	61	12	24	33		12	25			10	20	33	
4	100	8	8	15	30	-	10	20	30	39	10	22	-		8	16			10	21		
6	150	8	10	20	30	45	15	30	45	59	12	24	36		12	25			10	20	33	
8	200	8	15	30	40	52	18	36	54	68	12	24	36	48	10	20	33		10	20	30	43
10	250	12	15	30	45	56	20	40	60	73	12	24	36	48	10	20	31		10	20	30	40
12	300	12	18	36	50	64	20	40	60	83	15	30	45	56	12	24	37		12	24	36	48
14	350	12	18	36	50	66	20	40	60	75					12	24	36	49	15	30	45	64
16	400	16	20	40	60	75	20	40	60	80					12	24	36	45	15	30	45	59
18	450	16	30	60	90	120	30	60	90	132					15	30	45	56	20	40	60	73
20	500	20	35	75	115	140	35	75	115	154					15	30	45	60	20	40	60	78

* 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 plastic flanges, as high friction and seizing lead to unpredictable torque and a high incidence of cracking and poor sealing.

***Pass tightening flange bolts following recommended star pattern

Documentation

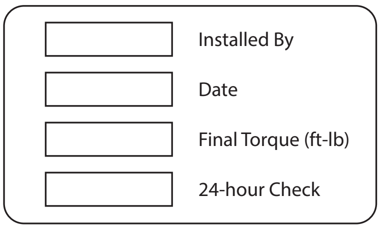
Provide a copy of these instructions to every installer on the job site prior to beginning installation. Installers who have worked primarily with metal flanges often make critical mistakes when installing plastic flanges. Even experienced plastic installers will benefit from a quick review of good installation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

Installation Tags

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")

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

Valves must be well-supported. 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.

O-Ring Placement

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)

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.

Optional: Further Tightening (2")

Based on experience, or system requirements, the installer may choose to turn the nut an additional ⅛ 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 ⅛ turn past the index mark applied after assembly.

Do not exceed ⅛ 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.

Tightening Guide for Union and Ball Valve Nuts

Nominal Size (inch)	Initial	Additional Pre-Test	Additional Post-Test
½	Hand-Tight	None	⅛ Turn (max)
¾	Hand-Tight	None	⅛ Turn (max)
1	Hand-Tight	None	⅛ Turn (max)
1½	Hand-Tight	None	⅛ Turn (max)
2	Hand-Tight	⅛ Turn (max)	⅛ Turn (max)

Post-Test Tightening (Sizes ⅜" to 1½" only)

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

In the unlikely event that a leak occurs, the union nut at the leaking joint may be tightened an additional ⅛ 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 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

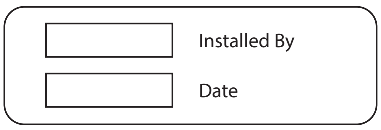
Provide a copy of these instructions to every installer on the job site prior to beginning installation.

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.



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 Threaded Joints

Introduction

NPT threaded connections are not recommended for high pressure systems or those larger 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 molded or machined adapters may be threaded. Threading reduces the rated pressure of the pipe.

Preparation: Thread Sealant

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

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. GF recommends no more than 3 wraps.

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.

Threaded Connection Guide

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

Alignment

Threaded connections are susceptible to fracture or leaking due to misalignment. Pipe should be installed without bending.

Fusion Joining

This section provides an overview of various fusion joining methods. GF strongly recommends that installers are trained by GF personnel before operating GF fusion machines or fusion joining GF products.

Socket Fusion

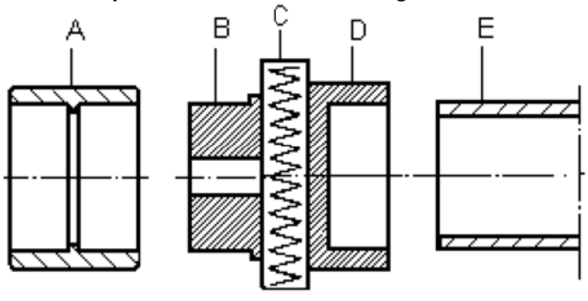
Socket fusion joining can be used to join socket fusion fittings available in sizes 16–110 mm (⅜"–4"). The socket fusion method of joining uses a heated non-stick "female" bushing (D)to melt the outside of the pipe end (E) and a heated non-stick "male" bushing (B) to heat the inside of the corresponding size of fitting (A). After several seconds, when the outside of the pipe and the inside of the fitting are melted, the bushings are removed and the pipe is pushed into the fitting. Due to the large area of pipe to fitting contact (3–5 times the cross sectional area of the pipe), the resulting joint is actually several times stronger than the pipe itself. The pipe and fittings for this system are also manufactured to have an interference fit; because of this interference, it is not possible to slide a fitting over the pipe without the use of heat to melt the surface to be joined. This feature prevents the possibility of inadvertently leaving a joint unfused, and more importantly, causes displacement of some material during fusion thereby guaranteeing a high strength, reliable, reproducible joint.

Advantages

- Fast fusion times
- Low installation cost
- Easiest fusion method
- Corrosion resistant

Details of the requirements for machines and equipment used for fusion jointing thermoplastics are contained in DVS 2208 Part 1.

The Principle of Socket Fusion Joining



General Requirements

The basic rule is that only similar materials can be fusion joined. For best results, only components which have a similar density and a compatible melt flow index range should be fusion joined.

Tools Required

Apart from the tools normally used in plastic piping construction, such as pipe cutters or a saw with a cutting guide, the socket fusion jointing method requires certain special tools.

Important: The tools described here may be used for GF socket fusion fittings made of PVDF, PP and PE.

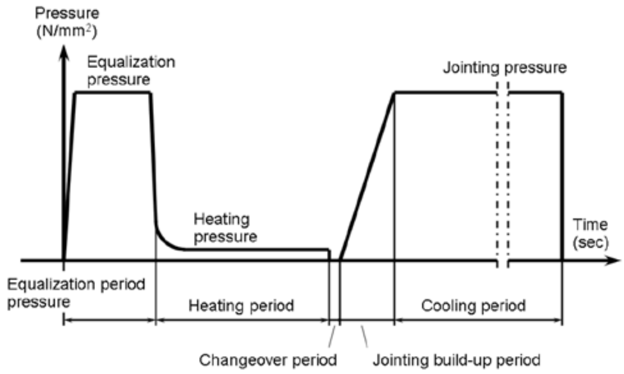
Pipe Peeling and Chamfering Tool

This is used to calibrate the pipe end. This reduces the force exerted to push the pipe into the heating bush, while preventing damage to the surface coating of the heating bush. At the same time, the pipe end is chamfered and the insertion depth marked.

Note: Further information on the fusion joining equipment hire service and training courses are available from GF.

Pressure/Time Diagram

Fusion joining requires different pressures to be applied during equalization and joining on the one hand and during the heat soak period on the other.



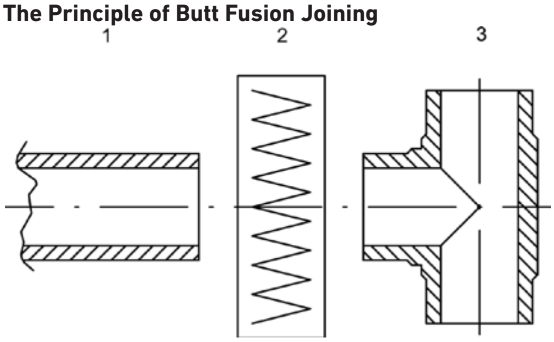
Contact (Conventional) Butt Fusion

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

The Principle of Butt Fusion Joining

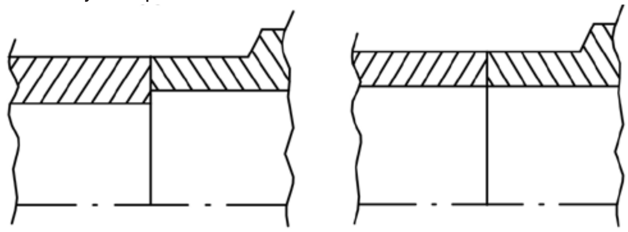


1 Pipe **2 Heating element** **3 Fitting**

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 an acceptable range should be fusion joined. The components to be joined must have the same wall thicknesses in the fusion area.

Join only components with similar wall thicknesses.



Incorrect **Correct**

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 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 41°F (5°C) or above 113°F (45°C), measures must be taken to ensure that the temperature in the working area is in the range required for satisfactory joining and does not hinder the necessary manual tasks.

IR Plus® Infrared Butt Fusion Joining

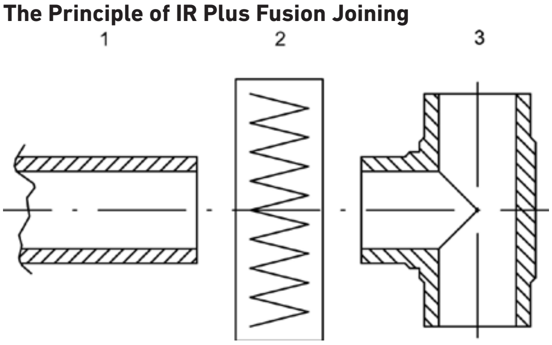
IR Plus Infrared Butt Fusion Joining is an ideal method to join IR fusion fittings to achieve the maximum joint consistency.

Using the computer 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 automated fusion machinery
- Automatic fusion joining record (if desired) using optional printer or PC download
- Faster fusion and cooling time than conventional butt fusion

The Principle of IR Plus Fusion Joining



1 Pipe **2 Heating element** **3 Fitting**

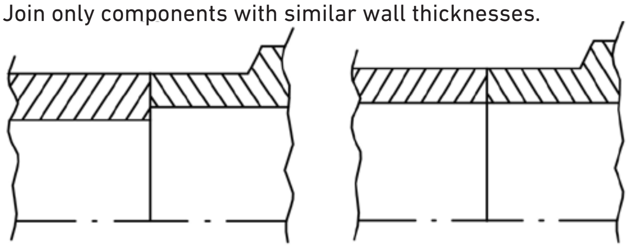
The resulting fusion joints are homogeneous and display the following characteristics:

- 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.

Join only components with similar wall thicknesses.



Incorrect **Correct**

IR fusion joining must only be performed by personnel trained in the use of this method. Training is provided worldwide 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.).

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 41°F (5°C) and 104°F (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.

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, compared with conventional butt fusion welding, 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, on labels, or to employ electronic data output.

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

BCF® Plus (Bead and Crevice Free) Fusion Joining

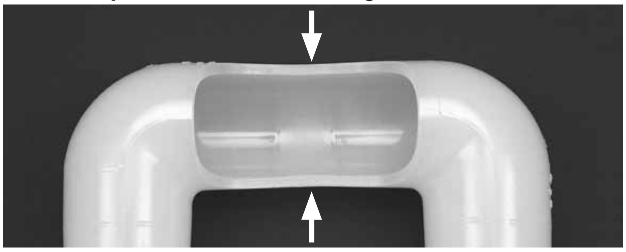
GF's BCF (Bead and Crevice Free) joining system produces bead and crevice free joints for SYGEF PVDF and PROGEF Natural Polypropylene piping. It is used where there is extreme concern about the presence of small beads or crevices in the piping system. Such applications can be found in the Pharmaceutical (BPE Required Installations, fully drainable system requirements) and Food and Beverage Industries.

The BCF joining machine automatically clamps and aligns the pipe and fitting, and produces the seamless joint by a proprietary heat fusion method. The machine's electronic logic circuits provide temperature monitoring and heat sensing to automatically produce the proper weld for the particular pipe size. The BCF system is offered in 20 mm through 110 mm pipe diameters, with 90° elbows, tees, unions, diaphragm valves, zero static diaphragm valves, reducers, and flange adapters.

Advantages

- Completely smooth inner surface
- Low stress joint
- Ease of operation due to automated fusion machinery
- Automatic fusion joining record (if desired) using optional printer or PC download

The Principle of BCF Fusion Joining



Tools required

BCF joining requires the GF BCF Plus joining machine in addition to the tools normally used for plastic pipework construction (pipe cutters, etc.).

Properties and characteristics of BCF Plus fusion joints

Welding free from beads and crevices

The result of the jointing process is a surface similar to the actual pipeline components, free from beads or crevices. There are therefore no dead spaces, the surface roughness lies in the range Ra 9.8µin (0.25µm).

Reproducible jointing processes

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, on labels, or to employ electronic data output.

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

Electrofusion Joining

Electrofusion joining is an excellent joining solution that provides numerous advantages. The process of joining pipe to a fitting socket uses wires to transfer the heat energy to the plastic material. The heat energy is sufficient to melt the plastic surrounding the wires. This generates a zone called the "melt zone." This "melt zone" encapsulates the wires, which are at its origin along the center line.

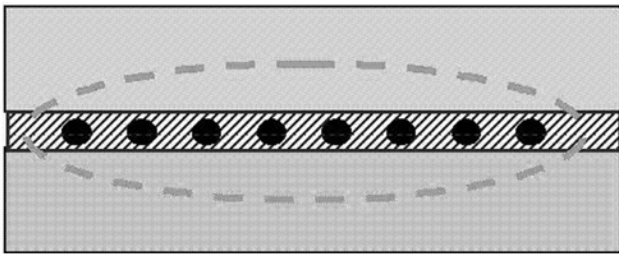
These features makes this one of the safest and easiest fusion technologies on the market.

Advantages

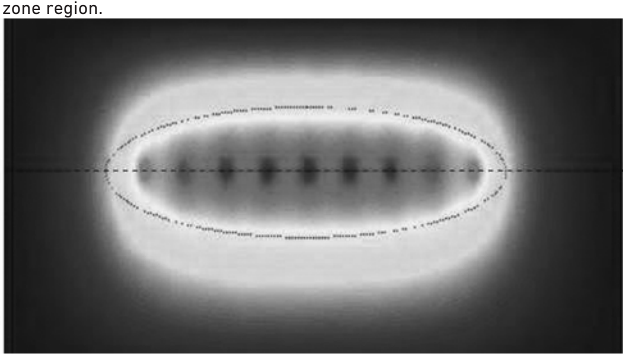
- Fast fusion times
- Fuse multiple joints in one heat cycle
- Easiest fusion method
- Corrosion resistant

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 GF fusion joining machines that tightly control the fusion parameters.

The Principle of Electrofusion Joining



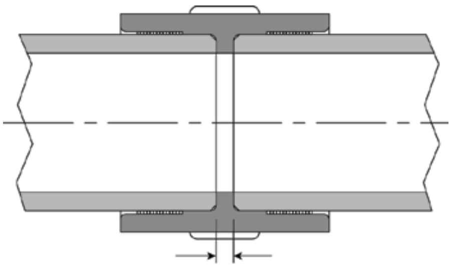
The computer simulation below shows the heat distribution and the "melt" zone region.



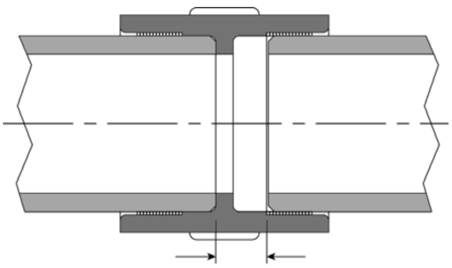
General Requirements

The basic rule is that only similar materials can be fusion joined, i.e. PP with PP. 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.

Electrofusion should only be performed by GF trained and certified personnel.



Correct



Incorrect

Pressure Testing

Introduction

A lot of international and national standards and guidelines are available for leak and pressure tests. Therefore often it is not easy to find the applicable test procedure or for example the test pressure.

The purpose of a pressure test is to:

- Ensure the resistance to pressure of the pipeline and
- Show the leak tightness against the test media.

Usually the pressure test is done as a water pressure test and only in exceptional cases (with consideration to special safety precautions) as a gas pressure test with air or nitrogen.

The following comparison should point out the difference between water and air as a test medium:

- Water is an incompressible medium, which means setting, for example, a 3.2 ft (1m) PVDF pipe 6" (160mm) under a pressure of 45 psi (3 bar) results in an energy of ca. 1 Joule.
- In contrast, air is a compressible medium; the same pipe has with 45 psi (3 bar) pressure an energy of already 5000 Joule.
- If there were a failure during the pressure test, the water-filled pipe would fly 1" high, the air-filled pipe 360ft! And this with a test pressure of only 45psi (3 bar).

Fractural Behavior of Thermoplastics

In case of failures thermoplastic materials show different behaviors. PE has a ductile behavior, meaning that brittle fracture cannot occur. On the other hand, materials like PVDF are less ductile, and can potentially fail in a brittle mode.

Nevertheless, the following safety precautions must be taken into consideration during the internal pressure test. As mentioned before the pressure test is the first dynamic loading placed on the piping to uncover any existing processing faults (e.g. insufficient welding).

Internal pressure test with water or a similar incompressible test fluid

General

The internal pressure test is done when installation work has been completed and necessitates an operational pipeline or operational test sections. The test pressure load should furnish experimental proof of operational safety. The test pressure is not based on the working pressure, but rather on the internal pressure load capacity, derived from the pipe wall thickness.

Test pressures are therefore determined in relation to SDR and the pipe wall temperature. The piping system should only be pressure tested with water.

Pre-test

A pre-test serves to prepare the piping system for an actual test (main test). In the course of pre-testing, a tension-expansion equilibrium in relation to an increase in volume will develop in the piping system (the piping system will expand). A material-related drop in pressure (see table below for typical values of various piping materials) will occur which will require repeated pumping to restore the test pressure and also frequently a re-tightening of the flange connection screws. Note that this is normal and does not necessarily indicate leaks in the system.

Material	Pressure Drop
PVC	7.2 psi/h (0.5 bar/h)
CPVC	7.2 psi/h (0.5 bar/h)
ABS	8.7 psi/h (0.6 bar/h)
PP	11.6 psi/h (0.8 bar/h)
PE	17.4 psi/h (1.2 bar/h)
PVDF	11.6 psi/h (0.8 bar/h)

Main test

In the context of the main test, a much smaller drop in pressure can be expected at constant pipe wall temperatures so that it is not necessary to pump again. The checks can focus primarily on leak detection at the flange joints and any position changes of the pipe.

Observe if using compensators

If the pipeline to be tested contains compensators, this has an influence on the expected axial forces of the pipeline. Because the test pressure is higher than the working pressure, the axial forces on the fixed points become higher. This has to be taken into account when designing the fixed points.

Observe if using valves

When using a valve at the end of a pipeline (end or final valve), the valve and the pipe end should be closed by a blind flange or cap. This prevents inadvertent opening of the valve or any pollution of the inside of the valve.

Filling the pipeline

Before starting with the internal pressure test, the following points must be checked:

- Was installation done according to the available plans?
- All pressure relief devices mounted in the flow direction?
- All end valves shut?
- Valves in front of other devices are shut to protect against pressure.
- Visual inspection of all joints, pumps, measurement devices and tanks.
- Has the waiting period after the last fusion/cementing been observed?

Now the pipeline can be filled from the lowest point. Special attention should be given to the air vent. If possible, vents should be provided at all the high points of the pipeline and these should be open when filling the system. Flushing velocity should be at least 3ft/sec.

Adequate time should be allowed between filling and testing the pipeline, so that the air contained in the piping system can escape via the vents: approximately 6-12 hours, depending on the nominal diameter.

Checks during testing

The following measurement values must be recorded consistently during testing:

- Internal pressure at the absolute low point of the pipeline
- Medium and ambient temperature
- Water volume input
- Water volume output
- Pressure drop rates

Pressure Test Procedure for all GF Thermoplastic Piping Systems

The following is a general test procedure for GF plastic piping. It applies to most applications. Certain applications may require additional consideration. For further questions regarding your application, please contact a GF representative.

1. All piping systems should be pressure tested prior to being put 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. For example, if the system is designed to operate at 80 psi, then the test will be done at 120 psi.
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 ¼ 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 that some pressure loss is normal the first time a piping system is pressurized, due to expansion of the material as described earlier.)

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

Testing with gases is not recommended.

If it is not possible to do an internal pressure test with water (e.g. pipeline must be kept dry), a leak test can be carried out with slight overpressure. For safety reasons the test pressure must then be limited to maximum 5 psi.

For the leak test all the joints can be coated with a soap solution for visual leak detection, but only use fluids or soaps that are compatible with the material they are being applied to.

Attention: Commercial leak detection sprays can cause stress cracks in plastics. If using these sprays, remove any residues after testing.

Modifications and repairs

The following safety measures are to be observed when modifying or repairing piping systems:

- wear protective clothing
- drain the respective pipeline section completely
- rinse the pipe section
- protect against dripping
- clean and dry the joints

An important factor for the competent repair of piping systems is to have the work carried out by trained professionals.

Modifications and repair work may not weaken the piping system mechanically.

To ensure the operational safety of the piping system following a modification or a repair, an internal pressure test should be done.

Commissioning

When putting a pipeline into operation for the first time, besides the internal pressure test, temperature effects are also generally examined. Thermal stress, i.e. expansion, was not simulated during testing.

We recommend an initial inspection at the earliest 3 days, at the latest 7 days, after commissioning and recording the results.

The inspection checks should include:

- critical points in the system (visual inspection)
- flange joints, unions, valves (leak-proof)
- safety and leak detection equipment (condition, function)

Continuous inspection of the piping system should be done by operating personnel during their usual rounds according to the operating instructions.

Sterilization and Sanitization Methods

Autoclave Sterilization

PVDF piping components exhibit no changes upon repeated exposure to typical temperatures experienced in autoclave cycles; however, autoclaving is not recommended for PVDF valves due to dissimilar materials for construction of diaphragm and valve bonnets.

In-Line Steam

PVDF piping, fittings and valves exhibit thermal stability up to 284°F (140°C). Therefore, in-line steam sterilization, typically executed at temperatures of up to 273°F (134°C), can be performed without adverse affects, provided that the pipe is properly supported. PVDF offers better insulation than metal and has a significantly lower surface temperature. Due to the high temperatures, PP cannot be sanitized with steam.

Hot Water Sanitization

PVDF is rated up to maximum operating temperatures of 284°F (140°C), it can be hot water sanitized which requires no additives or removal processes. This method of sanitization is typically used to maintain USP and WFI systems for the pharmaceutical industry. PVDF systems that are operated for long periods of time at temperatures above 140°F (60°C) will need to be properly supported at all horizontal and vertical lengths of the piping system. PP is rated up to maximum operating temperatures of 176°F (80°C) and also needs to be properly supported during hot water sanitization. For both materials, recommended water temperature at point of introduction cannot exceed the maximum operating temperature of the material; for PP the maximum injection temperature would be 170°F (77°C). The temperature should be maintained during a 3-4 hour cycle and be a minimum of 110°F (43°C) to 120°F (49°C) at point of discharge.

Ozone Sanitization

PVDF can be sanitized using continuous ozone concentration levels of up to 0.2 ppm without adverse effects. Ozone is commonly removed using UV light at a wavelength of 1.0×10^{-5} in (254 nm). The light sources can be safely installed in PVDF piping systems provided a 90° deflection is introduced by either a fully lined diaphragm valve or a 90° stainless steel elbow. Ozone does not require the purchase of additional cleaning agents; does not require rinsing of the system afterwards; and does not add unwanted substances in the water. Best practice installations in the industry are showing that PP can be successfully sanitized by using ozone in concentrations of <0.5ppm and sanitization times of less than 3 hours (including flushing) at ambient temperature.

Chemical Sanitization

PVDF and PP can also be sterilized at system startup using a 10% concentration hydrogen peroxide solution circulated for 12 hours, or 1% concentration Minncare (by Minntech) solution for 1-2 hours.

In all cases, valves should be in the open position during sterilization and sanitization. Solution should be flowing through all branches of the system (ideally at a rate of 5 fps) and end-of-line- valves should be opened to allow sanitizing solution to fully circulate through the entire piping system. After chemical flushing is achieved, DI water shall be flushed through the system until all traces of chemical solution is removed (should also be checked using test strips). Flushing shall continue until chemical levels are checked at outlets to levels of 0.1ppm or lower.