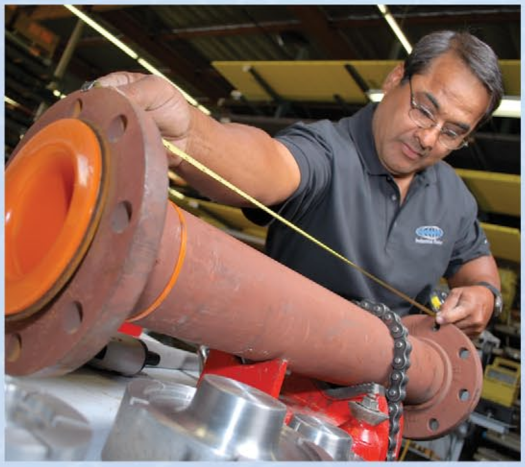
HARRINGTON
Industrial Plastics



ENGINEERING HANDBOOK

FOR INDUSTRIAL PLASTIC PIPING SYSTEMS

HARRINGTON Industrial Plastics

Harrington's Corporate Office Chino, California

OUR MISSION

To be your first choice for high-purity
and corrosive solutions.

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Disclaimer

POLYVINYLS

PVC (POLYVINYL CHLORIDE) has a relatively high tensile strength and modulus of elasticity and therefore is stronger and more rigid than most other thermoplastics. The maximum service temperature is 140°F for Type 1. PVC has excellent chemical resistance to a wide range of corrosive fluids but may be damaged by ketones, aromatics, and some chlorinated hydrocarbons. It has proved an excellent material for process piping (liquids and slurries), water service, and industrial and laboratory chemical waste drainage. Joining methods are solvent welding, threading (Schedule 80 only), or flanging.

CPVC (CHLORINATED POLYVINYL CHLORIDE) is particularly useful for handling corrosive fluids at temperatures up to 210°F. In chemical resistance, it is comparable to PVC. It weighs about one-sixth as much as copper, will not sustain combustion (self-extinguishing), and has low thermal conductivity. Suggested uses include process piping for hot, corrosive liquids; hot and cold water lines in office buildings and residences; and similar applications above the temperature range of PVC. CPVC pipe may be joined by solvent welding, threading, or flanging.

POLYOLEFINS

POLYPROPYLENE (HOMOPOLYMER) is the lightest thermoplastic piping material, yet it has considerable strength, outstanding chemical resistance, and may be used at temperatures up to 180°F in drainage applications. Polypropylene is an excellent material for laboratory and industrial drainage piping where mixtures of acids, bases, and solvents are involved. It has found wide application in the petroleum industry where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal lines, chill water loops, and demineralized water. Joining methods are coil fusion and socket heat welding.

COPOLYMER POLYPROPYLENE is a copolymer of propylene and polybutylene. It is made of high molecular weight copolymer polypropylene and possesses excellent dielectric and insulating properties because of its structure as a nonpolar hydrocarbon polymer. It combines high chemical resistance with toughness and strength at operating temperatures from freezing to 200°F. It has excellent abrasion resistance and good elasticity, and is joined by butt and socket fusion.

POLYETHYLENE is generally described in three classifications according to the relative degree of branching (side chain formation) in their molecular structures and density.

Low Density Polyethylene (LDPE) has more extensive branching resulting in less compact molecular structures and lower mechanical strength than other Polyethylenes. Good for temperatures to 140°F and is frequently used for food handling equipment, brine tanks and dispensing equipment. It may be hot gas welded if required.

High Density Polyethylene (HDPE) has minimal branching, which makes it more rigid and less permeable than LDPE. Good for temperatures to 160°F and is frequently used for abrasion resistant piping, caustic storage tanks, and control tubing. It may be hot gas welded.

Cross-Linked High Density Polyethylene (XLPE) is a three-dimensional polymer of extremely high molecular weight with individual molecular chains bonded together using heat plus chemicals or radiation. This structure provides superior environmental stress-crack resistance and extremely high impact strength. Cross-linked Polyethylene becomes a thermoset material after manufacturing and cannot be hot gas welded. Good for temperatures to 160°F with most common uses including large tanks for outdoor service. All polyethylene has excellent chemical resistance to a wide range of common chemicals. Avoid strong oxidizing agents and solvents.

FLUOROPOLYMERS

PVDF (POLYVINYLIDENE FLUORIDE) is a strong, tough, and abrasion-resistant fluoroplastic material. It resists distortion and retains most of its strength to 280°F. As well as being ideally suited to handle wet and dry chlorine, bromine, and other halogens. It also withstands most acids, bases, and organic solvents. PVDF is not recommended for strong caustics. It is most widely recognized as the material of choice for high purity piping such as deionized water. PVDF is joined by thermal butt, socket, or electrofusion.

ECTFE (HALAR) is a durable copolymer of ethylene and chlorofluoroethylene with excellent resistance to a wide variety of strong acids, chlorine, solvents, and aqueous caustics. Halar has excellent abrasion resistance, electric properties, low permeability, temperature capabilities from cryogenic to 340°F, and radiation resistance. Halar has excellent application for high purity hydrogen peroxide and is joined by thermal butt fusion.

TEFLON

There are three members of the Teflon family of resins.

PTFE TEFLON is the original Teflon resin developed by DuPont in 1938. This fluoropolymer offers the most unique and useful characteristics of all plastic materials. Products made from this resin handle liquids or gases up to 500°F. The unique properties of this resin prohibit extrusion or injection molding by conventional methods. When melted, PTFE does not flow like other thermoplastics and it must be shaped initially by techniques similar to powder metallurgy. Normally PTFE is an opaque white material. Once sintered it is machined to the desired part.

FEP TEFLON was also invented by DuPont and became a commercial product in 1960. FEP is a true thermoplastic that can be melt-extruded and fabricated by conventional methods. This allows for more flexibility in manufacturing. The dielectric properties and chemical resistance are similar to other Teflons, but the temperature limits are -65°F to a maximum of 300°F. FEP has a glossy surface and is transparent in thin sections. It eventually becomes translucent as thickness increases. FEP Teflon is the most transparent of the three Teflons. It is widely used for its high ultraviolet light–transmitting ability.

PFA TEFLON, a close cousin of PTFE, was introduced in 1972. It has excellent melt-process ability and properties rivaling or exceeding those of PTFE Teflon. PFA permits conventional thermoplastic molding and extrusion processing at high rates and also has higher mechanical strength at elevated temperatures to 500°F. Premium grade PFA Teflon offers superior stress and crack resistance with good flex-life in tubing. It is generally not as permeable as PTFE.

Caution: While the Teflon resin family has great mechanical properties and excellent temperature resistance, care must be taken when selecting the proper method of connections for your piping system. Generally, Teflon threaded connections will handle pressures to 120 psig. Loose ferrule connections are limited to 60 psig at ambient temperatures. Teflon loses its ability to bear a load at elevated temperatures quicker than other thermoplastics. When working with the PTFE products shown in this catalog. External ambient temperatures ranging from -60°F to 250°F (-51°C to 121°C) may be handled safely. Fluid or gas temperatures inside the product should be limited to -60°F to 400°F (-51°C to 204°C) unless otherwise noted. Always use extreme care when working with chemicals at elevated temperatures.

DURAPLUS

ABS (ACRYLONITRILE-BUTADIENE-STRENE) There are many possibilities for polymer properties by combining these resins. For our purposes we will limit it to two products. One is the less expensive ABS resin used in drain, waste, and vent applications. The other resin for more stringent industrial applications has a different combination of the three polymers that make up the copolymer. The Duraplus product is made from this copolymer and has outstanding impact resistance even at low temperatures. The product is very tough and abrasion resistant. Temperature range is -40°F to 158°F.

RYTON (PPS) POLYPHENYLENE SULFIDE remains quite stable during both long and short term exposure to high temperatures. The high tensile strength and flexural modulus typical of PPS compounds decrease with an increase in temperature. PPS is also highly resistant to chemical attack. Relatively few chemicals react to this material even at high temperatures. Its broad range of chemical resistance is second only to that of Teflon (PTFE). Ryton is used primarily for precision pump parts.

ELASTOMERS

VITON (FLUOROCARBON) is inherently compatible with a broad spectrum of chemicals. Because of this extensive chemical compatibility which spans considerable concentration and temperature ranges, Viton has gained wide acceptance as a sealing for valves, pumps, and instrumentation. Viton can be used in most applications involving mineral acids, salt solutions, chlorinated hydrocarbons, and petroleum oils.

EPDM (EPT) is a terpolymer elastomer made from ethylenepropylene diene monomer. EPDM has good abrasion and tear resistance and offers excellent chemical resistance to a variety of acids and alkalies. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids, or strong alkalies.

HYTREL is a multipurpose polyester elastomer similar to vulcanized thermoset rubber. Its chemical resistance is comparable to Neoprene, Buna-N and EPDM; however, it is a tougher material and does not require fabric reinforcement as do the other three materials. Temperature limits are -10°F minimum to 190°F maximum. This material is used primarily for pump diaphragms.

THERMOSETS

FIBERGLASS REINFORCED PLASTICS (FRP) including epoxy, polyester, and vinylester have become a highly valuable process engineering material for process piping. FRP has been accepted by many industries because it offers the following significant advantages: (a) moderate initial cost and low maintenance; (b) broad range of chemical resistance; (c) high strength-to-weight ratio; (d) ease of fabrication and flexibility of design; and (e) good electrical insulation properties.

EPOXY pipe and fittings have been used extensively by a wide variety of industries since 1960. It has good chemical resistance and excellent temperatures to pressure properties (to 300°F). Epoxy has been used extensively for fuel piping and steam condensate return lines.

POLYESTER pipe and fittings have been used by the industry since 1963. They have proven resistance to most strong acids and oxidizing materials. They can be used in applications up to 200°F. Polyester is noted for its strength in both piping and structural shapes.

VINYLESTER resin systems are recommended for most chlorinated mixtures as well as caustic and oxidizing acids up to 200°F. For most services, Vinylester has superior chemical resistance to epoxy or polyester.

NYLONS are synthetic polymers that contain an amide group. Their key characteristics are: (a) excellent resistance and low permeation to fuels, oils, and organic solvent, including aliphatic, aromatic, and halogenated hydrocarbons, esters, and ketones; (b) outstanding resistance to fatigue and repeated impact; and (c) wide temperature range from -30°F to 250°F.

Caution: Acids will cause softening, loss of strength, rigidity, and eventual failure.

POLYURETHANES

There are essentially two types of polyurethanes: polyester based and polyether based. Both are used for tubing applications.

POLYESTER- based is the toughest of the two, having greater resistance to oil and chemicals. It does not harden when used with most oils, gasoline, and solvents. Polyurethane is extremely resistant to abrasives making it ideal for slurries, solids, and granular material transfer. Temperature limit is 170°F.

Caution: Polyester-based polyurethanes may be subject to hydrolysis under certain conditions, high relative humidity at elevated temperatures, aerated water, fungi, and bacteria. Where these potentials exist, we recommend polyether-based polyurethane.

POLYETHER- based polyurethane possesses better low temperature properties, resilience, and resistance to hydrolytic degradation than the polyester previously discussed.

Accelerated testing indicates that polyether-based polyurethanes have superior hydrolytic stability as compared to polyester-based material. Made with no plasticizers and with a low level of extractables, polyether is ideal for high-purity work. It will not contaminate laboratory samples and is totally non-toxic to cell cultures. Compared with PVC tubing, polyurethanes have superior chemical resistance to fuels, oils, and some solvents. Its excellent tensile strength and toughness make it suitable for full vacuums. This tubing can withstand temperatures from -94°F to 200°F.

PTBP

Polybutylene terephthalate is a little known specialty material belonging to the polyimide group. It has excellent mechanical properties and good mechanical stress properties under corrosive environments. PTBP is used mainly for valve actuators and bonnet assemblies.

RELATIVE PROPERTIES

Table 1

MATERIAL	SPECIFIC GRAVITY ASTM-D792	WATER ABSORPTION %/24 hr. at 73°F ASTM-D570	TENSILE STRENGTH psi at 73°F ASTM-D638	MODULUS OF ELASTICITY IN TENSION psi @ 73°F X 10^5 ASTM-D638	FLEXURAL STRENGTH psi ASTM-D256	IZOD IMPACT 78° ft. lbs./in. notched ASTM-D256	COMPRESSIVE STRENGTH psi ASTM-D695	POISSON'S RATIO
STEEL Gr. B	7.86	—	60,000	290	—	32	—	0.33
ALUMINUM 3003	2.73	—	16,000	100	—	20	—	0.33
COPPER	8.94	—	30,000	170	—	43	—	—
DURAPLUS (ABS)	1.04	—	5,500	2.40	—	8.5	6,150	—
POLYVINYL CHLORIDE (PVC) TYPE 1	1.38	0.05	7,940	4.0-4.2	14,500	0.65	9,600	0.35-0.38
CHLORINATED POLYVINYL CHLORIDE (CPVC)	1.55	0.05	8,400	3.6-4.2	15,800	2.0	9,000 - 22,000	0.35-0.38
POLYPROPYLENE (PP) NON PPFR / POLYPROPYLENE FLAME RETARDANT (PPFR)	0.905	0.02	5,000	1.7-2.5	7,000	1.3	5,000 - 8,000	0.38-0.4
POLYPROPYLENE/ POLYBUTYLENE COPOLYMER (PROLINE)	0.905	0.02	5,800	1.1	2,900	4.7	7,000	0.34-0.4
POLYPHYLENE SULFIDE 40% GLASS FIBER REINFORCED (RYTON)	1.6	0.05	19,500	1.6	29,000	1.4	21,000	—
POLYVINYLIDENE FLUORIDE (PVDF)	1.75-1.78	0.04	5,000-7,000	2.13	12,180	2.8	10,500	0.38
HALAR (ECTFE)	1.69	0.04	4,500	2.40	—	No Break	—	0.3-0.4
TEFLON (PTFE) POLYTETRAFLUORETHYLENE	2.14	0.02	2,600	1.0	81,000	No Break	3.500	—
TEFLON (PFA) PERFLUOROALKOXY	2.2	0.0	2,000-5,000	0.58	—	3.0	1,700	—
TEFLON (FEP) FLUORINATED ETHYLENE PROPYLENE	2.1	0.0	2,700 - 3,100	0.50	—	No Break	2,200	—
POLYETHYLENE (LDPE) - LOW DENSITY	0.925	0.01	2,300	0.14 - .38	—	9.0	—	—
POLYETHYLENE (HDPE) - HIGH DENSITY	0.965	0.01	4,500	0.6 - 1.8	7,000	4.0	3,600	—
POLYETHYLENE (XLPE) - CROSS LINK PE	1.28	0.02	3,000	—	5,000	2.0	4,000	—
EPOXY FIBERGLASS	1.6	0.05-0.20	10,000	1.35	10,000	1.0	25,000	—
VINYLESTER FIBERGLASS	1.6	0.02	10,500	1.4	15,600	2.5	18,000	—
POLYSULFONE	1.24	00.3	10,200	3.6	15,400	1.3	—	—

Note: Common relative properties will vary slightly depending on the specific resin formulation used by each manufacturer even though all resins used may conform to the same ASTM specifications. Harrington recommends specifying a specific manufacturer when engineering calculations are critical.

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RELATIVE PROPERTIES

Table 2

MATERIAL	WORKING STRESS @ 73° FM, psi	COEFFICIENT OF LINEAR EXPANSION in/(in °F) x 10^{-5} ASTM-D696	THERMAL EXPANSION inches per 10°F change per 100' of pipe	RESISTANCE TO HEAT °F Continous	HEAT DISTORTION 66 psi ASTM-D648	HEAT DISTORTION TEMP °F @ 264 psi ASTM-D648	THERMAL CONDUCTIVITY BTU/hr/sq. ft./°F/in. ASTM - C177	BURNING RATE ASTM-D635	LIMITED OXYGEN index (%) ASTM-D2863-70	BURNING CLASS UL 94	SURFACE BURNING OF BLDG MATERIALS E-84: FLAME	SURFACE BURNING OF BLDG MATERIALS E-84: SMOKE
STEEL Gr. B	20,000	0.06	1/16"	750°	—	—	290	—	—	—		
ALUMINUM 3003	—	—	5/35"	400°	—	—	1450	—	—	—		
COPPER	—	—	1/8"	400°	—	—	2610	—	—	—		
DURAPLUS (ABS)	—	5.6	5/8"	158°	194	223	1.7	*	—	—	—	—
POLYVINYL CHLORIDE (PVC) TYPE 1	2,000	2.9-3.0	1/3"	140°	173	160	1.2	*	43	V-0	15	850
CHLORINATED POLYVINYL CHLORIDE (CPVC)	2,000	3.4-3.8	1/2"	210°	238	221	0.95	*	60	V-0	10	295
POLYPROPYLENE (PP) NON-PPFR	725-800	4.2-5.0	5/8"	180°	220	125-140	1.2	Slow	17	V-2	119	791
POLYPROPYLENE FLAME RETARDANT (PPFR)											115	412
POLYPROPYLENE/ POLYBUTYLENE COPOLYMER (PROLINE)	800	8.33	1"	200°	—	—	1.2	Slow	—	V-2	—	—
POLYPHYLENE SULFIDE 40% GLASS FIBER REINFORCED (RYTON)	—	—	1/2"	200°	—	485	1.5 - 0.91	*	—	V-0	—	—
POLYVINYLIDENE FLUORIDE (PVDF)	2,300	6.8-8.7	1"	280°	284	195	1.32	*	44	V-0	—	—
HALAR (ECTFE)	—	4.4-9.2	1"	300°	195	151	1.07	*	60	V-0	—	—
TEFLON (PTFE) POLYTETRAFLUORETHYLENE	—	10.0	2/3"	500°	250	—	6.0	*	95	V-0	—	—
TEFLON PERFLUOROALKOXY (PFA)	—	7.6	9/10"	500°	—	—	1.3	*	95	V-0	—	—
TEFLON FLUORINATED ETHYLENE PROPYLENE (FEP)	—	8.3-10.5	1/3"	300°	158	—	6.0	*	95	V-0	—	—
LOW DENSITY POLYETHYLENE (LDPE)	—	10.0-22.0	1-1/4"	140°	100-121	90-105	2.3	Very Slow	—	V-1	—	—
HIGH DENSITY POLYETHYLENE (HDPE)	—	7.2-9.0	7/8"	160°	175-196	110-130	3.5	Very Slow	226	V-1	—	—
CROSS LINK PE POLYETHYLENE (XLPE)	—	—	—	180°	180	120	—	Slow	—	V-1	—	—
EPOXY FIBERGLASS	—	4.0-10.0	1/10"	300°	—	300	1.7	*	—	V-0	—	—
VINYLESTER FIBERGLASS	—	—	1/10"	200°	—	200	2.0	*	—	V-0	—	—
POLYSULFONE	—	3.1	—	300°	—	345	1.8	*	33	V-0	—	—

* Self-extinguishing

Note: Common relative properties will vary slightly depending on the specific resin formulation used by each manufacturer even though all resins used may conform to the same ASTM specifications. Harrington recommends specifying a specific manufacturer when engineering calculations are critical.

INDUSTRY STANDARDS

The standards referenced herein, like all other standards, are of necessity minimum requirements. It should be recognized that two different plastic resin materials of the same kind, type, and grade will not exhibit identical physical and chemical properties. Therefore, the plastic pipe purchaser is advised to obtain specific values or requirements from the resin supplier to assure the best application of the material not covered by industry specifications; this suggestion assumes paramount importance. Listed below are some of the many organizations providing standards and specification for the products sold by Harrington Industrial Plastics. Note: not all applicable standards or specifications, from any of the organizations, are shown below.

ANSI
AMERICAN NATIONAL STANDARDS INSTITUTE, INC.

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ANSI PRESSURE CLASSES
ANSI Class 125 means 175 psi at 100°F
ANSI Class 150 means 285 psig at 100°F
ANSI Class 300 means 740 psig at 100°F

ANSI B-16-1	Cast iron pipe flanges and flanged fittings Class 25, 125, 150, 250, and 800
ANSI B-16.42	Ductile iron pipe flanges and flanged fittings
ANSI B-16.5	Steel pipe flanges and flanged fittings Class 150, 300, 400, 600, 900, 1500, and 2500
ANSI Z-124.6	Standard for Plastic Sinks

The following ASTM standards have been accepted by ANSI and assigned the following designations.

Table 3

ANSI Designation	ASTM Designation	ANSI Designation	ASTM Designation
B 72.1	D 2239	B 72.11	D 2412
B 72.2	D 2241	B 72.13	D 2447
B 72.3	B 723	B 72.16	D 2564
B 72.4	B 724	B 72.17	D 2657
B 72.5	B 723 B 725	B 72.18	D 2661
B 72.6	D 1598	B 72.20	D 2672
B 72.7	D 1785	B 72.22	F 645
B 72.8	D 2104	B 72.23	D 2235
B 72.9	D 2152		

ASSE
AMERICAN SOCIETY OF SANITARY ENGINEERING

901 Canterbury Rd., Ste. A,
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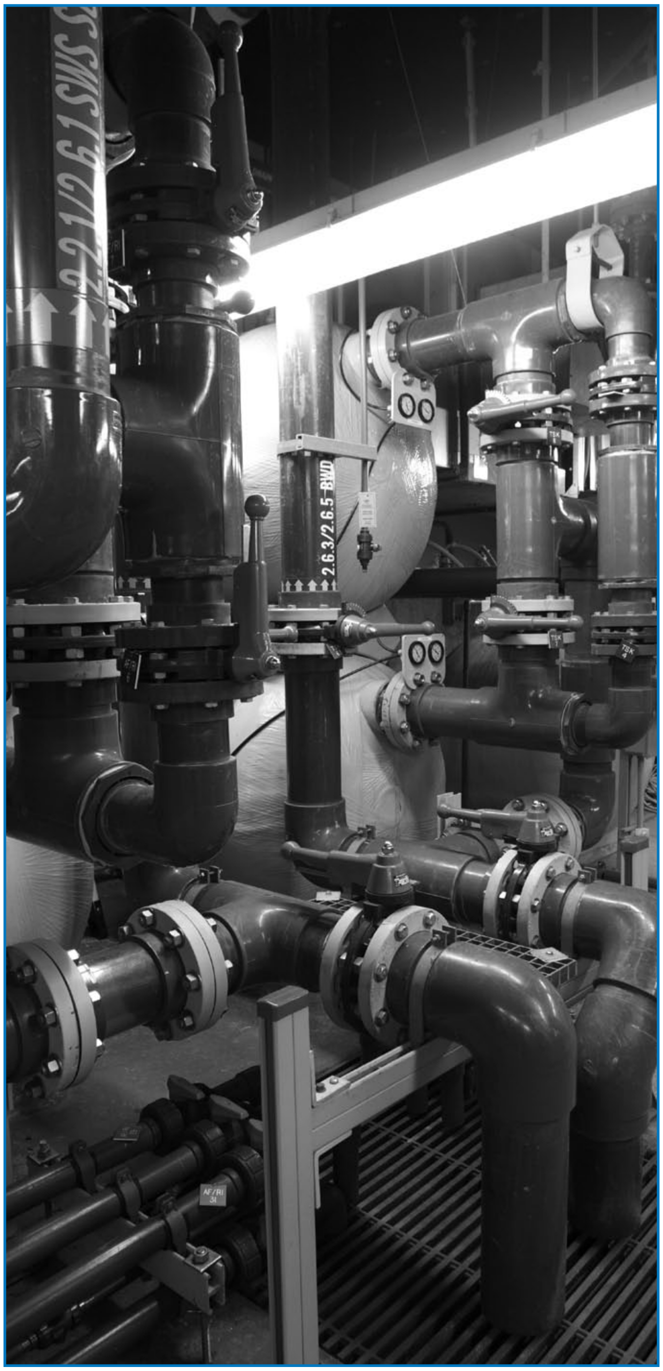
ASSE is an ANSI accredited product certification agency

ASSE 1020	Pressure Vacuum Breaker Assembly
ASSE 1035	Laboratory Faucet Backflow Preventers
ASSE 1043	Cast Iron Solvent Sanitary Drainage Systems



INDUSTRY STANDARDS

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ASTM predates other standards organizations such as BSI (1901), DIN (1917) and AFNOR (1926), but differs from these in that it is not a national standards body, that role being taken in the USA by ANSI. However, ASTM has a dominant role among standards developers in the USA, and claims to be the world's largest developer of standards. Using a consensus process, ASTM supports thousands of volunteer technical committees, which draw their members from around the world and collectively develop and maintain more than12,000 standards. Shown below are just a few of the most commonly sited standard encountered by our customers.

ASTM STANDARD SPECIFICATIONS	
ASTM A 105/A105M	Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A 126	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A 216/A216M	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
ASTM A 234/A234M	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A 395/A395M	Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
ASTM A 53/A53M	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A 587	Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry
ASTM D 1784	Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
ASTM D 1785	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120,
ASTM D 1866	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Schedule 40 Drainage and DWV Fabricated Fittings
ASTM D 1998	Standard Specification for Polyethylene Upright Storage Tanks
ASTM D 2241	Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
ASTM D 2464	Standard Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
ASTM D 2466	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
ASTM D 2467	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
ASTM D 2513	Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings
ASTM D 2564	Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D 2661	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings
ASTM D 2665	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings

INDUSTRY STANDARDS

ASTM STANDARD SPECIFICATIONS	
ASTM D 2672	Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement
ASTM D 2846	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems
ASTM D 3139	Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
ASTM D 4101	Standard Specification for Polypropylene Injection and Extrusion Materials
ASTM D 6263	Standard Specification for Extruded Bars bade from Rigid Poly (Vinyl Chloride) (PVC) and Chlorinated Poly (Vinyl Chloride) (CPVC)
ASTM D 883	Standard Terminology Relating to Plastics
ASTM F 1282	Standard Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe
ASTM F 1545	Standard Specification for Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges
ASTM F 1673	Standard Specification for Polyvinylidene Fluoride (PVDF) Corrosive Waste Drainage Systems
ASTM F 1970	Standard Specification for Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Systems
ASTM F 1974	Standard Specification for Metal Insert Fittings for Polyethylene/Aluminum/Polyethylene and Cross-linked Polyethylene/Aluminum/Cross-linked Polyethylene Composite Pressure Pipe
ASTM F 2389	Standard Specification for Pressure-Rated Polypropylene (PP) Piping Systems
ASTM F 412	Standard Terminology Relating to Plastic Piping Systems
ASTM F 437	Standard Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
ASTM F 438	Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40
ASTM F 439	Standard Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
ASTM F 441	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
ASTM F 442	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)
ASTM F 477	Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
ASTM F 480	Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedules 40 and 80
ASTM F 493	Standard Specification for Solvent Cements for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
ASTM F 656	Standard Specification for Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings
ASTM F 913	Standard Specification for Thermoplastic Elastomeric Seals (Gaskets) for Joining Plastic Pipe

INDUSTRY STANDARDS

ASTM STANDARD TEST METHODS	
ASTM C 177	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D 1525	Standard Test Method for Vicat Softening Temperature of Plastics
ASTM D 1598	Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
ASTM D 1599	Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
ASTM D 1693	Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D 2122	Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
ASTM D 2152	Standard Test Method for Adequacy of Fusion of Extruded Poly (Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion
ASTM D 2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
ASTM D 2444	Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
ASTM D 256	Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
ASTM D 2765	Standard Test Method for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics
ASTM D 2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
ASTM D 2863	Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D 2924	Standard Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASTM D 3895	Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
ASTM D 570	Standard Test Method for Water Absorption of Plastics
ASTM D 635	Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D 638	Standard Test Method for Tensile Properties of Plastics
ASTM D 648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
ASTM D 695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D 696	Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C With a Vitreous Silica Dilatometer
ASTM D 790	Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D 792	Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM E 84	Standard Test Method for Surface Burning Characteristics of Building Materials

INDUSTRY STANDARDS

ASTM STANDARD TEST METHODS	
ASTM F 2023	Standard Test Method for Evaluating the Oxidative Resistance of Cross-linked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water
ASTM F 610	Standard Test Method for Evaluating the Quality of Molded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings by the Heat Reversion Technique

ASTM STANDARD PRACTICES	
ASTM D 2321	Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
ASTM D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
ASTM D 2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping
ASTM D 2855	Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings
ASTM D 543	Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
ASTM D 618	Standard Practice for Conditioning Plastics for Testing
ASTM F 1057	Standard Practice for Evaluating the Quality of Extruded Poly (Vinyl Chloride) (PVC) Pipe by the Heat Reversion Technique
ASTM F 402	Standard Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastics Pipe and Fittings
ASTM F 645	Standard Guide for Selection, Design, and Installation of Thermoplastic Water Pressure Systems
ASTM F 690	Standard Practice for Underground Installation of Thermoplastic Pressure Piping Irrigation System
ASTM STANDARD SYMBOLS & TERMINOLOGY	
ASTM D 2749	Standard Symbols for Dimensions of Plastic Pipe Fittings
ASTM D 1600	Standard Terminology for Abbreviated Terms Relating to Plastics

CSA
CANADIAN STANDARDS ASSOCIATION
5060 Spectrum Way
Mississauga, Ontario
L4W 5N6 Canada
Phone: (416) 747-4000
Fax: (416) 747-2473
www.csa.ca

The Standards Council of Canada (SCC) has responsibility for co-ordination of the National Standards System (NSS) in Canada and has accredited CSA as one of four nationally accredited Standards Developing Organization (SDO).

To achieve and maintain accreditation, several criteria must be met including:

1. Development of consensus standards which adhere to the principles used in Canada governing the consensus process.
2. Complying with criteria established for approval of National Standards of Canada.

FM Global (formerly Factory Mutual Insurance)
1301 Atwood Avenue
P.O. Box 7500
Johnston, RI 02919
United States
Phone: +1 (1) 401 275 3000, ext.: 2036
Fax: +1 (1) 401 275 3032
www.fmglobal.com

FM Global is a commercial insurance corporation, that embraces all aspects of risk management. They have the largest fire testing facility in the world. Fire is the largest cause of loss in industry. FM not only offers commercial property insurance but they also have a staff of loss prevention engineers to identify potential areas of loss and make recommendations to eliminate them before a loss occurs. FM Global offers product testing and certification that uses the highest standards of industry test methods, both national and international.

INDUSTRY STANDARDS

ICC (Formerly ICBO)
INTERNATIONAL CODE COUNCIL

500 New Jersey Avenue, NW, 6th Floor
Washington, DC 20001-2070
Phone: 1-888-ICC-SAFE (422-7233)
Fax: (202) 783-2348
www.iccsafe.org

The International Conference of Building Officials (ICBO), now known as the International Code Council (ICC), publishes codes that establish minimum performance requirements for all aspects of the construction industry. ICBO is a founding member of the International Code Council (ICC), which was established in 1994 to develop a single set of comprehensive and coordinated national model construction codes.

ICBO Uniform Codes address the abatement of dangerous buildings, administrative, building, energy conservation, fire prevention, housing, mechanical, security, signage, urban-wildland interface, and zoning segments of the construction industry.

IAPMO
International Association of Plumbing and Mechanical Officials

5001 E. Philadelphia St.
Ontario, CA 91761 – USA
Phone: (909) 472.4100
Fax: (909) 472.4150
www.iapmo.org

Develops and maintains the Uniform Plumbing Code (UPC), Uniform Mechanical Code (UMC), Uniform Swimming Pool, Spa and Hot Tub Code (USPC) and the Uniform Solar Energy Code (USEC).

The IAPMO code development process is accredited by the American National Standards Institute (ANSI).

Codes include:

IAPMO PS 33-2007a	Flexible PVC Hose for Pools, Hot Tubs, Spas and Jetted Bathtubs
IAPMO PS 110-2006a	PVC Cold Water Compression Fittings
IAPMO PS 111-1999	PVC Cold Water Gripper Fittings
IAPMO PS 112-1999	PVC Plastic Valves for Cold Water Distribution Systems Outside a Building and CPVC Plastic Valves for Hot and Cold Water Distribution Systems

NSF International World Headquarters

(formerly known as the National Sanitation Foundation)
789 Dixboro Road
P.O. Box 130140
Ann Arbor, MI 48113-0140
Toll Free: (800) NSF-Mark
Phone: (734) 769-8010
Fax: (734) 769-0109
www.nsf.org

NSF Seal of Approval: Listing of Plastic Materials, Pipe, Fittings, and Appurtenances for Potable Water and Waste Water (NSF Testing Laboratory).

NSF/ANSI-14: Plastics Piping System Components and Related Materials This Standard addresses healt effects (by reference to Standard 61) and performance of plastics plumbing system components such as pipe, fittings, valves, materials, resins, ingredients, and joining materials.

NSF/ANSI-60: Drinking Water Treatment Chemicals - Health Effects Standard 60 is the nationally recognized health effects standard for chemicals, which are used to treat drinking water.

NSF/ANSI-61: Drinking Water System Components - Health Effects Standard 61 is the nationally recognized health effects standard for all devices, components and materials, which contact drinking water.

UL — Underwriters Laboratories Inc.

333 Pfingsten Road
Northbrook, IL 60062-2096
Phone: (847) 272-8800
Fax: (847) 272-8129
www.ul.com
UL Standards:

508A	Standard for Industrial Control Panels
651	Standard for Schedule 40 and 80 Rigid PVC Conduit and Fittings
651A	Type EB and A Rigid PVC Conduit and HDPE Conduit
651B	Standard for Continuous Length HDPE Conduit
1285	Standard for Safety Pipe and Couplings, Polyvinyl Chloride (PVC), for Underground Fire Service
1316	Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures
1821	Standard for Safety for Thermoplastic Sprinkler Pipe and Fittings for Fire Protection Service
1887	Standard for Fire Test of Plastic Sprinkler Pipe for Visible Flame and Smoke Characteristics
2360	Standard for Test Methods for Determining the Combustibility Characteristics of Plastics Used in Semi-Conductor Tool Construction

INDUSTRY STANDARDS

NEMA
National Electrical Manufacturers Association
1300 North 17th Street
Suite 1752
Rosslyn, Virginia 22209
Phone: (703) 841-3200
Fax: (703) 841-5900
www.nema.org

NEMA enclosures:	
Type 1	General Purpose - Indoor: This enclosure is intended for use indoors, primarily to prevent accidental contact of personnel with the enclosed equipment in areas where unusual service conditions do not exist. In addition, they provide protection against falling dirt.
Type 2	Drip Proof - Indoor: Type 2 drip proof enclosures are for use indoors to protect the enclosed equipment against falling noncorrosive liquids and dirt. These enclosures are suitable for applications where condensation may be severe such as encountered in cooling rooms and laundries.
Type 3	Dust Tight, Rain Tight, Sleet (Ice) Resistant Outdoor: Type 3 enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water. They are not sleet (ice) proof.
Type 3R	Rainproof and Sleet (Ice) Resistant Outdoor: Type 3R enclosures are intended for use outdoors to protect the enclosed equipment against rain and meet the requirements of Underwriters' Laboratories, Inc., Publication No. UL 508, applying to "Rainproof Enclosures." They are not dust, snow, or sleet (ice) proof.
Type 3S	Dust Tight, Rain Tight, and Sleet (Ice) Proof-Outdoor: Type 3S enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water and to provide for its operation when the enclosure is covered by external ice or sleet. These enclosures do not protect the enclosed equipment against malfunction resulting from internal icing.
Type 4	Watertight and Dust Tight - Indoor and Outdoor: This type is for use indoors or outdoors to protect the enclosed equipment against splashing and seepage of water or streams of water from any direction. It is sleet-resistant but not sleet proof.
Type 4X	Watertight, Dust Tight and Corrosion-Resistant Indoor and Outdoor: This type has same provisions as Type 4 and, in addition, is corrosion-resistant.
Type 5	Superseded by Type 12 for Control Apparatus.

NEMA enclosures:	
Type 6	Submersible, Watertight, Dust tight, and Sleet (Ice) Resistant - Indoor and Outdoor: Type 6 enclosures are intended for use indoors and outdoors where occasional submersion is encountered, such as in quarries, mines, and manholes. They are required to protect equipment against a static head of water of 6 feet for 30 minutes and against dust, splashing or external condensation of non-corrosive liquids, falling or hose directed lint and seepage. They are not sleet (ice) proof.
Type 7	Class I, Group A, B, C, and D-Indoor Hazardous Locations - Air-Break Equipment: Type 7 enclosures are intended for use indoors, in the atmospheres and locations defined as Class 1 and Group A, B, C or D in the National Electrical Code. Enclosures must be designed as specified in Underwriters' Laboratories, Inc. "Industrial Control Equipment for Use in Hazardous locations," UL 698. Class I locations are those in which flammable gases or vapors may be present in explosive or ignitable amounts. The group letters A, B, C, and D designate the content of the hazardous atmosphere under Class 1 as follows: **Group A** - Atmospheres containing acetylene. **Group B** - Atmospheres containing hydrogen or gases or vapors of equivalent hazards such as manufactured gas. **Group C** - Atmospheres containing ethyl ether vapors, ethylene, or cyclopropane. **Group D** - Atmospheres containing gasoline, hexane, naphtha, benzene, butane, propane, alcohols, acetone, lacquer solvent vapors and natural gas.
Type 8	Class I, Group A, B, C or D - Indoor Hazardous Locations Oil-Immersed Equipment: These enclosures are intended for indoor use under the same class and group designations as Type 7, but are also subject to immersion in oil.

INDUSTRY STANDARDS

NEMA enclosures:	
Type 9	Class II, Group E, F and G - Indoor Hazardous Locations - Air-Break Equipment: Type 9 enclosures are intended for use indoors in the atmospheres defined as Class II and Group E, F, or G in the National Electrical Code. These enclosures shall prevent the ingress of explosive amounts of hazardous dust. If gaskets are used, they shall be mechanically attached and of a non-combustible, non-deteriorating, vermin-proof material. These enclosures shall be designed in accordance with the requirements of Underwriters' Laboratories, Inc. Publication No. UL 698. Class II locations are those in which combustible dust may be present in explosive or ignitable amounts. The group letter E,F, and G designate the content of the hazardous atmosphere as follows: **Group E** - Atmosphere containing metal dusts, including aluminum, magnesium, and their commercial alloys. **Group F** - Atmospheres containing carbon black, coal, or coke dust. **Group G** - Atmospheres containing flour, starch, and grain dust.
Type 10	Bureau of Mines: Enclosures under Type 10 must meet requirements of Schedule 2G (1968) of the Bureau of Mines, U.S. Department of the Interior, for equipment to be used in mines with atmospheres containing methane or natural gas, with or without coal dust.
Type 11	Corrosion-Resistant and Drip Proof, Oil-Immersed-Indoor: Type 11 enclosures are corrosion-resistant and are intended for use indoors to protect the enclosed equipment against dripping, seepage, and external condensation of corrosive liquids. In addition, they protect the enclosed equipment against the corrosive effects of fumes and gases by providing for immersion of the equipment in oil.
Type 12	Industrial Use - Dust Tight and Drip Tight - Indoor: Type 12 enclosures are intended for use indoors to protect the enclosed equipment against fibers, flyings, lint, dust and dirt, and light splashing, seepage, dripping and external condensation of non-corrosive liquids.
Type 13	Oil Tight and Dust Tight - Indoor: Type 13 enclosures are intended for use indoors primarily to house pilot devices such as limit switches, foot switches, push buttons, selector switches, pilot lights, etc., and to protect these devices against lint and dust, seepage, external condensation, and spraying of water, oil or coolant. They have oil-resistant gaskets.

INDUSTRY STANDARDS

Government Regulatory Agencies

DEPARTMENT OF COMMERCE

National Institute of Standards and Technology
Public and Business Affairs Div.
820 West Diamond Ave.
Gaithersburg, MD 20889
Phone: (301) 975-2762
Fax: (301) 926-1630
www.nist.gov

The National Institute of Standards and Technology (NIST) focuses on tasks vital to the country's technology infrastructure that neither industry nor the government can do separately NIST works to promote U.S. economic growth by working with industry to develop and apply technology, measurements, and standards.

Part of the Commerce Department's Technology Administration, NIST has four major programs that reflect U .S. industry's diversity and multiple needs. These programs include the Advanced Technology Program; Manufacturing Extension Partnership; Laboratory Research and Services; and the Baldrige National Quality Program.

DEPARTMENT OF ENERGY

Consumer Affairs
1000 Independence Avenue SW
Washington, DC 20585
Phone: (800) 342-5363
Fax: (202) 586-4403
www.energy.gov

The Department of Energy is entrusted to contribute to the welfare of the nation by providing the technical information and scientific and educational foundation for technology, policy, and institutional leadership necessary to achieve efficiency in energy used, diversity in energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense.

DEPARTMENT OF THE INTERIOR

1849 C Street NW
Washington, DC 20240
Phone: (202) 208-3100
Fax: (202) 208-6950
www.interior.gov

As the nation's principal conservation agency, the Department of the Interior's responsibilities include: encouraging and providing appropriate management, preservation and operation of the nation's public lands and natural resources; developing and using resources in an environmentally sound manner; carrying out related scientific research and investigations in support of these objectives; and carrying out trust responsibilities of the U.S. government with respect to American Indians and Alaska Natives. It manages more than 440 million acres of federal lands.

DEPARTMENT OF LABOR

Office of Information and Public Affairs
200 Constitution Avenue, NW
Washington, DC 20210
Phone: (877) 889-5627
Fax: (202) 219-8699
www.dol.gov

The Department of Labor's principal mission is to help working people and those seeking work.

The department's information and other services, particularly in job training and labor law enforcement, benefit and affect many other groups, including employers, business organizations, civil rights groups and government agencies at all levels as well as the academic community.

DEPARTMENT OF TRANSPORTATION

Office of Public Affairs
1200 New Jersey Ave SE
Washington, DC 20590
Phone: (202) 366-4000
Fax: (202) 366-6337
www.dot.gov

The Department of Transportation ensures the safety of all forms of transportation; protects the interests of consumers; conducts planning and research for the future; and helps cities and states meet their local transportation needs.

The Department of Transportation Is composed of 10 operating administrations, including the Federal Aviation Administration; the Federal Highway Administration; the Federal Railroad Administration; the Federal Transit Administration; the National Highway Traffic Safety Administration; the Maritime Administration; the St. Lawrence Seaway Development Corp.; the U.S. Coast Guard; the Research and Special Programs Administration; and the Bureau of Transportation Statistics.

DEPARTMENT OF THE TREASURY

Bureau of Alcohol, Tobacco and Firearms
Liaison and Public Information
1500 Pennsylvania Ave NW
Washington, DC 20220
Phone: (202) 622-2000
Fax: (202) 622-6415
www.ustreas.gov

The Bureau of Alcohol, Tobacco and Firearms (ATF) is an agency of the U.S. Department of the Treasury.

ATF's responsibilities are law enforcement; regulation of the alcohol, tobacco, firearms and explosives industries; and ensuring the collection of taxes on alcohol, tobacco, and firearms.

ATF's mission is to curb the illegal traffic in and criminal use of firearms; to assist federal, state and local law enforcement agencies in reducing crime and violence; to investigate violations of federal explosive laws; to regulate the alcohol, tobacco, firearms and explosives industries; to ensure the collection of all alcohol, tobacco and firearms tax revenues; and to suppress commercial bribery, consumer deception, and other prohibited trade practices in the alcoholic beverage industry.

INDUSTRY STANDARDS

Government Regulatory Agencies

ENVIRONMENTAL PROTECTION AGENCY

Communication, Education and Public Affairs
Ariel Rios Building
1200 Pennsylvania Ave NW
Washington, DC 20460
Phone: (202) 272-0167
Fax: (202) 260-6257
www.epa.gov

The Environmental Protection Agency (EPA) is an independent agency in the executive branch of the U.S. government. THe EPA controls pollution through a variety of activities, which includes research, monitoring, standards setting, and enforcement. The Environmental Protection Agency supports research and antipollution efforts by state and local governments as well as by public service institutions and universities.

FEDERAL AVIATION ADMINISTRATION

800 Independence Avenue, SW
Washington, DC 20591
Phone: (866) 289-9673
www.fda.gov

The Federal Aviation Administration (FAA) provides a safe, secure and efficient global aerospace system that contributes to national security and the promotion of U.S. aerospace. As the leading authority in the international aerospace community, FAA is responsive to the dynamic nature of customer needs, economic conditions and environmental concerns.

FOOD AND DRUG ADMINISTRATION

Office of Public Affairs
Public Health Service Department of Health & Human Services
5600 Fishers Lane
Rockville, MD 20857
Phone: (888) 463-6332
www.faa.gov

The Food and Drug Administration (FDA) works to protect, promote, and enhance the health of the American people by ensuring that foods are safe, wholesome, and sanitary; human and veterinary drugs, biological products and medical devices are safe and effective; cosmetics are safe; electronic products that emit radiation are safe; regulated products are honestly, accurately, and informatively represented; these products are in compliance with the law and the FDA regulations; and noncompliance is identified and corrected and any unsafe and unlawful products are removed from the marketplace.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

300 E Street SW
Washington, DC 20546
Phone: (202) 358-0001
Fax: (202) 358-3469
www.nasa.gov

The National Aeronautics and Space Administration explores, uses and enables the development of space for human enterprise; advances scientific knowledge and understanding of the Earth, the solar system and universe; uses the environment of space for research; and researches, develops, verifies and transfers advanced aeronautics, space and related technologies.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

395 E Street SW Suite 9200
Patriots Plaza Building
Washington, DC 20201
Phone: (202) 245-0625
Fax: (202) 245-0628
www.cdc.gov

The National Institute for Occupational Safety and Health (NIOSH) was established by the Occupational Safety and Health Act of 1970. NIOSH is part of the Centers for Disease Control and Prevention and is the federal institute responsible for conducting research and making recommendations for the prevention of work-related illnesses and injuries.

The Institute's responsibilities include: investigating potentially hazardous working conditions as requested by employers or employees; evaluating hazards in the workplace; creating and disseminating methods for preventing disease, injury, and disability; conducting research and providing scientifically valid recommendations for protecting workers; and providing education and training to individuals preparing for or actively working in the field of occupational safety and health.

NIOSH identifies the causes of work-related diseases and injuries and the potential hazards of new work technologies and practices. It determines new ways to protect workers from chemicals, machinery, and hazardous working conditions.

NATIONAL TRANSPORTATION SAFETY BOARD

490 L'Enfant Plaza SW
Washington, DC 20594
Phone: (202) 314-6000
www.ntsb.gov

The National Transportation Safety Board (NTSB) is an independent federal accident investigation agency that also promotes transportation safety.

The board conducts safety studies; maintains official U.S. census of aviation accidents; evaluates the effectiveness of government agencies involved in transportation safety; evaluates the safeguards used in the transportation of hazardous materials; and evaluates the effectiveness of emergency responses to hazardous material accidents.

NUCLEAR REGULATORY COMMISSION

Office of Public Affairs
Washington, DC 20555-0001
Phone: (301)415-8200
Fax: (301) 415-3716
www.nrc.gov

The Nuclear Regulatory Commission (NRC) regulates the civilian uses of nuclear materials in the United States to protect the public health and safety, the environment, and the common defense and security. The mission is accomplished through licensing of nuclear facilities and the possession, use and disposal of nuclear materials; the development and implementation of requirements governing licensed activities; and inspection and enforcement to assure compliance.

INDUSTRY STANDARDS

Government Regulatory Agencies

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Office of Information and Consumer Affairs
200 Constitution Avenue NW, Room N3647
Washington, DC 20210
Phone: (800) 321-6742
Fax: (202) 219-5986
www.osha.gov

The Occupational Safety and Health Administration (OSHA) sets and enforces workplace safety and health standards with a goal of ensuring safe and healthful working conditions for all Americans. OSHA issues standards and rules for safe and healthful working conditions, tools, equipment, facilities, and processes.

OCCUPATIONAL SAFETY AND HEALTH REVIEW COMMISSION

Office of Public Information
One Lafayette Center
1120 20th Street NW, Ninth Floor
Washington, DC 20036-3457
Phone: (202) 606-5400
Fax: (202) 606-5050
www.oshrc.gov

The Occupational Safety and Health Review Commission (OSHRC) is an independent federal agency that serves as a court to provide decisions in workplace safety and health disputes arising between employers and the Occupational Safety and Health Administration in the Department of Labor.

U.S. COAST GUARD

Hazard Materials Standards Branch
2100 Second Street SW
Washington, DC 20593-0001
Phone: (202) 372-1420
Fax: (202) 372-1926
www.uscg.mil

The U.S. Coast Guard is the United States' primary maritime law enforcement agency as well as a federal regulatory agency and one of the armed forces.

The U.S. Coast Guard duties include aids to navigation; defense operations; maritime pollution preparedness and response; domestic and international ice breaking operations in support of commerce and science; maritime law enforcement; marine inspection and licensing; port safety and security; and search and rescue.

Chemical Industry Trade Associations

ADHESIVES MANUFACTURERS ASSOCIATION

1200 19th Street NW, Suite 300
Washington, DC 20036
Phone: (202) 429-5100
Fax: (202) 857-1115

The Adhesives Manufacturers Association (AMA) is a national organization comprised of major U.S. companies engaged in the manufacturing, marketing, and selling of formulated adhesives or formulated adhesives coatings to the industrial marketplace. Associate members supply raw materials to the industry.

AIR & WASTE MANAGEMENT ASSOCIATION

1 Gateway Center, 3rd Floor
420 Duquesne Blvd
Pittsburgh, PA 15222
Phone: (412) 232-3444
Fax: (412) 232-3450
www.awma.org

The Air & Waste Management Association (A&WMA) is a non-profit, technical and educational organization with 17,000 members in 58 countries. Founded in 1907, the association provides a neutral forum in which all viewpoints of an environmental issue (technical, scientific, economic, social, political, and health-related) receive equal consideration. The association serves its members and the public by promoting environmental responsibility and providing technical and managerial leadership in the fields of air and waste management.

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS

130 Holiday Court, Suite 100
Annapolis, MD 21401
Phone: (410) 266-3311
Fax: (410) 266-7653
www.aaee.net

This organization certifies environmental engineers.

AMERICAN BOILER MANUFACTURERS ASSOCIATION

8221 old Courthouse Road, Suite 202
Vienna, VA 22182
Phone: (703) 356-7172
Fax: (703) 356-4543
www.abma.com

The mission of the American Boiler Manufacturers Association is to improve services to the public; to be proactive with government in matters affecting the industry; to promote safe, economical, and environmentally friendly services of the industry; and to carry out other activities recognized as lawful for such organizations.

THE AMERICAN CERAMIC SOCIETY

600 N Cleveland Ave, Suite 210
Westerville, OH 43082
Phone: (614) 890-4700
Fax: (614) 794-5892

The American Ceramic Society is the headquarters for the professional organization for ceramic engineers.

INDUSTRY STANDARDS

Chemical Industry Trade Associations

AMERICAN CHEMICAL SOCIETY (ACS)

1155 Sixteenth Street NW
Washington, DC 20036
Phone: (202) 872-4600 or (800) 227-5558
Fax: (202) 872-6067
www.acs.org

ACS has 149,000 members. The members are chemists, chemical engineers, or people who have degrees in related fields.

AMERICAN COKE AND COAL CHEMICALS INSTITUTE

1140 Connecticut Ave NW Suite 705
Washington, DC 20036
Phone: (202) 452-7198
Fax: (202) 463-6573
www.accci.org

The ACCI's mission is to represent the interests of the coke and coal chemicals industry by communicating positions to legislative and regulatory officials, cooperating with all government agencies having jurisdiction over the industry, providing a forum for the exchange of information, and discussion of problems and promoting the use of coke and its byproducts in the marketplace.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

Kemper Woods Center
1330 Kemper Meadow Drive, Suite 600
Cincinnati, OH 45240
Phone: (513) 742-2020
Fax: (513) 742-3355
www.acgih.org

The ACGIH is an organization of more than 5,500 industrial hygienists and occupational health and safety professionals devoted to the technical and administrative aspects of worker health and safety.

CROPLIFE AMERICA - FORMERLY AMERICAN CROP PROTECTION ASSOCIATION

1156 15th Street NW, Suite 400
Washington, DC 20005
Phone: (202) 296-1585
Fax: (202) 463-0474
www.croplifeamerica.com

ACPA is the trade association for the manufacturers and formulators/distributors representing virtually all of the active ingredients manufactured, distributed, and sold in the United States for agricultural uses, including herbicides, insecticides, and fungicides.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS (AIChE)

3 Park Avenue
New York, NY 10016-5991
Phone: (800) 242-4363
Fax: (203) 775-5177
www.aiche.org

AMERICAN INSTITUTE OF MINING, METALLURGICAL AND PETROLEUM ENGINEERS (AIME)

8307 Shaffer Parkway
Littleton, CO 80127-4012
Phone: (303) 948-4255
Fax: (303) 948-4260
www.aimeny.org

AIME serves as the unifying forum for the member societies, which include the Society for Mining, Metallurgy and Exploration; The Minerals, Metals & Materials Society; Iron and Steel Society; Society of Petroleum Engineers; and the AIME Institute Headquarters.

AMERICAN PETROLEUM INSTITUTE (API)

1220 L Street NW
Washington, DC 20005
Phone: (202) 682-8000
Fax: (202)682-8154
www.api.org

The American Petroleum Institute (API) is the U.S. petroleum industry's primary trade association. API provides public policy development and advocacy, research, and technical services to enhance the ability of the petroleum industry to meet its mission.

AMERICAN SOCIETY OF BREWING CHEMISTS

3340 Pilot Knob Road
St. Paul, MN 55121
Phone: (651) 454-7250
Fax: (651) 454-0766
www.abcnet.org

A nonprofit organization that publishes scientific books and journals.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS (ASHRAE)

1791 Tullie Circle NE
Atlanta, GA 30329
Phone: (404) 636-8400
Fax: (404) 321-5478
www.ashrae.org

ASHRAE is an engineering society whose members are engineers specializing in heating, refrigerating, and air conditioning. It serves members through meetings and publications.

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING (ASNT)

1711 Arlingate Lane
P.O. Box 28518
Columbus, OH 43228-0518
Phone: (614) 274-6003
Fax: (614) 274-6899
www.asnt.org

A nonprofit organization that has 10,000 members worldwide. It sells technical books as well as providing testing for certification for nondestructive testing. This organization also publishes a monthly magazine.

AMERICAN SOCIETY FOR QUALITY (ASQ) FORMERLY ASQC

P.O. Box 3005
Milwaukee, WI 53201-3005
Phone: (414) 272-8575
Fax: (414) 272-1734
www.asq.org

This organization facilitates continuous improvement and increased customer service by identifying, communicating, and promoting the use of quality concepts and technology.

INDUSTRY STANDARDS

Chemical Industry Trade Associations

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Three Park Avenue
New York, NY 10016-5990
Phone: (800) 843-2763
www.asme.org

AMERICAN SOCIETY OF SAFETY ENGINEERS

1800 E. Oakton
Des Plaines, IL 60018-2187
Phone: (847) 699-2929
Fax: (847) 768-3434
www.asse.org

This is the oldest and largest organization servicing safety engineers. It has more than 32,000 members and 139 local chapters. The society provides safety education seminars, technical publications, and a monthly magazine among other services.

AMERICAN CHEMISTRY COUNCIL (FORMERLY THE CMA)

1300 Wilson Boulevard
Arlington, VA 22209
Phone: (703) 741-5000
Fax: (703) 741-6050

CMA is one of the oldest trade associations in North America. The CMA is also the focal point for the chemical industry's collective action on legislative, regulatory, and legal matters at the international, national, state and local levels.

CHLORINE INSTITUTE, INC

1300 Wilson Boulevard, Suite 525
Arlington, VA 22209
Phone: (703) 894-4140
Fax: (703) 894-4130
www.chlorineinstitute.org

This organization supports the chloralkaline industry and serves as a public service for safety and health.

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

1010 N Glebe Rd. Suite 450
Arlington, VA 22201
Phone: (703) 525-0511
Fax: (703) 525-0743
www.acmanet.org

American Composites Manufacturers Association provides educational services including seminars, video training tapes, publications, a monthly technical magazine, and an annual convention. It offers free technical, government, and regulatory service to its members.

PERSONAL CARE PRODUCTS COUNCIL (FORMERLY THE CTFA)

1101 17th Street NW, Suite 300
Washington, DC 20036-4702
Phone: (202) 331-1770
Fax: (202) 331-1969
www.personalcarecouncil.org

The Personal Care Products Council is the leading trade association for the personal care product industry, representing the majority of U.S. personal care product sales. The industry trade association was founded in 1894.

AMERICAN COATINGS ASSOCIATION

1500 Rhode Island Ave NW
Washington, DC 20005
Phone: (202) 462-6272
Fax: (202) 462-8549
www.paint.org

This is a trade association for the paint industry.

HAZARDOUS MATERIALS ADVISORY COUNCIL

1100 H Street NW Suite 740
Washington, DC 20005
Phone: (202) 289-4550
Fax: (202) 289-4074
www.hmac.org

Incorporated in 1978, the Hazardous Materials Advisory Council (HMAC) is an international, nonprofit organization devoted to promoting regulatory compliance and safety in the transportation of hazardous materials, substances, and wastes.

ISA

67 Alexander Drive, P.O. Box 12277
Research Triangle Park, NC 27709
Phone: (919) 549-8411
Fax: (919) 549-8288

ISA develops standards for the instrumentation and control field.

METAL FINISHING SUPPLIERS' ASSOCIATION

801 N Cass Avenue, Suite 300
Westmont, IL 60559
Phone: (708) 887-0797
Fax: (708) 887-0799

MFSA is an organization representing 175 member companies who are suppliers of equipment, chemicals, and services to the metal finishing industry.

NACE INTERNATIONAL

National Association of Corrosion Engineers
1440 South Creek Drive
Houston, TX 77084-4906
Phone: (281) 228-6200
Fax: (281) 228-6300
www.nace.org

This organization provides a number of services to its members: the selling of books, publications, magazines, classes, seminars and symposiums are among some of those services.

NATIONAL ASSOCIATION OF CHEMICAL RECYCLERS

1900 M Street NW, Suite 750
Washington, DC 20036
Phone: (202) 296-1725
Fax: (202) 296-2530

NATIONAL ASSOCIATION OF PRINTING INK MANUFACTURERS, INC. (NAPIM)

581 Main Street
Woodbridge, NJ 07095
Phone: (732) 855-1525
Fax: (732) 855-1838
www.napim.org

INDUSTRY STANDARDS

Chemical Industry Trade Associations

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

1 Batterymarch Park
Quincy, MA 02269-9101
Phone: (617) 770-3000
Fax: (617) 770-0700
www.nfpa.org

Fire protection standards and manuals. Services and interpretation of standards are available to members only.

PHARMACEUTICAL RESEARCH AND MANUFACTURERS OF AMERICA

950 F Street NW, Suite 300
Washington, DC 20004
Phone: (202) 845-3400
Fax: (202) 835-3414
www.phrma.org

The Pharmaceutical Research and Manufacturers of America (PhRMA) represents the country's largest research-based pharmaceutical and biotechnology companies. Investing nearly $16 billion a year in discovering and developing new medicines. PhRMA companies are the source of nearly all new drug discoveries worldwide.

PROCESS EQUIPMENT MANUFACTURERS' ASSOCIATION

201 Park Washington Court
Falls Church, VA 22046
Phone: (703) 538-1796
Fax: (703) 241-5603
www.pemanet.org

The Process Equipment Manufacturers' Association is an organization of firms and corporations engaged in the manufacture of process equipment such as agitators, mixers, crushing, grinding and screening equipment, vacuum and pressure filters, centrifuges, furnaces, kilns, dryers, sedimentation and classification devices, and waste treatment equipment.

PINE CHEMICALS ASSOCIATION, INC

3350 Riverwood Parkway SE, Suite 1900
Atlanta, GA 30339
Phone: (770) 984-5340
Fax: (404) 890-5665

The Pulp Chemicals Association, Inc., is an international trade association serving the common goals of its membership. Any person, firm or corporation who manufactures chemical products derived from the pulp and forest products industries is eligible for membership.

RUBBER MANUFACTURERS ASSOCIATION

1400 K Street NW, Suite 900
Washington, DC 20005
Phone: (202) 682-4800
Fax: (202) 682-4854
www.rma.org

The Rubber Manufacturers Association is a trade association representing the rubber and tire industry in North America.

SOAP AND DETERGENT ASSOCIATION

1500 K Street, NW
Washington, DC 20005
Phone: (202) 347-2900
Fax: (202) 347-4110
www.cleaning101.com

This is a national, nonprofit trade association that represents the manufacturers of soaps and detergents.

SOCIETY FOR THE ADVANCEMENT OF MATERIAL AND PROCESS ENGINEERING (SAMPE)

1161 Park View Drive, Suite 200
Covina, CA 91724-3759
Phone: (626) 331-0616
Fax: (626) 332-8929
www.sampe.org

SAMPE is a global, member-governed, volunteer, not-for-profit organization, which supplies information on advanced state-of-the art materials and process opportunities for career development within the materials and process industries.

SOCIETY OF PLASTICS ENGINEERS

13 Church Hill Rd
Newton, CT 06470
Phone: (203) 775-0471
Fax: (203) 775-8490
www.4spe.org

This society deals with education, holds seminars and conferences, and produces magazines and journals. Membership of 37,500 worldwide individuals in all areas of the plastics industry, in 70 countries.

THE SOCIETY OF THE PLASTICS INDUSTRY INC.

1667 K Street NW, Suite 1000
Washington, DC 20006
Phone: (202) 974-5200
Fax: (202) 296-7005
www.plasticsindustry.org

VALVE MANUFACTURERS ASSOCIATION OF AMERICA (VMA)

1050 17th Street NW, Suite 280
Washington, DC 20036
Phone: (202) 331-8105
Fax: (202) 296-0378
www.vma.org

WATER ENVIRONMENT FEDERATION

601 Wythe Street
Alexandria, VA 22314-1994
Phone: (800) 666-0206
Fax: (703) 684-2492
www.wef.org

INDUSTRY STANDARDS

HAZARDOUS MATERIAL SIGNALS

Hazardous Material Signals based on the National Fire Protection Association Code number 704M and Federal Standard 313. This system provides for identification of hazards to employees and to outside emergency personnel.

The numerical and symboled system shown here are the standards used for the purpose of safeguarding the lives of those who are concerned with fires occurring in an industrial plant or storage location where the fire hazards of material may not be readily apparent.

IDENTIFICATION OF HEALTH HAZARD COLOR CODE: BLUE		IDENTIFICATION OF FLAMMABILITY COLOR CODE: RED		IDENTIFICATION OF REACTIVITY COLOR CODE: YELLOW	
SIGNAL	TYPE OF POSSIBLE INJURY	SIGNAL	SUSCEPTIBILITY OF MATERIAL TO BURNING	SIGNAL	SUSCEPTIBILITY OF RELEASE OF ENERGY
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given.	**4**	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.	**4**	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3	Materials which on short exposure could cause serious, temporary or residual injury even though prompt medical treatment were given	**3**	Liquids and solids that can be ignited under almost all ambient temperature conditions.	**3**	Materials which in themselves are capable of detonation or of explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water
2	Material which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given.	**2**	Materials that must be moderately heated or exposed to relatively high ambient temperatures befor ignition can occur.	**2**	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which on exposure would cause irritation but only minor residual injury, even if no treatment is given.	**1**	Materials that must be preheated before ignition can occur.	**1**	Materials which, in themselves, are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.
0	Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material	**0**	Materials that will not burn.	**0**	Materials, which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

INDUSTRY STANDARDS

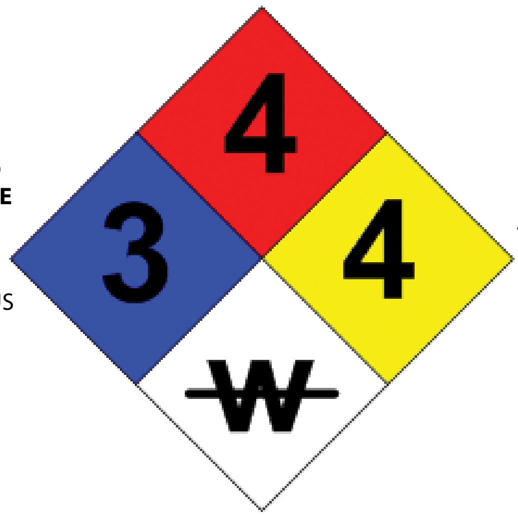
HAZARDOUS MATERIAL SIGNALS

Shown below is the correct spatial arrangement and order of signals used for the identification of materials by hazard.

Figure 1

FIRE HAZARD
COLOR CODE: RED
4 = BELOW 73°F
3 = BELOW 100°F
2 = BELOW 200°F
1 = ABOVE 200°F
0 = WILL NOT BURN

HEALTH HAZARD
COLOR CODE: BLUE
4 = DEADLY
3 = EXTREME DANGER
2 = HAZARDOUS
1 = SLIGHTLY HAZARDOUS
0 = NORMAL MATERIAL



INSTABILITY HAZARD
COLOR CODE: YELLOW
4 = MAY DETONATE
3 = SHOCK AND HEAT MAY DETONATE
2 = VIOLENT CHEMICAL CHANGE
1 = UNSTABLE IF HEATED
0 = STABLE

SPECIFIC HAZARD
COLOR CODE: WHITE

OXY	= OXIDIZER
ACID	= ACID
ALK	= ALKALI
BIO	= BIOLOGICAL
COR	= CORROSIVE
CRY	= CRYOGENIC
POI	= POISONOUS
~~W~~	= USE NO WATER
☢	= RADIATION HAZARD

STORAGE TANK

OSHA Standards

The Occupational Safety and Health Administration (OSHA) Federal Hazard Communication Standard 29 CFR 1910.1200 has become known as the "Right-To-Know" law. This standard gives both employers and employees a right to know about the hazardous chemicals they use in the workplace.

It is designed to reduce the incidence of chemical source injury and illness in the workplace. To accomplish this, employers are required to:

1. Have Material Safety Data Sheets (MSDS) on file for every hazardous chemical in the workplace available to all employees during their work shift.
2. Train employees about the potential hazards, how to identify and safely work with hazardous chemicals, and the proper personal protection necessary when working with hazardous chemicals. Employees must be trained before they start a work assignment
3. Identify and list all of the hazardous chemicals in the workplace.
4. Have a written hazard communication program available for employees, OSHA and outside contractors who enter the workplace.
5. Have labels on all hazardous chemical containers that:

List the name and address of the manufacturer	List the chemical name
List the type of potential hazard that exist	List the precautions necessary
List target organ information	Are easily related to the appropriate MSDS on file

6. Maintain reports, records and logs for the entire program.
7. Report this information (if required by your state) to the state agency, department of labor, health department or fire department depending on the state law that is in effect.

Hard work is necessary to come into compliance with the law. Brady offers a wide variety of products to keep your work to a minimum, while enabling you to implement a complete program that will bring your company into compliance with the Hazard Communication Standard.

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

In the engineering of thermoplastic piping systems to comply with the Uniform Building Code, Uniform Fire Code, Uniform Mechanical Code, and Uniform Plumbing Code, it is necessary to have not only a working knowledge of piping design, but also an awareness of the unique properties of thermoplastics. The selection of the proper piping material is based upon **S T A M P:**

1. **S**ize
2. **T**emperature
3. **A**pplication
4. **M**edia
5. **P**ressure

Size of piping is determined by carrying capacity of the piping selected. Carrying capacity and friction loss are discussed on pages 28-35.

Temperature refers to the temperature of the liquid being piped and is the most critical factor in selecting plastic piping. Refer to the Continuous Resistance To Heat column in the Relative Properties tables on pages 4-5 to select an appropriate plastic material. Temperature of media must not exceed continuous resistance to heat. Temperature also refers to the maximum and minimum media or climactic conditions which the piping will experience. These maximum and minimum temperatures directly affect chemical resistance, expansion and contraction, support spacing, pressure rating, and most other physical properties of the piping material. These different considerations are discussed separately later.

Application asks what the pipe is being designed to do. Above or below ground, in a building or outside, drainage or pumped, in a floor trench or in a ceiling, high purity, short-/or long-term application, FDA requirement, flame and smoke spread required, and double containment required are all questions which should be answered.

Media is the liquid being contained and its concentration. Specific gravity, percent of suspended solids, and crystallization should be determined. Consult with the chemical resistance chart to make a selection based on liquid, concentration, and temperature.

Pressure is the pressure within the piping. Pressure is directly affected by temperature, wall thickness, diameter, and method of joining being employed. Refer to the Temperature-Pressure charts on pages 28-35 to conform the desired installation. Pressure inside the pipe may be less than the surrounding soil or atmospheres such as in vacuum or deep burial applications, and collapse pressure of piping must be determined from the tables on page 26. If more than one material meets the **STAMP** criteria, cost of material, personal preferences, and additional safety considerations are used to determine the right material for the service.

After piping, fitting, valve, and gasket materials are chosen for the service being considered, engineering the piping system begins with calculations for:

1. Pressure Ratings
2. Water Hammer
3. Temperature-Pressure Relationships
4. Flow Rate and Friction Loss Characteristics
5. Dimensional and Weight Data

It must be noted that storage, handling, and use of gaseous, liquid, and solid hazardous production material (HPM), as defined and discussed in the Uniform Building Code and Uniform Fire Code, requires very careful consideration and compliance to provide piping systems that comply with the law and are safe to man and the environment.

PRESSURE RATINGS OF THERMOPLASTICS
DETERMINING PRESSURE-STRESS-PIPE RELATIONSHIPS

ISO EQUATION

Circumferential stress is the largest stress present in any pressurized piping system. It is this factor that determines the pressure that a section of pipe can withstand. The relationship of stress, pressure, and pipe dimensions is described by the ISO (International Standardization Organization) equation. In various forms this equation is:

$$P = \frac{2S}{R-1}$$

$$\frac{2S}{P} = R-1$$

$$S = \frac{P(R-1)}{2} \quad \text{or } S = \frac{P(D_o/t-1)}{2}$$

Where:
P = Internal Pressure, psi
S = Circumferential Stress, psi
t = Wall Thickness, in.
D_0 = Outside Pipe Diameter, in.
R = D_0/t

Table 4 PIPE O.D. CONVERSION CHART

U.S. (ANSI) Standards		ISO Standards	
NOMINAL PIPE SIZE (INCHES)	ACTUAL O.D. (INCHES)	NOMINAL MILLIMETERS	ACTUAL O.D. (INCHES)
⅛	0.405	10	0.394
¼	0.540	12	0.472
⅜	0.675	16	0.630
½	0.840	20	0.787
¾	1.050	25	0.984
1	1.315	32	1.260
1¼	1.660	40	1.575
1½	1.900	50	1.969
2	2.375	63	2.480
2½	2.875	75	2.953
3	3.500	90	3.543
4	4.500	110	4.331
5	5.563	140	5.512
6	6.625	160	6.299
8	8.625	225	8.858
10	10.750	280	11.024
12	12.750	315	12.402
14	13.000	355	13.980
16	16.000	400	15.750

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

LONG-TERM STRENGTH

To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends and subjected to various internal pressure to produce circumferential stresses that will produce failure from 10 to 10,000 hours. The test is run according to ASTM D-1598 - *Standard Test for Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure*.

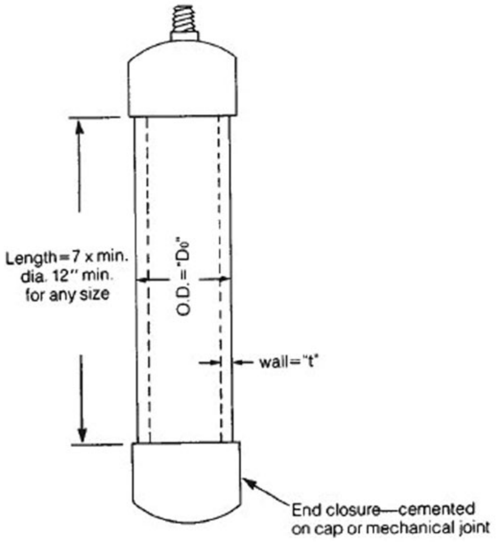


Figure 2

The resulting failure points are used in a statistical analysis (outlined in ASTM D-2837, see page 9) to determine the characteristics of the regression curve that represents the stress/time-to-failure relationship for the particular thermoplastic pipe compound under test.

The regression curve may be plotted on a log-log paper, a shown below, and extrapolated from 10,000 to 100,000 hours (11.4 years). The stress at 100,000 hours is known as the Long-Term Hydrostatic Strength (LTHS) for that particular thermoplastic compound. From this (LTHS) the Hydrostatic Design Stress (HDS) is determined by applying the service factor multiplier, as described below:

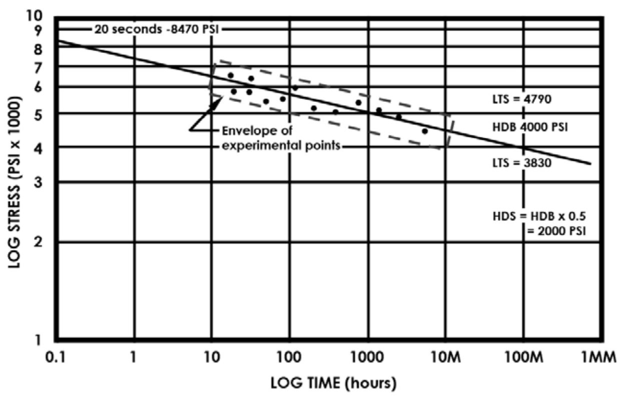


Figure 3

This curve is represented by the equation:

Log = 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.

SERVICE FACTOR

The Hydrostatic Stress Committee of the Plastics Pipe Institute (PPI) has determined that a service (design) factor of one-half the hydrostatic design basis would provide an adequate safety margin for use with water to ensure useful plastic-pipe service for a long period of time. While not stated in the standards, it is generally understood within the industry that this "long period of time" is a minimum of 50 years.

The standards for plastic pipe, using the 0.5 service factor, require that the pressure rating of the pipe be based upon this hydrostatic design stress, again calculated with the ISO equation.

While early experience indicated that this service factor, or multiplier, of 0.5 provided adequate safety for many if not most uses, some experts felt that a more conservative service factor of 0.4 would better compensate for water hammer pressure surges, as well as for slight manufacturing variations and damage suffered during installation.

The PPI has issued a policy statement officially recommending this 0.4 service factor. This is equivalent to recommending that the pressure rating of the pipe should equal 1.25 times the system design pressure for any particular installation. Based upon this policy, many thousands of miles of thermoplastic pipe have been installed in the United States without failure.

It is best to consider the actual surge conditions, as outlined later in this section. In addition, substantial reductions in working pressure are advisable when handling aggressive chemical solutions and in high-temperature service.

Numerical relationships for service factors and design stresses of PVC are shown below:

SERVICE FACTORS AND HYDROSTATIC DESIGN STRESS (HDS)
(Hydrostatic design basis equals 4000 psi)

SERVICE FACTOR	HDS
0.5	2000 psi (13.8 MPa)
0.4	1600 psi (11MPa)

Material: PVC Type I & CPVC

Harrington offers a complete line of pressure instrumentation. Please see our complete catalog for details.

HARRINGTON

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

TEMPERATURE-PRESSURE AND MODULUS RELATIONSHIPS

Temperature Derating

Pressure ratings for thermoplastic pipe are generally determined in a water medium at room temperature (73°F). As the system temperature increases, the thermoplastic pipe becomes more ductile, increases in impact strength, and decreases in tensile strength. The pressure ratings of thermoplastic pipe must therefore be decreased accordingly.

The effects of temperature have been exhaustively studied and correction (derating) factors developed for each thermoplastic piping compound. To determine the maximum operating pressure at any given temperature, multiply the pressure rating at ambient shown below by the temperature correction factor for that material shown on the next page. Attention must also be given to the pressure rating of the joining technique, i.e., threaded system normally reduces pressure capabilities substantially. These correction factors are applicable to pipe and fittings only, correction factors for valves vary with manufacturers and designs.

Table 5 MAXIMUM OPERATING PRESSURES (PSI) AT 73°F BASED UPON A SERVICE FACTOR OF 0.5

NOMINAL SIZE (IN.)	PVC & CPVC			CLEAR PVC		POLYPROPYLENE (PP)			POLYVINYLIDENE FLUORIDE (PVDF)				ECTFE
	Sch 40	Sch 80		Sch 40	Sch 80	Sch 80	Copolymer[1]		Sch 80		PURAD™		HALAR®
	Solvent Weld	Solvent Weld	Threaded	Solvent Weld	Solvent Weld	Fusion	SDR 11	SDR 32	Fusion	Threaded	SDR 21	SDR 33	Fusion
⅛	810	1230	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
¼	780	1130	—	390	570	N/A							
⅜	620	920	—	310	460	N/A							
½	600	850	420	300	420	410		150	975	290	230		230
¾	480	690	340	240	340	330		150	790	235	230		200
1	450	630	320	220	320	310		150	725	215	230		200
1¼	370	520	260	180	260	260		150	600	180	230		150
1½	330	470	240	170	240	230		150	540	160	230		150
2	280	400	200	140	200	200		150	465	135	230		120
2½	300	420	210**	150	210	N/A	N/A	N/A	N/A	N/A	230		120
3	260	370	190**	130	190	190		150	430		230	150	120
3½	240	350	—	120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	220	320	160**	110	160	160	45	150	370	N/A	230	150	N/A
5	190	290		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	180	280		90	140	140	45	150			230	150	
8	160	250		80			45	150			230	150	
10	140	230		70			45	150			230	150	
12	130	230		70			45	150				150	
14	130	220					45	150					
16	130	220					45	150					
18	130	220					45	150					
20	120	220					45	150					
24	120	210					45						

— = Data not available at printing; N/R = Not Recommended; N/A = Not Available (not manufactured)

*Threaded polypropylene is not recommended for pressure applications.

**For threaded joints properly backwelded.

[1]Copolymer polypropylene is a copolymer of propylene and polybutylene.

NOTE: The pressure ratings in this chart are based on water and are for pipe only.
Systems that include valves, flanges, or other weaker items will require derating the entire piping system.

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

Table 6 TEMPERATURE CORRECTION FACTORS

OPERATING TEMPERATURES °F	FACTORS						
	PVC	CPVC	POLYPROPYLENE		POLYVINYLIDENE FLUORIDE		HALAR
			NATURAL	COPOLYMER [1]	SCHEDULE 80	PURAD™	
73	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.88	0.96	0.93	—	0.93	0.95	0.90
90	0.75	0.91	0.83	—	0.87	0.87	—
100	0.62	0.82	0.74	0.64	0.82	0.80	0.82
110	0.50	0.74	0.66	—	0.76	—	—
120	0.40	0.65	0.58	—	0.71	0.68	0.73
130	0.30	0.58	0.51	—	0.65	—	—
140	0.22	0.50	0.40	0.40	0.61	0.58	0.65
150	N/R	0.45	0.38	—	0.57	—	—
160	N/R	0.40	0.35	—	0.54	0.49	0.54
180	N/R	0.25	0.23	0.28	0.47	0.42	0.39
200	N/R	0.20	0.14	0.10	0.41	0.36	—
210	N/R	*	0.10	N/R	0.38	—	0.20
220	N/R	N/R	N/R	N/R	0.35	—	—
240	N/R	N/R	N/R	N/R	—	0.25	—
250	N/R	N/R	N/R	N/R	0.28	—	0.10
280	N/R	N/R	N/R	N/R	0.22	0.18	*

*Recommended for intermittent drainage applications only. — Data unavailable at time of printing. N/R Not Recommended
[1]Copolymer Polypropylene is a copolymer of propylene and polybutylene.

Design Pressure = Pressure rating at 73°F x temperature correction factor shown above.

Warning: threading of Schedule 40 pipe is not a recommended practice due to insufficient wall thickness. Thread only Schedule 80 or heavier wall piping. Threading requires a 50% reduction in pressure ratings stated for plain end pipe at 73°F.

Note pressure ratings for fittings vary with manufacturer and pipe sizes; not all manufacturers produce fittings with the same pressure rating as the equivalent size pipe.

Maximum pressure for any flanged system is 150 psi. At elevated temperatures the pressure capability of a flanged system must be de rated as shown.

Table 7 MAXIMUM OPERATING PRESSURE (PSI) FOR FLANGED SYSTEMS

OPERATION TEMP °F	PVC*	CPVC*	PP**	PVDF
100	150	150	150	150
100	135	145	140	150
120	110	135	130	150
130	75	125	118	150
140	50	110	105	150
150	N/R	100	93	140
160	N/R	90	80	133
170	N/R	80	70	125
180	N/R	70	50	115
190	N/R	60	N/R	106
200	N/R	50	N/R	97
210	N/R	40	N/R	90
240	N/R	N/R	N/R	60
280	N/R	N/R	N/R	25

N/R = Not Recommended

*PVC and CPVC flanges sizes 2 ½ through 3 and 4 inch. Threaded must be backwelded for the above pressure capability to be applicable.

**Threaded PP flanges size ½ through 4 inch as well as the 6" backwelded socket flange are not recommended for pressure applications (drainage only).

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

EXTERNAL PRESSURES - COLLAPSE RATING

Thermoplastic pipe is frequently specified for situations where uniform external pressures are applied to the pipe, such as in underwater applications. In these applications, the collapse rating of the pipe determines the maximum permissible pressure differential between external and internal pressures. The basic formulas for collapsing external pressure applied uniformly to a long pipe are:

1. For thick wall pipe where collapse is caused by compression and failure of the pipe material:

$$Pc = \frac{o}{2Do^2} \left(Do^2 - Di^2\right)$$

2. For thin wall pipe where collapse is caused by elastic instability of the pipe wall:

$$Pc = \frac{2cE}{1-v^2} \left(\frac{t}{Dm}\right)^3$$

Where:

Pc = Collapse Pressure (external minus internal pressure), psi
o = Compressive Strength, psi
E = Modulus of elasticity, psi
v = Poisson's Ratio
Do = Outside Pipe Diameter, in.
Dm = Mean Pipe Diameter, in.
Di = Inside Pipe Diameter, in.
t = Wall Thickness, in.
c = Out-of-Roundness Factor, Approximately 0.66

Choice of Formula - By using formula 2 on thick-wall pipe, an excessively large pressure will be obtained. It is therefore necessary to calculate, for a given pipe size, the collapse pressure using both formulas and use the lower value as a guide to safe working pressure. For short-term loading conditions, the values of E, *o* and v from the relative properties charts shown on pages 4-5 will yield reasonable results. See individual materials charts for short-term collapse pressures at 73°F. For long-term loading conditions, appropriate long-term data should be used.

SHORT-TERM COLLAPSE PRESSURE

Thermoplastic pipe is often used for suction lines or in applications where external pressures are applied to the pipe, such as in heat exchangers, or underwater loading conditions. The differential pressure rating of the pipe between the internal and external pressures is determined by derating collapse pressures of the pipe. The differential pressure rating of the pipe is determined by derating the short-term collapse pressures shown below.

Collapse pressures must be adjusted for temperatures other than 73°F, shown in the table below. The pressure temperature correction factors on page 25 may be used to adjust pipe pressure ratings for this purpose.

Table 8

SHORT-TERM COLLAPSE PRESSURE IN PSI AT 73°F											
½	¾	1	1¼	1½	2	3	4	6	8	10	12
SCHEDULE 40 PVC											
2095	1108	900	494	356	211	180	109	54	39	27	22
SCHEDULE 80 PVC											
2772	2403	2258	1389	927	632	521	335	215	147	126	117
SCHEDULE 80 CPVC - IPS											
2772	2403	2258	1389	927	632	521	335	215	147	126	117
SCHEDULE 80 PRESSURE POLYPROPYLENE - IPS											
1011	876	823	612	412	278	229	147	94	65	55	51
SCHEDULE 80 PVDF - IPS											
2936	1576	1205	680	464	309	255	164	105	72	61	57
PROLINE PRO 150											
40	40	40	40	40	40	40	40	40	40	40	40
PROLINE PRO 45											
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
PURAD™											
202	99	92	44	41	22	5.8	5.8	5.8	5.8	5.8	5.8

NOTE: These are short-term ratings; long-term ratings should be reduced by ⅓ to ½ of the short-term ratings.

Vacuum Service - All sizes of Schedule 80 thermoplastic pipe are suitable for vacuum service up to 140°F and 30 inches of mercury. Solvent-cemented joints are recommended for vacuum applications when using PVC. Schedule 40 PVC will handle full vacuum up to 24" diameter.

Laboratory tests have been conducted on Schedule 80 PVC pipe to determine performance under vacuum at temperatures above recommended operating conditions. Pipe sizes under 6 inches show no deformation at temperatures to 170°F and 27 inches of mercury vacuum. The 6 inch pipe showed slight deformation at 165°F, and 20 inches of mercury. Above this temperature, failure occurred due to thread deformation.

SYSTEM ENGINEERING DATA FOR THERMOPLASTIC PIPING

FRICTION LOSS CHARACTERISTICS OF WATER THROUGH PLASTIC PIPE, FITTINGS AND VALVES

INTRODUCTION

A major advantage of thermoplastic pipe is its exceptionally smooth inside surface area, which reduces friction loss compared to other materials.

Friction loss in plastic pipe remains constant over extended periods of time, in contrast to some other materials where the value of the Hazen and Williams C factor (constant for inside roughness) decreases with time. As a result, the flow capacity of thermoplastics is greater under fully turbulent flow conditions like those encountered in water service.

C FACTORS

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

The most significant losses occur as a result of the length of pipe and fittings and depend on the following factors.

1. Flow velocity of the fluid.
2. The type of fluid being transmitted, especially its viscosity.
3. Diameter of the pipe.
4. Surface roughness of interior of the pipe.
5. The length of the pipeline.

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:

$$f = 0.2083\left(\frac{100}{C}\right)^{1.852} \times \frac{q^{1.852}}{Di^{4.8655}}$$

$$= 0.0983\frac{q^{1.852}}{Di^{4.8655}} \quad \text{for } C = 150$$

$$P = 0.4335f$$

Where:

f = Friction Head in ft. of Water per 100 ft. of Pipe
P = Pressure Loss in psi per 100 ft. of Pipe
Di = Inside Diameter of Pipe, in.
q = Flow Rate in U.S. gal/min.
C = Constant for Inside Roughness (C equals 150 thermoplastics)

WATER VELOCITIES

Velocities for water in feet per second at different GPM and pipe inside diameters can be calculated as follows:

$$V = 0.3208\frac{G}{A}$$

Where:

V = velocity in feet per second
G = gallons per minute
A = inside cross-sectional area in square inches

VELOCITY

Thermoplastic pipe is not subject to erosion caused by high velocities and turbulent flow, and in this respect is superior to metal piping systems, particularly where corrosive or chemically aggressive fluids are involved. The Plastics Pipe Institute has issued the following policy statement on water velocity:

The maximum safe water velocity in a thermoplastic piping system depends on the specific details of the system and the operating conditions. In general, ***5 feet per second is considered to be safe.*** *Higher velocities may be used in cases where the operating characteristics of valves and pumps are known so that sudden changes in flow velocity can be controlled. The total pressure in the system at any time (operating plus surge or water hammer) should not exceed 150 percent of the pressure rating of the system.*

Harrington Industrial Plastics does not recommend flow velocities in excess of five feet per second for any plastic piping system.

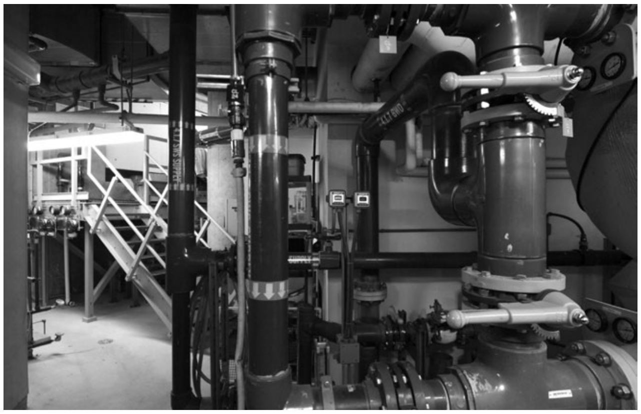
PIPE SIZING

Carrying Capacity & Friction Loss Tables are provided on pages 28 through 35 to assist the user in selecting the proper pipe size to carry a known volume of water or similar fluids. First select the Schedule or SDR of the desired piping system. Then simply read down the left-hand column to find the desired volume and then read right to a velocity column showing approximately 5 feet per second. Next follow the column vertically until the pipe size is found. Page 36 provides a table showing the equivalent lengths of straight pipe for the most common fittings. To complete system friction loss calculations, don't forget to include the pressure drop through valves and strainers as shown on page 38. Because most pressure applications require a pump of some type, friction losses are presented in both psi and feet of head (per 100 feet of pipe). These pressures are mutually convertible, one to the other, as follows:

$$\frac{psi \times 2.31}{S.G.} = \text{Head in Feet}$$

Where:

psi = pound per square inch
S.G. = specific gravity



Pipe Carrying Capacity Charts

Table 9 CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 40 THERMOPLASTIC PIPE

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"																							
1	0.002	1.13	1.16	0.50	¾"																				
2	0.004	2.26	4.19	1.81	1.26	1.03	0.44	1"			1 ¼"														
5	0.011	5.64	22.88	9.90	3.16	5.60	2.42	1.93	1.69	0.73	1.10	0.43	0.19	1 ½"											
7	0.016	7.89	42.66	18.47	4.43	10.44	4.52	2.70	3.14	1.36	1.55	0.81	0.35	1.13	0.38	0.16	2"								
10	0.022				6.32	20.21	8.75	3.86	6.08	2.63	2.21	1.57	0.68	1.62	0.73	0.32	0.98	0.21	0.09	2 ½"					
12	0.027				7.59	28.33	12.26	4.63	8.53	3.69	2.65	2.20	0.95	1.94	1.03	0.44	1.46	0.45	0.20	1.03	0.19	0.08	3"		
15	0.033				9.48	42.82	18.54	5.79	12.89	5.58	3.31	3.32	1.44	2.42	1.55	0.67	1.95	0.77	0.33	1.37	0.33	0.14	1.10	0.17	0.07
20	0.045							7.72	21.96	9.51	4.42	5.65	2.45	3.23	2.64	1.14	2.44	1.17	0.51	1.71	0.49	0.21	1.32	0.24	0.10
25	0.056							9.65	33.20	14.37	5.52	8.55	3.70	4.04	4.00	1.73	2.93	1.64	0.71	2.05	0.69	0.30	1.55	0.32	0.14
30	0.067							11.58	46.54	20.15	6.63	11.98	5.19	4.85	5.60	2.42	3.41	2.18	0.94	2.39	0.92	0.40	1.77	0.41	0.18
35	0.078										7.73	15.94	6.90	5.66	7.45	3.23	3.90	2.79	1.21	2.73	1.18	0.51	1.99	0.51	0.22
40	0.089	4"									8.84	20.41	8.84	6.47	9.54	4.13	4.39	3.47	1.50	3.08	1.46	0.63	2.21	0.61	0.27
45	0.100	1.15	0.13	0.06							9.94	25.39	10.99	7.27	11.87	5.14	4.88	4.22	1.83	3.42	1.78	0.77	2.43	0.73	0.32
50	0.111	1.28	0.16	0.07							11.05	30.86	13.36	8.08	14.43	6.25	5.36	5.03	2.18	3.76	2.12	0.92	2.65	0.86	0.37
55	0.123	1.41	0.19	0.08										8.89	17.21	7.45	5.85	5.92	2.56	4.10	2.49	1.08	2.87	1.00	0.43
60	0.134	1.53	0.23	0.10										9.70	20.22	8.75	6.34	6.86	2.97	4.44	2.89	1.25	3.09	1.15	0.50
65	0.145	1.66	0.26	0.11	5"									10.51	23.45	10.15	6.83	7.87	3.41	4.79	3.32	1.44	3.31	1.30	0.56
70	0.156	1.79	0.30	0.13	1.14	0.10	0.04							11.32	26.90	11.65	7.32	8.94	3.87	5.13	3.77	1.63	3.53	1.47	0.63
75	0.167	1.92	0.34	0.15	1.22	0.11	0.05										7.80	10.08	4.36	5.47	4.25	1.84	3.75	1.64	0.71
80	0.178	2.05	0.39	0.17	1.30	0.13	0.06										8.29	11.27	4.88	5.81	4.75	2.06	3.97	1.82	0.79
90	0.201	2.30	0.48	0.21	1.46	0.16	0.07	6"									8.78	12.53	5.43	6.15	5.28	2.29	4.20	2.02	0.87
100	0.223	2.56	0.59	0.25	1.62	0.19	0.08	1.12	0.08	0.03							9.27	13.85	6.00	6.49	5.84	2.53	4.42	2.22	0.96
125	0.279	3.20	0.89	0.38	2.03	0.29	0.13	1.40	0.12	0.05							9.75	15.23	6.59	6.84	6.42	2.78	5.52	3.35	1.45
150	0.334	3.84	1.24	0.54	2.44	0.41	0.18	1.69	0.17	0.07										8.55	9.70	4.20	6.62	4.70	2.03
175	0.390	4.47	1.65	0.72	2.84	0.55	0.24	1.97	0.22	0.10	8"									10.26	13.60	5.89	7.73	6.25	2.71
200	0.446	5.11	2.12	0.92	3.25	0.70	0.30	2.25	0.29	0.12	1.30	0.08	0.03										8.83	8.00	3.46
250	0.557	6.36	3.20	1.39	4.06	1.06	0.46	2.81	0.43	0.19	1.62	0.11	0.05										11.04	12.10	5.24
300	0.668	7.67	4.49	1.94	4.87	1.49	0.64	3.37	0.61	0.26	1.94	0.16	0.07	10"											
350	0.780	8.95	5.97	2.58	5.69	1.98	0.86	3.93	0.81	0.35	2.27	0.21	0.09	1.44	0.07	0.03									
400	0.891	10.23	7.64	3.31	6.50	2.54	1.10	4.49	1.03	0.45	2.59	0.27	0.12	1.64	0.09	0.04									
450	1.003				7.31	3.15	1.36	5.06	1.29	0.56	2.92	0.34	0.15	1.85	0.11	0.05	12"								
500	1.114				8.12	3.83	1.66	5.62	1.56	0.68	3.24	0.41	0.18	20.5	0.14	0.06	1.30	0.05	0.02						
600	1.337				9.75	5.37	2.33	6.74	2.19	0.95	3.89	0.57	0.25	2.46	0.19	0.08	1.45	0.06	0.02						
700	1.560				11.37	7.15	3.09	7.87	2.92	1.26	4.54	0.76	0.33	2.87	0.25	0.11	1.74	0.08	0.03	14"					
800	1.782	18"						8.99	3.73	1.62	5.18	0.98	0.42	3.29	0.32	0.14	2.02	0.11	0.05	1.44	0.05	0.02			
900	2.005	1.30	0.03	0.01				10.11	4.64	2.01	5.83	1.22	0.53	3.70	0.40	0.17	2.31	0.14	0.06	1.67	0.07	0.03			
1000	2.228	1.45	0.04	0.02							6.48	1.48	0.64	4.11	0.49	0.21	2.60	0.17	0.07	1.91	0.09	0.04	16"		
1250	2.785	1.81	0.06	0.03	20"						8.10	2.24	0.97	5.13	0.74	0.32	2.89	0.21	0.09	2.15	0.11	0.05	1.47	0.05	0.02
1500	3.342	2.17	0.08	0.04	1.75	0.05	0.02				9.72	3.14	1.36	6.16	1.03	0.45	3.61	0.31	0.14	2.39	0.13	0.06	1.65	0.06	0.02
2000	4.456	2.89	0.14	0.06	2.33	0.08	0.04	24"						8.21	1.76	0.76	4.34	0.44	0.19	2.99	0.20	0.09	1.83	0.07	0.03
2500	5.570	3.62	0.21	0.09	2.91	0.12	0.05	2.01	0.05	0.02				10.27	2.66	1.15	5.78	0.75	0.32	3.59	0.28	0.12	2.29	0.10	0.04
3000	6.684	4.34	0.29	0.13	3.49	0.17	0.08	2.41	0.07	0.03							7.23	1.13	0.49	4.78	0.47	0.20	2.75	0.15	0.06
3500	7.798	5.06	0.39	0.17	4.07	0.23	0.10	2.81	0.09	0.04							8.68	1.59	0.69	5.98	0.71	0.31	3.66	0.25	0.11
4000	8.912	5.79	0.50	0.22	4.65	0.30	0.13	3.22	0.12	0.05							10.12	2.11	0.92	7.18	1.00	0.43	4.58	0.37	0.16
4500	10.026	6.51	0.62	0.27	5.24	0.37	0.16	3.62	0.15	0.06										8.37	1.33	0.58	5.50	0.52	0.23
5000	11.140	7.23	0.76	0.33	5.82	0.45	0.19	4.02	0.18	0.08										9.57	1.71	0.74	6.41	0.70	0.30
5500	12.254	7.96	0.91	0.39	6.40	0.53	0.23	4.42	0.22	0.09										10.76	2.12	0.92	7.33	0.89	0.39
6000	13.368	8.68	1.06	0.46	6.98	0.63	0.27	4.83	0.25	0.11													8.24	1.11	0.48
6500	14.482	9.40	1.23	0.53	7.56	0.73	0.31	5.23	0.30	0.13													9.16	1.35	0.58
7000	15.596	10.13	1.42	0.61	8.14	0.83	0.36	5.63	0.34	0.15													10.08	1.61	0.70
7500	16.710				8.73	0.95	0.41	6.03	0.39	0.17															
8000	17.824				9.31	1.07	0.46	6.43	0.43	0.19															
8500	18.938				9.89	1.19	0.52	6.84	0.49	0.21															
9000	20.052				10.47	1.33	0.57	7.24	0.54	0.23															
9500	21.166							7.64	0.60	0.26															
10000	22.280							8.04	0.66	0.28															

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

PIPE CARRYING CAPACITY CHARTS

Table 10 CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 80 THERMOPLASTIC PIPE

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"																							
1	0.002	1.48	2.24	0.97	¾"			1"																	
2	0.004	2.95	8.10	3.51	1.57	1.73	0.75	0.93	0.49	0.21	1 ¼"														
5	0.011	7.39	44.21	19.14	3.92	9.47	4.10	2.33	2.67	1.16	1.30	0.64	0.28	1 ½"											
7	0.016	10.34	82.43	35.69	5.49	17.65	7.64	3.27	4.98	2.16	1.82	1.20	0.52	1.31	0.54	0.24									
10	0.022				7.84	34.18	14.79	4.67	9.65	4.18	2.59	2.32	1.00	1.88	1.05	0.46									
12	0.027				9.41	47.90	20.74	5.60	13.52	5.85	3.11	3.25	1.40	2.25	1.47	0.64	2"								
15	0.033				11.76	72.42	31.35	7.00	20.44	8.85	3.89	4.91	2.12	2.81	2.23	0.96	1.68	0.63	0.27	2 ½"					
20	0.045							9.33	34.82	15.07	5.19	8.36	3.62	3.75	3.80	1.64	2.23	1.07	0.47	1.56	0.45	0.19			
25	0.056							11.66	52.64	22.79	6.49	12.64	5.47	4.69	5.74	2.48	2.79	1.63	0.70	1.95	0.68	0.29	3"		
30	0.067										7.78	17.71	7.67	5.63	8.04	3.48	3.35	2.28	0.99	2.34	0.95	0.41	1.49	0.32	0.14
35	0.078										9.08	23.56	10.20	6.57	10.70	4.63	3.91	3.03	1.31	2.73	1.26	0.55	1.74	0.43	0.18
40	0.089										10.38	30.17	13.06	7.50	13.71	5.93	4.47	3.88	1.68	3.12	1.62	0.70	1.99	0.54	0.24
45	0.100	4"												8.44	17.05	7.38	5.03	4.83	2.09	3.51	2.01	0.87	2.24	0.68	0.29
50	0.111	1.43	0.21	0.09										9.38	20.72	8.97	5.58	5.87	2.54	3.90	2.45	1.06	2.49	0.82	0.36
55	0.123	1.57	0.25	0.11										10.32	24.72	10.70	6.14	7.00	3.03	4.29	2.92	1.26	2.74	0.98	0.43
60	0.134	1.71	0.30	0.13										9.70	20.22	8.75	6.70	8.22	3.56	4.68	3.43	1.48	2.99	1.15	0.50
65	0.145	1.85	0.34	0.15										10.51	23.45	10.15	7.26	9.54	4.13	5.07	3.97	1.72	3.24	1.34	0.58
70	0.156	2.00	0.39	0.17										11.32	26.90	11.65	7.82	10.94	4.74	5.46	4.56	1.97	3.49	1.54	0.66
75	0.167	2.14	0.45	0.19	5"												8.38	12.43	5.38	5.85	5.18	2.24	3.74	1.74	0.76
80	0.178	2.28	0.51	0.22	1.44	0.16	0.07										8.93	14.01	6.06	6.23	5.84	2.53	3.99	1.97	0.85
90	0.201	2.57	0.63	0.27	1.62	0.20	0.09										10.05	17.42	7.54	7.01	7.26	3.14	4.48	2.45	1.06
100	0.223	2.85	0.76	0.33	1.80	0.25	0.11	6"									11.17	21.18	9.17	7.79	8.83	3.82	4.98	2.97	1.29
125	0.279	3.56	1.16	0.50	2.25	0.38	0.16	1.57	0.16	0.07										9.74	13.34	5.78	6.23	4.49	1.95
150	0.334	4.28	1.62	0.70	2.70	0.53	0.23	1.88	0.22	0.10										11.69	18.70	8.10	7.47	6.30	2.73
175	0.390	4.99	2.16	0.93	3.15	0.70	0.30	2.19	0.29	0.13													8.72	8.38	3.63
200	0.446	5.70	2.76	1.19	3.60	0.90	0.39	2.51	0.37	0.16	8"												9.97	10.73	4.65
250	0.557	7.13	4.17	1.81	4.49	1.36	0.59	3.13	0.57	0.24	1.43	0.10	0.04												
300	0.668	8.55	5.85	2.53	5.39	1.90	0.82	3.76	0.79	0.34	1.79	0.14	0.06	10"											
350	0.780	9.98	7.78	3.37	6.29	2.53	1.10	4.39	1.05	0.46	2.14	0.20	0.09	1.59	0.09	0.04									
400	0.891	11.41	9.96	4.31	7.19	3.24	1.40	5.02	1.35	0.58	2.50	0.27	0.12	1.81	0.11	0.05	12"								
450	1.003				8.09	4.04	1.75	5.64	1.68	0.73	2.86	0.34	0.15	2.04	0.14	0.06	1.44	0.06	0.03						
500	1.114				8.99	4.90	2.12	6.27	2.04	0.88	3.21	0.43	0.18	2.27	0.17	0.07	1.60	0.07	0.03	14"					
600	1.337				10.79	6.87	2.98	7.52	2.86	1.24	3.57	0.52	0.22	2.72	0.24	0.10	1.92	0.10	0.04	1.59	0.07	0.03			
700	1.560							8.78	3.81	1.65	4.28	0.73	0.31	3.17	0.32	0.14	2.24	0.14	0.06	1.86	0.09	0.04			
800	1.782							10.03	4.88	2.11	5.00	0.97	0.42	3.63	0.41	0.18	2.56	0.18	0.08	2.12	0.11	0.05	16"		
900	2.005	18"									5.71	1.24	0.54	4.08	0.51	0.22	2.88	0.22	0.09	2.39	0.14	0.06	1.62	0.06	0.02
1000	2.228	1.59	0.05	0.02							6.43	1.54	0.67	4.54	0.62	0.27	3.20	0.27	0.12	2.65	0.17	0.07	1.82	0.07	0.03
1250	2.785	1.99	0.07	0.03	20"						7.14	1.87	0.81	5.67	0.94	0.41	4.01	0.40	0.17	3.32	0.25	0.11	2.02	0.09	0.04
1500	3.342	2.39	0.10	0.04	1.93	0.06	0.03				8.93	2.83	1.23	6.80	1.32	0.57	4.81	0.57	0.24	3.98	0.36	0.15	2.53	0.13	0.06
2000	4.456	3.19	0.18	0.08	2.58	0.10	0.05	24"			10.71	3.97	1.72	9.07	2.24	0.97	6.41	0.96	0.42	5.31	0.61	0.26	3.03	0.18	0.08
2500	5.570	3.98	0.27	0.12	3.22	0.16	0.07	2.23	0.06	0.03				11.34	3.39	1.47	8.01	1.46	0.63	6.63	0.92	0.40	4.04	0.31	0.14
3000	6.684	4.78	0.37	0.16	3.86	0.22	0.10	2.67	0.09	0.04							9.61	2.04	0.88	7.96	1.29	0.56	5.05	0.47	0.21
3500	7.798	5.58	0.50	0.21	4.51	0.30	0.13	3.12	0.12	0.05							11.21	2.71	1.17	9.29	1.71	0.74	6.06	0.66	0.29
4000	8.912	6.37	0.64	0.28	5.15	0.38	0.16	3.56	0.15	0.07										10.61	2.20	0.95	7.07	0.88	0.38
4500	10.026	7.17	0.79	0.34	5.80	0.47	0.20	4.01	0.19	0.08										11.94	2.73	1.18	8.08	1.13	0.49
5000	11.140	7.97	0.96	0.42	6.44	0.57	0.25	4.45	0.23	0.10													9.09	1.14	0.61
5500	12.254	8.77	1.15	0.50	7.08	0.68	0.30	4.90	0.28	0.12													10.10	1.71	0.74
6000	13.368	9.56	1.35	0.58	7.73	0.80	0.35	5.35	0.33	0.14															
6500	14.482	10.36	1.56	0.68	8.37	0.93	0.40	5.79	0.38	0.16															
7000	15.596				9.02	1.07	0.46	6.24	0.44	0.19															
7500	16.710				9.66	1.21	0.52	6.68	0.49	0.21															
8000	17.824				10.30	1.37	0.59	7.13	0.56	0.24															
8500	18.938				10.95	1.53	0.66	7.57	0.62	0.27															
9000	20.052							8.02	0.69	0.30															
9500	21.166							8.46	0.77	0.33															
10000	22.280							8.91	0.84	0.36															

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

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Table 11 CARRYING CAPACITY AND FRICTION LOSS FOR 315 PSI AND SDR 13.5 THERMOPLASTIC PIPE

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"			¾"																				
1	0.002	0.85	1.03	0.45	0.54	0.34	0.15	1"			1 ¼"			1 ½"			2"								
2	0.004	1.69	2.05	0.89	1.07	0.68	0.29	0.68	0.40	0.17	0.42	0.13	0.06	0.32	0.065	0.028	0.20	0.03	0.013	2 ½"			3"		
5	0.011	4.22	11.58	5.01	2.68	3.82	1.65	1.69	1.24	0.54	1.05	0.39	0.17	0.80	0.20	0.088	0.51	0.075	0.033	0.35	0.038	0.016	0.24	0.02	0.009
7	0.016	5.91	21.24	9.20	3.75	7.01	3.03	2.36	2.28	0.99	1.47	0.72	0.31	1.12	0.37	0.16	0.72	0.125	0.054	0.49	0.53	0.023	0.33	0.03	0.012
10	0.022	8.44	40.46	17.52	5.35	13.34	5.78	3.37	4.33	1.87	2.10	1.37	0.59	1.60	0.71	0.31	1.02	0.24	0.10	0.70	0.09	0.039	0.47	0.04	0.017
15	0.033	4"			8.03	28.27	12.24	5.06	9.18	3.97	3.15	2.91	1.26	2.40	1.50	0.65	1.53	0.50	0.22	1.04	0.20	0.087	0.70	0.08	0.035
20	0.045	0.57	0.04	0.017	10.70	48.17	20.86	6.74	15.64	6.77	4.21	4.96	2.91	3.20	2.55	1.10	2.04	0.85	0.37	1.39	0.34	0.15	0.94	0.13	0.056
25	0.056	0.71	0.06	0.026	5"			8.43	23.65	10.24	5.26	7.49	3.24	4.00	3.85	1.67	2.55	1.29	0.56	1.74	0.51	0.22	1.17	0.19	0.082
30	0.067	0.85	0.08	0.035	0.56	0.03	0.013	10.11	33.15	14.35	6.31	10.50	4.55	4.80	5.40	2.34	3.05	1.80	0.78	2.09	0.71	0.31	1.41	0.27	0.12
35	0.078	0.99	0.11	0.048	0.65	0.04	0.017				7.36	13.97	6.05	5.60	7.19	3.11	3.57	2.40	1.04	2.44	0.95	0.41	1.64	0.36	0.16
40	0.089	1.14	0.14	0.060	0.74	0.05	0.022				8.41	17.90	7.75	6.40	9.20	3.98	4.08	3.07	1.33	2.78	1.21	0.52	1.88	0.46	0.20
45	0.100	1.28	0.17	0.074	0.84	0.06	0.026	6"			9.46	22.26	9.64	7.20	11.44	4.95	4.59	3.82	1.65	3.13	1.51	0.65	2.11	0.58	0.25
50	0.111	1.42	0.21	0.091	0.93	0.07	0.030	0.66	0.03	0.013	10.52	27.05	11.71	8.00	13.91	6.02	5.10	4.64	2.01	3.48	1.83	0.79	2.35	0.70	0.30
60	0.134	1.70	0.29	0.13	1.12	0.10	0.043	0.79	0.04	0.017				9.60	19.50	8.44	6.12	6.50	2.81	4.18	2.57	1.11	2.82	0.98	0.42
70	0.156	1.99	0.38	0.16	1.30	0.14	0.061	0.92	0.06	0.026							7.14	8.65	3.75	4.87	3.42	1.48	3.29	1.31	0.57
75	0.167	2.13	0.44	0.19	1.40	0.16	0.069	0.98	0.07	0.030							7.65	9.83	4.26	5.22	3.88	1.68	3.52	1.49	0.65
80	0.178	2.27	0.49	0.21	1.49	0.18	0.078	1.05	0.08	0.035							8.16	11.08	4.80	5.57	4.37	1.89	3.76	1.68	0.73
90	0.201	2.56	0.61	0.26	1.67	0.22	0.095	1.18	0.09	0.039							9.18	13.78	5.97	6.27	5.44	2.36	4.23	2.09	0.90
100	0.223	2.84	0.74	0.32	1.86	0.27	0.12	1.31	0.11	0.048							10.20	16.75	7.25	6.96	6.61	2.86	4.70	2.54	1.10
125	0.279	3.55	1.13	0.49	2.33	0.40	0.18	1.64	0.17	0.074										8.70	10.01	4.33	5.88	3.84	1.66
150	0.334	4.26	1.58	0.68	2.79	0.56	0.24	1.97	0.24	0.10										10.44	14.01	6.07	7.04	5.37	2.33
175	0.390	4.97	2.10	0.91	3.26	0.75	0.33	2.30	0.32	0.14													8.22	7.15	3.10
200	0.446	5.68	2.69	1.16	3.72	0.96	0.42	2.62	0.41	0.18													9.39	9.15	3.96
250	0.557	7.10	4.07	1.76	4.66	1.46	0.63	3.28	0.62	0.27													11.74	13.86	6.00
300	0.668	8.52	5.69	2.46	5.58	2.03	0.88	3.93	0.87	0.38															
350	0.780	9.94	7.58	3.29	6.52	2.70	1.17	4.59	1.16	0.50															
400	0.891	11.36	9.70	4.20	7.44	3.46	1.50	5.24	1.48	0.64															
450	1.003				8.37	4.31	1.87	5.90	1.84	0.80															
500	1.114				9.30	5.24	2.27	6.56	2.23	0.97															
750								9.83	4.73	2.05															
1000	2.228							13.11	8.06	3.49															

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

Table 12 CARRYING CAPACITY AND FRICTION LOSS FOR DR 21 THERMOPLASTIC PIPE

GPM	cu ft/sec
1	0.002
2	0.004
5	0.011
7	0.016
10	0.022
12	0.027
15	0.033
20	0.045
25	0.056
30	0.067
35	0.078
40	0.089
45	0.100
50	0.111
55	0.123
60	0.134
65	0.145
70	0.156
75	0.167
80	0.178
90	0.201
100	0.223
125	0.279
150	0.334
175	0.390
200	0.446
250	0.557
300	0.668
350	0.780
400	0.891
450	1.003
500	1.114
600	1.337
700	1.560
800	1.782
900	2.005
1000	2.228
1250	2.785
1500	3.342
2000	4.456
2500	5.570
3000	6.684
3500	7.798
4000	8.912
4500	10.026
5000	11.140
5500	12.254
6000	13.368
6500	14.482
7000	15.596
7500	16.710
8000	17.824
8500	18.938
9000	20.052
9500	21.166
10000	22.280

½"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
1	1.88	2.68	1.16
2	4.69	14.69	6.33
5	6.57	27.27	11.81
7	9.38	52.79	22.85
10	11.26	74.00	32.03

¾"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
1	1.08	0.70	0.30
2	2.70	3.81	1.65
5	3.78	7.11	3.08
7	5.40	13.77	5.96
10	6.48	19.30	8.35
12	8.10	29.17	12.63
15	10.80	49.70	21.51

1"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
5	1.59	1.05	0.45
7	2.22	1.95	0.84
10	3.17	3.78	1.63
12	3.81	5.29	2.29
15	4.76	8.00	3.46
20	6.35	13.63	5.90
25	7.93	20.60	8.92
30	9.52	28.88	12.50
35	11.10	38.42	16.63

1 ¼"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
10	1.87	1.04	0.45
12	2.24	1.45	0.63
15	2.80	2.20	0.95
20	3.73	3.75	1.62
25	4.66	5.66	2.45
30	5.60	7.94	3.44
35	6.53	10.56	4.57
40	7.46	13.53	5.86
45	8.40	16.82	7.28
50	9.33	20.45	8.85
55	10.26	24.40	10.56

1 ½"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
12	1.70	0.74	0.32
15	2.12	1.12	0.49
20	2.83	1.91	0.83
25	3.54	2.89	1.25
30	4.24	4.05	1.75
35	4.95	5.38	2.33
40	5.66	6.89	2.98
45	6.36	8.57	3.71
50	7.07	10.42	4.51
55	7.78	12.43	5.38
60	8.49	14.60	6.32
65	9.19	16.94	7.33
70	9.90	19.43	8.41
75	10.61	22.08	9.56

2"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
20	1.80	0.64	0.28
25	2.25	0.97	0.42
30	2.71	1.35	0.59
35	3.16	1.80	0.78
40	3.61	2.31	1.00
45	4.06	2.87	1.24
50	4.51	3.49	1.51
55	4.96	4.16	1.80
60	5.41	4.89	2.12
65	5.86	5.67	2.45
70	6.31	6.50	2.81
75	6.76	7.39	3.20
80	7.21	8.32	3.60
90	8.12	10.35	4.48
100	9.02	12.58	5.45
125	11.27	19.02	8.24

2 ½"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
25	1.53	0.38	0.16
30	1.84	0.53	0.23
35	2.15	0.71	0.31
40	2.45	0.90	0.39
45	2.76	1.12	0.49
50	3.07	1.37	0.59
55	3.37	1.63	0.71
60	3.68	1.91	0.83
65	3.99	2.22	0.96
70	4.29	2.55	1.10
75	4.60	2.89	1.25
80	4.91	3.26	1.41
90	5.52	4.6	1.76
100	6.14	4.93	2.14
125	7.67	7.46	3.23
150	9.20	10.45	4.52
175	10.74	13.90	6.02

3"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
40	1.65	0.34	0.15
45	1.86	0.43	0.19
50	2.06	0.52	0.23
55	2.27	0.62	0.27
60	2.48	0.73	0.32
65	2.68	0.85	0.37
70	2.89	0.97	0.42
75	3.10	1.10	0.48
80	3.30	1.25	0.54
90	3.72	1.55	0.67
100	4.13	1.88	0.81
125	5.16	2.85	1.23
150	6.19	3.99	1.73
175	7.23	5.31	2.30
200	8.26	6.80	2.94
250	10.32	10.27	4.45

4"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
65	1.62	0.25	0.11
70	1.75	0.29	0.12
75	1.87	0.32	0.14
80	2.00	0.37	0.16
90	2.25	0.46	0.20
100	2.50	0.55	0.24
125	3.12	0.84	0.36
150	3.74	1.17	0.51
175	4.37	1.56	0.68
200	4.99	2.00	0.86
250	6.24	3.02	1.31
300	7.49	4.23	1.83
350	8.74	5.63	2.44
400	9.99	7.21	3.12
450	1.23	8.97	3.88

5"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
100	1.63	0.20	0.09
125	2.04	0.30	0.13
150	2.45	0.42	0.18
175	2.86	0.56	0.24
200	3.27	0.71	0.31
250	4.09	1.08	0.47
300	4.90	1.51	0.65
350	5.72	2.01	0.87
400	6.54	2.57	1.11
450	7.35	3.20	1.38
500	8.17	3.89	1.68
600	9.80	5.45	2.36
700	11.44	7.25	3.14

6"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
150	1.73	0.18	0.08
175	2.02	0.24	0.10
200	2.31	0.30	0.13
250	2.88	0.46	0.20
300	3.46	0.65	0.28
350	4.03	0.86	0.37
400	4.61	1.10	0.48
450	5.19	1.37	0.59
500	5.76	1.66	0.72
600	6.92	2.33	1.01
700	8.07	3.10	1.34
800	9.22	3.97	1.72
900	10.37	4.94	2.14

8"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
250	1.70	0.13	0.06
300	2.04	0.18	0.08
350	2.38	0.24	0.10
400	2.72	0.30	0.13
450	3.06	0.38	0.16
500	3.40	0.46	0.20
600	4.08	0.64	0.28
700	4.76	0.86	0.37
800	5.44	1.10	0.48
900	6.11	1.37	0.59
1000	6.79	1.66	0.72
1250	8.49	2.51	1.09
1500	10.19	3.52	1.52

10"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
350	1.53	0.08	0.04
400	1.75	0.10	0.05
450	1.97	0.13	0.06
500	2.19	0.16	0.07
600	2.62	0.22	0.10
700	3.06	0.29	0.13
800	3.50	0.38	0.16
900	3.94	0.47	0.20
1000	4.37	0.57	0.25
1250	5.47	0.86	0.37
1500	6.56	1.20	0.52
2000	8.75	2.06	0.89
2500	10.93	3.10	1.34

12"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
500	1.55	0.07	0.03
600	1.87	0.10	0.04
700	2.18	0.13	0.06
800	2.49	0.16	0.07
900	2.80	0.20	0.09
1000	3.11	0.25	0.11
1250	3.89	0.37	0.16
1500	4.66	0.53	0.23
2000	6.22	0.89	0.39
2500	7.77	1.35	0.59
3000	9.33	1.90	0.82
3500	10.88	2.52	1.09

14"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
600	1.55	0.06	0.03
700	1.80	0.08	0.04
800	2.06	0.10	0.05
900	2.32	0.13	0.06
1000	2.58	0.16	0.07
1250	3.22	0.24	0.10
1500	3.87	0.33	0.14
2000	5.16	0.57	0.25
2500	6.45	0.86	0.37
3000	7.74	1.20	0.52
3500	9.02	1.60	0.69
4000	10.31	2.05	0.89

16"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
800	1.58	0.05	0.02
900	1.78	0.07	0.03
1000	1.97	0.08	0.04
1250	2.47	0.12	0.05
1500	2.96	0.17	0.08
2000	3.95	0.30	0.13
2500	4.94	0.45	0.19
3000	5.92	0.63	0.27
3500	6.91	0.84	0.36
4000	7.90	1.07	0.46
4500	8.88	1.33	0.58
5000	9.87	1.62	0.70
5500	10.86	1.93	0.84

18"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
1000	1.56	0.05	0.02
1250	1.95	0.07	0.03
1500	2.34	0.10	0.04
2000	3.12	0.17	0.07
2500	3.90	0.25	0.11
3000	4.68	0.35	0.15
3500	5.46	0.47	0.20
4000	6.24	0.60	0.26
4500	7.02	0.75	0.33
5000	7.80	0.91	0.40
5500	8.58	1.09	0.47
6000	9.36	1.28	0.55
6500	10.15	1.48	0.64

20"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
1500	1.90	0.06	0.03
2000	2.53	0.10	0.04
2500	3.16	0.15	0.07
3000	3.79	0.21	0.09
3500	4.42	0.28	0.12
4000	5.06	0.36	0.16
4500	5.69	0.45	0.19
5000	6.32	0.55	0.24
5500	6.95	0.65	0.28
6000	7.58	0.77	0.33
6500	8.22	0.89	0.38
7000	8.85	1.02	0.44
7500	9.48	1.16	0.50
8000	10.11	1.31	0.57

24"

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
2500	2.19	0.06	0.03
3000	2.63	0.09	0.04
3500	3.07	0.12	0.05
4000	3.51	0.15	0.06
4500	3.95	0.19	0.08
5000	4.39	0.23	0.10
5500	4.83	0.27	0.12
6000	5.27	0.32	0.14
6500	5.71	0.37	0.16
7000	6.15	0.42	0.18
7500	6.58	0.48	0.21
8000	7.02	0.54	0.23
8500	7.46	0.60	0.26
9000	7.90	0.67	0.29
9500	8.34	0.74	0.32
10000	8.78	0.81	0.35

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

Pipe Carrying Capacity Charts

Table 13 CARRYING CAPACITY AND FRICTION LOSS FOR DR 26 THERMOPLASTIC PIPE

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"			¾"			1"			1 ¼"		
1	0.002												
2	0.004												
5	0.011												
7	0.016												
10	0.022												
12	0.027												
15	0.033		not available										
20	0.045					not available							
25	0.056								not avaialble				
30	0.067												
35	0.078											not available	
40	0.089												
45	0.100												
50	0.111												
55	0.123												
60	0.134												
65	0.145	4"											
70	0.156	1.67	0.26	0.11									
75	0.167	1.79	0.29	0.13									
80	0.178	1.91	0.33	0.14									
90	0.201	2.15	0.41	0.18	5"								
100	0.223	2.39	0.50	0.22	1.57	0.18	0.08						
125	0.279	2.99	0.75	0.33	1.96	0.27	0.12	6"					
150	0.334	3.59	1.06	0.46	2.35	0.38	0.16	1.66	0.16	0.07			
175	0.390	4.19	1.41	0.61	2.74	0.50	0.22	1.93	0.21	0.09			
200	0.446	4.79	1.80	0.78	3.13	0.64	0.28	2.21	0.27	0.12	8"		
250	0.557	5.98	2.72	1.18	3.92	0.97	0.42	2.76	0.42	0.18	1.63	0.11	0.05
300	0.668	7.18	3.82	1.65	4.70	1.36	0.59	3.31	0.58	0.25	1.95	0.16	0.07
350	0.780	8.37	5.08	2.20	5.48	1.81	0.79	3.86	0.77	0.34	2.28	0.21	0.09
400	0.891	9.57	6.50	2.82	6.27	2.32	1.01	4.42	0.99	0.43	2.61	0.27	0.12
450	1.003	10.77	8.09	3.50	7.05	2.89	1.25	4.97	1.23	0.53	2.93	0.34	0.15
500	1.114				7.84	3.51	1.52	5.52	1.50	0.65	3.26	0.41	0.18
600	1.337				9.40	4.92	2.13	6.62	2.10	0.91	3.91	0.58	0.25
700	1.560				10.97	6.55	2.83	7.73	2.79	1.21	4.56	0.77	0.34
800	1.782							8.83	3.58	1.55	5.21	0.99	0.43
900	2.005	18"						9.94	4.45	1.93	5.86	1.23	0.53
1000	2.228	1.50	0.04	0.02				11.04	5.41	2.34	6.51	1.50	0.65
1250	2.785	1.87	0.06	0.03	20"						8.14	2.26	0.98
1500	3.342	2.24	0.09	0.04	1.82	0.05	0.02				9.77	3.17	1.37
2000	4.456	2.99	0.15	0.07	2.42	0.09	0.04	24"					
2500	5.570	3.74	0.23	0.10	3.03	0.14	0.06	2.10	0.06	0.02			
3000	6.684	4.49	0.32	0.14	3.63	0.19	0.08	2.52	0.08	0.03			
3500	7.798	5.23	0.43	0.18	4.24	0.25	0.11	2.94	0.10	0.05			
4000	8.912	5.98	0.54	0.24	4.85	0.33	0.14	3.37	0.13	0.06			
4500	10.026	6.73	0.68	0.29	5.45	0.41	0.18	3.79	0.17	0.07			
5000	11.140	7.48	0.82	0.36	6.06	0.49	0.21	4.21	0.20	0.09			
5500	12.254	8.23	0.98	0.43	6.66	0.59	0.25	4.63	0.24	0.10			
6000	13.368	8.97	1.15	0.50	7.27	0.69	0.30	5.05	0.28	0.12			
6500	14.482	9.72	1.34	0.58	7.87	0.80	0.35	5.47	0.33	0.14			
7000	15.596	10.47	1.53	0.66	8.48	0.92	0.40	5.89	0.38	0.16			
7500	16.710				9.09	1.04	0.45	6.31	0.43	0.19			
8000	17.824				9.69	1.18	0.51	6.73	0.48	0.21			
8500	18.938				10.30	1.32	0.57	7.15	0.54	0.23			
9000	20.052							7.57	0.60	0.26			
9500	21.166							7.99	0.67	0.29			
10000	22.280							8.41	0.73	0.32			

GPM	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
1												
2												
5												
7												
10	1 ½"											
12	1.66	0.70	0.30									
15	2.07	1.06	0.46	2"								
20	2.76	1.80	0.78	1.73	0.58	0.25						
25	3.45	2.73	1.18	2.16	0.87	0.38	2 ½"					
30	4.14	3.82	1.65	2.60	1.23	0.53	1.77	0.48	0.21			
35	4.84	5.08	2.20	3.03	1.63	0.71	2.06	0.64	0.28			
40	5.53	6.51	2.82	3.46	2.09	0.90	2.35	0.82	0.35	3"		
45	6.22	8.10	3.51	3.89	2.60	1.12	2.65	1.02	0.44	1.78	0.39	0.17
50	6.91	9.84	4.26	4.33	3.16	1.37	2.94	1.24	0.53	1.98	0.47	0.20
55	7.60	11.74	5.08	4.76	3.76	1.63	3.24	1.47	0.64	2.18	0.56	0.24
60	8.29	13.80	5.97	5.19	4.42	1.91	3.53	1.73	0.75	2.38	0.66	0.29
65	8.98	16.00	6.93	5.63	5.13	2.22	3.83	2.01	0.87	2.58	0.77	0.33
70	9.67	18.35	7.95	6.06	5.88	2.55	4.12	2.30	1.00	2.78	0.88	0.38
75	10.36	20.86	9.03	6.49	6.69	2.89	4.41	2.62	1.13	2.97	1.00	0.43
80				6.92	7.54	3.26	4.71	2.95	1.28	3.17	1.13	0.49
90				7.79	9.37	4.06	5.30	3.67	1.59	3.57	1.40	0.61
100				8.66	11.39	4.93	5.89	4.46	1.93	3.97	1.71	0.74
125				10.82	17.22	7.46	7.36	6.74	2.92	4.96	2.58	1.12
150							8.83	9.45	4.09	5.95	3.62	1.57
175							10.30	12.57	5.44	6.94	4.81	2.08
200										7.93	6.16	2.67
250										9.92	9.31	4.03
300										11.90	13.06	5.65
350	10"											
400	1.68	0.09	0.04									
450	1.89	0.12	0.05									
500	2.10	0.14	0.06	12"								
600	2.52	0.20	0.09	1.79	0.09	0.04	14"					
700	2.93	0.26	0.11	2.09	0.12	0.05	1.73	0.07	0.03	16"		
800	3.35	0.34	0.15	2.38	0.15	0.06	1.98	0.09	0.04	1.51	0.05	0.02
900	3.77	0.42	0.18	2.68	0.18	0.08	2.22	0.12	0.05	1.70	0.06	0.03
1000	4.19	0.51	0.22	2.98	0.22	0.10	2.47	0.14	0.06	1.89	0.07	0.03
1250	5.24	0.78	0.34	3.73	0.34	0.15	3.09	0.21	0.09	2.37	0.11	0.05
1500	6.29	1.09	0.47	4.47	0.47	0.21	3.71	0.30	0.13	2.84	0.16	0.07
2000	8.38	1.85	0.80	5.96	0.81	0.35	4.94	0.51	0.22	3.78	0.27	0.12
2500	10.48	2.80	1.21	7.45	1.22	0.53	6.18	0.77	0.34	4.73	0.40	0.17
3000				8.94	1.71	0.74	7.42	1.08	0.47	5.68	0.57	0.25
3500				10.43	2.27	0.98	8.65	1.44	0.62	6.62	0.75	0.33
4000							9.89	1.85	0.80	7.57	0.97	0.42
4500										8.52	1.20	0.52
5000										9.46	1.46	0.63
5500										10.41	1.74	0.75
6000												
6500												
7000												
7500												
8000												
8500												
9000												
9500												
10000												

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

Table 14 PROLINE-PRO 45 FLOW RATES

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		2"																							
5	0.011	0.38	0.02	0.01	2 ½"																				
7	0.016	0.53	0.07	0.03	0.37	0.02	0.01	3"																	
10	0.022	0.76	0.12	0.05	0.53	0.05	0.02	0.37	0.02	0.01															
15	0.033	1.13	0.23	0.10	0.80	0.12	0.05	0.55	0.05	0.02	4"														
20	0.045	1.51	0.42	0.18	1.07	0.18	0.08	0.74	0.07	0.03	0.50	0.02	0.01												
25	0.056	1.89	0.62	0.27	1.34	0.28	0.12	0.92	0.12	0.05	0.62	0.05	0.02												
30	0.067	2.27	0.88	0.38	1.60	0.37	0.16	1.11	0.14	0.06	0.74	0.07	0.03												
35	0.078	2.64	1.18	0.51	1.87	0.51	0.22	1.29	0.21	0.09	0.87	0.07	0.03												
40	0.089	3.02	1.50	0.65	2.14	0.65	0.28	1.48	0.25	0.11	0.99	0.09	0.04												
45	0.100	3.40	1.87	0.81	2.40	0.81	0.35	1.66	0.32	0.14	1.12	0.12	0.05												
50	0.111	3.78	2.29	0.99	2.67	0.97	0.42	1.84	0.39	0.17	1.24	0.14	0.06	6"											
60	0.134	4.53	3.19	1.38	3.20	1.36	0.59	2.22	0.55	0.24	1.49	0.21	0.09	0.70	0.02	0.01									
70	0.156	5.29	4.25	1.84	3.74	1.82	0.79	2.59	0.74	0.32	1.74	0.28	0.12	0.82	0.05	0.02									
80	0.178	6.04	5.43	2.35	4.27	2.38	1.03	2.96	0.95	0.41	1.99	0.37	0.16	0.94	0.07	0.03									
90	0.201	6.80	6.77	2.93	4.80	2.91	1.26	3.33	1.20	0.52	2.23	0.44	0.19	1.05	0.07	0.03									
100	0.223	7.55	8.22	3.56	5.34	3.53	1.53	3.69	1.43	0.62	2.48	0.55	0.24	1.17	0.09	0.04	8"								
125	0.279	9.44	12.43	5.38	6.68	5.41	2.34	4.62	2.17	0.94	3.10	0.83	0.36	1.46	0.14	0.06	0.93	0.02	0.01						
150	0.334				8.01	7.48	3.24	5.54	3.07	1.33	3.72	1.16	0.50	1.76	0.18	0.08	1.12	0.07	0.03	10"					
175	0.390				9.35	9.96	4.31	6.47	4.07	1.76	4.34	1.55	0.67	2.05	0.25	0.11	1.31	0.07	0.03	0.84	0.02	0.01			
200	0.446				10.68	12.77	5.53	7.39	5.22	2.26	4.96	1.99	0.86	2.34	0.32	0.14	1.50	0.07	0.03	0.96	0.05	0.02			
250	0.557							9.24	7.88	3.41	6.20	2.98	1.29	2.93	0.49	0.21	1.87	0.12	0.05	1.20	0.05	0.02			
300	0.668							11.08	11.04	4.78	7.44	4.18	1.81	3.51	0.67	0.29	2.24	0.16	0.07	1.44	0.07	0.03	12"		
350	0.780										8.68	5.59	2.42	4.10	0.90	0.39	2.62	0.23	0.10	1.68	0.09	0.04	1.06	0.02	0.01
400	0.891	14"									9.93	7.14	3.09	4.68	1.16	0.50	2.99	0.30	0.13	1.92	0.14	0.06	1.21	0.05	0.02
450	1.003	1.07	0.02	0.01							11.17	8.87	3.84	5.27	1.43	0.62	3.37	0.37	0.16	2.16	0.16	0.07	1.36	0.05	0.02
500	1.114	1.19	0.05	0.02	16"									5.85	1.73	0.75	3.74	0.44	0.19	2.40	0.21	0.09	1.51	0.07	0.03
600	1.337	1.43	0.05	0.02	1.12	0.02	0.01							7.02	2.43	1.05	4.49	0.60	0.26	2.87	0.28	0.12	1.81	0.09	0.04
700	1.560	1.66	0.07	0.03	1.31	0.05	0.02							8.19	3.23	1.40	5.24	0.63	0.36	3.35	0.35	0.15	2.11	0.12	0.05
800	1.782	1.90	0.09	0.04	1.50	0.05	0.02							9.36	4.13	1.79	5.98	1.04	0.45	3.83	0.46	0.20	2.41	0.14	0.06
900	2.005	2.14	0.12	0.05	1.68	0.07	0.03							10.53	5.15	2.23	6.73	1.29	0.56	4.31	0.60	0.26	2.71	0.18	0.08
1000	2.228	2.38	0.14	0.06	1.87	0.07	0.03							11.70	6.26	2.71	7.48	1.57	0.68	4.79	0.72	0.31	3.02	0.23	0.10
2000	4.456	4.75	0.46	0.20	3.74	0.25	0.11										14.96	5.71	2.47	9.58	2.56	1.11	6.03	0.83	0.36
2500	5.570	5.94	0.72	0.31	4.67	0.39	0.17													11.96	3.88	1.68	7.54	1.27	0.55
5000	11.140	11.88	2.54	1.10	9.35	1.41	0.61																		
7500	16.710				14.00	0.69	0.30																		
10000	21.280																								

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

HARRINGTON

Table 15 PROLINE-POLYPROPYLENE 150 FLOW RATES

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"			¾"			1"			1 1/4"														
1	0.002	1.17	1.27	0.55	0.68	0.35	0.15	0.39	0.09	0.04	0.24	0.02	0.01	1 ½"			2"			2 ½"					
2	0.004	2.34	4.60	1.99	1.37	1.25	0.54	0.78	0.32	0.14	0.49	0.09	0.04	0.32	0.05	0.02	0.35	0.02	0.01	0.24	0.02	0.01			
5	0.011	5.84	25.04	10.84	3.42	6.81	2.95	1.95	1.73	0.75	1.22	0.55	0.24	0.79	0.18	0.08	0.49	0.05	0.02	0.34	0.05	0.02			
7	0.016	8.18	46.69	20.21	4.79	12.73	5.51	2.72	3.21	1.39	1.71	1.04	0.45	1.11	0.37	0.16	0.70	0.09	0.04	0.49	0.07	0.03	3"		
10	0.022	11.70	90.37	39.32	6.85	24.62	10.66	3.89	6.24	2.70	2.45	2.01	0.87	1.58	0.69	0.30	1.05	0.21	0.09	0.73	0.14	0.06	0.49	0.02	0.01
12	0.027				10.30	52.18	22.59	5.84	13.21	5.72	3.67	4.27	1.85	2.37	1.48	0.64	1.41	0.35	0.15	0.97	0.23	0.10	0.65	0.05	0.02
15	0.033							7.78	22.50	9.74	4.90	7.28	3.15	3.16	2.52	1.09	1.76	0.53	0.23	1.22	0.30	0.13	0.81	0.07	0.03
20	0.045							9.73	34.00	14.72	6.12	11.02	4.77	3.95	3.79	1.64	2.11	0.74	0.32	1.46	0.39	0.17	0.98	0.12	0.05
25	0.056							11.70	47.66	20.63	7.34	15.43	6.68	4.74	5.31	2.30	2.46	0.99	0.43	1.70	0.53	0.23	1.14	0.14	0.06
30	0.067	4"									8.57	20.54	8.89	5.53	7.09	3.07	2.81	1.27	0.55	1.94	0.65	0.28	1.30	0.18	0.08
35	0.078	0.54	0.02	0.01							9.79	26.29	11.38	6.32	9.06	3.92	3.16	1.57	0.68	2.19	0.79	0.34	1.46	0.23	0.10
40	0.089	0.62	0.05	0.02							11.00	32.71	14.16	7.11	11.27	4.88	3.52	1.92	0.83	2.43	1.09	0.47	1.63	0.30	0.13
45	0.100	0.69	0.05	0.02										7.90	13.70	5.93	4.22	2.68	1.16	2.92	1.46	0.63	1.95	0.42	0.18
50	0.111	0.77	0.07	0.03	6"									9.48	19.20	8.31	4.92	3.56	1.54	3.40	1.87	0.81	2.28	0.55	0.24
60	0.134	0.92	0.07	0.03	0.59	0.02	0.01							11.10	25.64	11.10	5.62	4.55	1.97	3.89	2.31	1.00	2.60	0.69	0.30
70	0.156	1.08	0.09	0.04	0.69	0.05	0.02										6.33	5.68	2.46	4.38	2.82	1.22	2.93	0.88	0.38
80	0.178	1.23	0.12	0.05	0.79	0.05	0.02										7.03	6.91	2.99	4.86	4.25	1.84	3.25	1.06	0.46
90	0.201	1.39	0.14	0.06	0.89	0.07	0.03										8.79	10.44	4.52	6.08	5.91	2.56	4.06	1.59	0.69
100	0.223	1.54	0.16	0.07	0.98	0.07	0.03	8"									10.60	14.62	6.33	7.29	7.92	3.43	4.88	2.24	0.97
125	0.279	1.92	0.25	0.11	1.23	0.09	0.04	0.79	0.02	0.01										8.51	10.14	4.39	5.69	2.98	1.29
150	0.334	2.31	0.37	0.16	1.48	0.12	0.05	0.95	0.05	0.02										9.72	15.34	6.64	6.50	3.81	1.65
175	0.390	2.69	0.49	0.21	1.72	0.16	0.07	1.10	0.05	0.02										12.20	21.51	9.31	8.13	5.75	2.49
200	0.446	3.08	0.62	0.27	1.97	0.21	0.09	1.26	0.07	0.03	10"												9.75	8.09	3.50
250	0.557	3.85	0.92	0.40	2.46	0.30	0.13	1.58	0.12	0.05	0.99	0.02	0.01	12"									11.40	10.72	4.64
300	0.668	4.62	1.32	0.57	2.95	0.44	0.19	1.89	0.14	0.06	1.19	0.05	0.02	0.94	0.02	0.01									
350	0.780	5.39	1.73	0.75	3.44	0.60	0.26	2.21	0.21	0.09	1.39	0.07	0.03	1.09	0.05	0.02									
400	0.891	6.16	2.24	0.97	3.94	0.74	0.32	2.52	0.25	0.11	1.59	0.07	0.03	1.25	0.05	0.02	14"								
450	1.003	6.93	2.27	1.20	4.43	0.92	0.40	2.84	0.32	0.14	1.78	0.09	0.04	1.40	0.07	0.03	1.11	0.02	0.01						
500	1.114	7.69	3.37	1.46	4.92	1.13	0.49	3.15	0.37	0.16	1.98	0.12	0.05	1.56	0.07	0.03	1.23	0.05	0.02	16"					
600	1.337	9.23	4.71	2.04	5.90	1.59	0.69	3.78	0.53	0.23	2.38	0.16	0.07	1.87	0.09	0.04	1.48	0.05	0.02	1.17	0.02	0.01			
700	1.560	10.80	6.28	2.72	6.89	2.13	0.92	4.41	0.72	0.31	2.78	0.23	0.10	2.19	0.14	0.06	1.72	0.07	0.03	1.36	0.05	0.02			
800	1.782				7.87	2.70	1.17	5.04	0.92	0.40	3.17	0.30	0.13	2.50	0.16	0.07	1.97	0.09	0.04	1.55	0.05	0.02			
900	2.005				8.85	3.37	1.46	5.67	1.13	0.49	3.57	0.37	0.16	2.81	0.21	0.09	2.21	0.12	0.05	1.75	0.07	0.03			
1000	2.228				9.84	4.11	1.78	6.30	1.39	0.60	3.97	0.44	0.19	3.12	0.25	0.11	2.46	0.14	0.06	1.94	0.07	0.03			
2000	4.456							12.60	5.01	2.17	7.93	1.62	0.70	6.24	0.90	0.39	4.92	0.51	0.22	3.89	0.30	0.13			
2500	5.570										9.92	2.47	1.07	7.80	1.36	0.59	6.15	0.76	0.33	4.86	0.44	0.19			
5000	11.140																12.30	2.77	1.20	9.72	1.57	0.68			
7500	16.710																			14.80	3.30	1.43			

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

Table 16 PURAD PVDF FLOW RATES

GPM	cu ft/sec	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)	Velocity (ft/s)	Friction Head Loss (ft water/100 ft)	Friction Pressure (psi/100 ft)
		½"			¾"			1"			1 ¼"														
1	0.002	1.00	0.88	0.38	0.58	0.23	0.10	0.36	0.07	0.03	0.21	0.02	0.01	1 ½"											
2	0.004	2.00	3.14	1.36	1.17	0.85	0.37	0.71	0.25	0.11	0.42	0.07	0.03	0.27	0.02	0.01	2"								
5	0.011	5.00	17.14	7.42	2.92	4.64	2.01	1.78	1.36	0.60	1.06	0.39	0.17	0.67	0.14	0.06	0.41	0.05	0.02	2 ½"					
7	0.016	7.00	31.88	13.80	4.09	8.64	3.74	2.49	2.56	1.11	1.49	0.74	0.32	0.94	0.23	0.10	0.57	0.07	0.03	0.38	0.02	0.01			
10	0.022	10.00	61.91	26.80	5.84	16.72	7.24	3.55	4.99	2.16	2.12	1.43	0.62	1.35	0.46	0.20	0.81	0.14	0.06	0.54	0.05	0.02	3"		
15	0.033				8.76	35.34	15.30	5.33	10.56	4.57	3.19	3.03	1.31	2.02	0.99	0.43	1.22	0.30	0.13	0.81	0.12	0.05	0.40	0.02	0.01
20	0.045	4"			11.70	60.29	26.10	7.10	17.99	7.79	4.25	5.17	2.24	2.69	1.71	0.74	1.62	0.49	0.21	1.07	0.18	0.08	0.60	0.05	0.02
25	0.056	0.50	0.02	0.01				8.88	27.26	11.80	5.31	7.78	3.37	3.37	2.56	1.11	2.03	0.74	0.32	1.34	0.28	0.12	0.79	0.09	0.04
30	0.067	0.62	0.05	0.02				10.70	38.12	16.50	6.37	10.93	4.73	4.04	3.60	1.56	2.43	1.04	0.45	1.61	0.39	0.17	0.99	0.14	0.06
35	0.078	0.74	0.07	0.03							7.43	14.55	6.30	4.71	4.80	2.08	2.84	1.36	0.60	1.88	0.51	0.22	1.19	0.18	0.08
40	0.089	0.87	0.07	0.03							8.50	18.62	8.06	5.38	6.14	2.66	3.24	1.80	0.78	2.15	0.67	0.29	1.39	0.25	0.11
45	0.100	0.99	0.09	0.04	6"						9.56	23.10	10.00	6.06	7.65	3.31	3.65	2.22	0.96	2.42	0.83	0.36	1.59	0.32	0.14
50	0.111	1.12	0.12	0.05	0.59	0.02	0.01				10.62	28.18	12.20	6.73	9.29	4.02	4.05	2.70	1.17	2.69	0.99	0.43	1.79	0.39	0.17
60	0.134	1.24	0.14	0.06	0.70	0.05	0.02							8.08	13.01	5.63	4.86	3.79	1.64	3.22	1.39	0.60	1.99	0.49	0.21
70	0.156	1.49	0.21	0.09	0.82	0.05	0.02							9.42	17.30	7.49	5.67	5.04	2.18	3.76	1.85	0.80	2.38	0.67	0.29
80	0.178	1.74	0.28	0.12	0.94	0.07	0.03							10.80	22.18	9.60	6.48	6.44	2.79	4.30	2.38	1.03	2.78	0.90	0.39
90	0.201	1.99	0.37	0.16	1.05	0.07	0.03	8"									7.29	8.02	3.47	4.83	2.96	1.28	3.18	1.13	0.49
100	0.223	2.23	0.44	0.19	1.17	0.09	0.04	0.96	0.02	0.01							8.10	9.75	4.22	5.37	3.58	1.55	3.57	1.41	0.61
125	0.279	2.48	0.55	0.24	1.46	0.14	0.06	0.93	0.05	0.02							10.13	14.74	6.38	6.71	5.43	2.35	4.96	1.71	0.74
150	0.334	3.10	0.83	0.36	1.76	0.18	0.08	1.12	0.07	0.03										8.06	7.60	3.29	5.96	2.61	1.13
175	0.390	3.72	1.16	0.50	2.05	0.23	0.10	1.31	0.07	0.03	10"									9.40	10.09	4.37	6.95	3.65	1.58
200	0.446	4.34	1.96	0.85	2.34	0.32	0.14	1.50	0.09	0.04	0.96	0.02	0.01							10.70	12.94	5.60	7.94	4.85	2.10
250	0.557	4.96	2.98	1.29	2.93	0.49	0.21	1.87	0.16	0.07	1.20	0.05	0.02										9.93	6.19	2.68
300	0.668	6.20	4.18	1.81	3.51	0.67	0.29	2.24	0.23	0.10	1.44	0.07	0.03	12"									11.90	20.93	9.06
350	0.780	7.44	5.57	2.41	4.10	0.90	0.39	2.62	0.30	0.13	1.68	0.09	0.04	1.06	0.02	0.01									
400	0.891	8.68	7.14	3.09	4.68	1.13	0.49	2.99	0.37	0.16	1.92	0.14	0.06	1.21	0.05	0.02									
450	1.003	9.93	8.87	3.84	5.27	1.41	0.61	3.37	0.46	0.20	2.16	0.16	0.07	1.36	0.05	0.02									
500	1.114	11.20	10.79	4.67	5.85	1.73	0.75	3.74	0.58	0.25	2.40	0.18	0.08	1.51	0.07	0.03									
600	1.337				7.02	2.43	1.05	4.49	0.81	0.35	2.87	0.28	0.12	1.81	0.07	0.03									
700	1.560				8.19	3.23	1.40	5.24	1.09	0.47	3.35	0.37	0.16	2.11	0.12	0.05									
800	1.782				9.36	4.13	1.79	5.98	1.39	0.60	3.83	0.46	0.20	2.41	0.14	0.06									
900	2.005				10.50	5.15	2.23	6.73	1.73	0.75	4.31	0.60	0.26	2.71	0.18	0.08									
1000	2.228							7.48	2.10	0.91	4.79	0.72	0.31	3.02	0.23	0.10									
2000	4.456							15.00	7.60	3.29	9.58	2.56	1.11	6.03	0.83	0.36									
2500	5.570										12.00	3.88	1.68	7.54	1.27	0.55									
5000	11.140													15.10	4.55	1.97									

CAUTION: Do not use or test the products in this manual with compressed air or other gases including air-over-water boosters.

Table 17 EQUIVALENT LENGTH OF THERMOPLASTIC PIPE IN FEET

PVC & CPVC FITTINGS		¼	½	¾	1	1-¼	1-½	2	2-½	3	4	6	8	10	12	14	16	18	20	24
Standard Tee with flow through run		0.6	1.0	1.4	1.7	2.3	2.7	4.0	4.9	6.1	7.9	12.3	14.0	17.5	20.0	25.0	27.0	32.0	35.0	42.0
Standard Tee with flow through branch		1.8	3.8	4.9	6.0	7.3	8.4	12.0	14.7	16.4	22.0	32.7	49.0	57.0	67.0	78.0	88.0	107.0	118.0	137.0
90° Elbow		0.9	1.5	2.0	2.5	3.8	4.0	5.7	6.9	7.9	11.4	16.7	21.0	26.0	32.0	37.0	43.0	53.0	58.0	67.0
45° Elbow		0.5	0.8	1.1	1.4	1.8	2.1	2.6	3.1	4.0	5.1	8.0	10.6	13.5	15.5	18.0	20.0	23.0	25.0	30.0
PROLINE & DUO-PRO FITTINGS																				
Tee		—	3.25	4.0	6.0	8.0	9.0	12.0	14.0	17.0	21.0	34.0	44.0	55.0	58.0	80.0	90.0	100.0	110.0	140.0
90° Elbow		—	1.5	2.0	2.75	3.5	4.25	5.5	7.0	8.0	11.0	16.0	20.0	25.0	32.0	25.0	30.0	32.5	35.0	40.0
45° Elbow		—	0.8	1.0	1.25	1.70	2.0	2.5	3.0	3.6	5.0	7.5	10.0	12.5	15.0	12.0	15.0	16.0	17.0	20.0
EQUIVALENT LENGTH OF STRAIGHT NEW SCHEDULE 40 STEEL PIPE FOR VARIOUS STEEL FITTINGS & VALVES TURBULENT FLOW ONLY*																				
Standard Tee with flow through run	screwed	.79	1.7	2.4	3.2	4.6	5.6	7.7	9.3	12.0	17.0									
	flanged		0.69	.82	1.0	1.3	1.5	1.8	1.9	2.2	2.8	3.8	4.7	5.2	6.0	6.4	7.2	7.6	8.2	9.6
Standard Tee with flow through branch	screwed	2.4	4.2	5.3	6.6	8.7	9.9	12.0	13.0	17.0	21.0									
	flanged		2.0	2.6	3.3	4.4	5.2	6.6	7.5	9.4	12.0	18.0	24.0	30.0	34.0	37.0	43.0	47.0	52.0	62.0
90° Elbow	screwed	2.3	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0									
	flanged		0.92	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	8.9	12.0	14.0	17.0	18.0	21.0	23.0	25.0	30.0
90° Elbow - Long Radius	screwed	1.5	2.2	2.3	2.7	3.2	3.4	3.6	3.6	4.0	4.6									
	flanged		1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5.7	7.0	8.0	9.0	9.4	10.0	11.0	12.0	14.0
45° Elbow	screwed	.34	0.71	.92	1.3	1.7	2.1	2.7	3.2	4.0	5.5									
	flanged		0.45	.59	.81	1.1	1.3	1.7	2.0	2.6	3.5	5.6	7.7	9.0	11.0	13.0	15.0	16.0	18.0	22.0
Globe Valve	screwed	21.0	22.0	24.0	29.0	37.0	42.0	54.0	62.0	79.0	110.0									
	flanged		38.0	40.0	45.0	54.0	59.0	70.0	77.0	94.0	120.0	190.0	260.0	310.0	390.0					
Gate Valve	screwed	.32	0.56	0.67	0.84	1.1	1.2	1.5	1.7	1.9	2.5									
	flanged							2.6	2.7	2.8	2.9	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Angle Valve	screwed		15.0	15.0	17.0	18.0	18.0	18.0	18.0	18.0	18.0									
	flanged		15.0	15.0	17.0	18.0	18.0	21.0	22.0	28.0	38.0	63.0	90.0	120.0	140.0	160.0	190.0	210.0	240.0	300.0

Courtesy of Hydraulic Institute

SLOPE OF HORIZONTAL DRAINAGE PIPING

Horizontal drains are designated to flow at half full capacity under uniform flow conditions so as to prevent the generation of positive pressure fluctuations. A minimum of ¼" per foot should be provided for 3" pipe and smaller, ⅛" per foot for 4" through 6", and 1/16" per foot for 8" and larger. These minimum slopes are required to maintain a velocity of flow greater than 2 feet per second for scouring action. Table 21 gives the approximate velocities and discharge rated for given slopes and diameters of horizontal drains based on modified Manning Formula for ½ full pipe and n = 0.015. The valves for R, R ⅔, A, S, S ½ and n are in tables 18-21.

$$Q = A \times \frac{1.486}{n} \times R^{2/3} \times S^{1/2}(7.48 \times 60)$$

Where:

Q = Flow in GPM
A = Cross sectional area, sq. ft.
n = Manning coefficient
R = Hydraulic radius of pipe
S = Hydraulic gradient

Table 18

PIPE SIZE (IN.)	R = D/4 FT.	$R^{2/3}$	A - CROSS SECTIONAL AREA FOR FULL FLOW SQ. FT.	A - CROSS SECTIONAL AREA FOR HALF FULL FLOW SQ. FT.
1½	0.0335	0.1040	0.01412	0.00706
2	0.0417	0.1200	0.02180	0.01090
2½	0.0521	0.1396	0.03408	0.01704
3	0.0625	0.1570	0.04910	0.02455
4	0.0833	0.1910	0.08730	0.04365
5	0.1040	0.2210	0.13640	0.06820
6	0.1250	0.2500	0.19640	0.09820
8	0.1670	0.3030	0.34920	0.17460
10	0.2080	0.3510	0.54540	0.27270
12	0.2500	0.3970	0.78540	0.39270
14	0.3125	0.4610	1.22700	0.61350

Table 19 **VALUES OF S AND $S^{1/2}$**

SLOPE INCHES PER FOOT	S FOOT PER FOOT	$S^{1/2}$
⅛	0.0140	0.102
¼	0.0208	0.144
½	0.0416	0.204

Table 20 **VALUES OF n**

PIPE SIZE	n
1½"	0.012
2" & 3"	0.013
4"	0.014
5" & 6"	0.015
8" and larger	0.016

Table 21 **APPROXIMATE DISCHARGE RATES AND VELOCITIES IN SLOPING DRAINS**

ACTUAL INSIDE DIAMETER OF PIPE (INCHES)	FLOWING HALF FULL DISCHARGE RATE AND VELOCITY							
	1/16 IN./ FT. SLOPE		⅛ IN./ FT. SLOPE		¼ IN./ FT. SLOPE		½ IN./ FT. SLOPE	
	DISCHARGE GPM	VELOCITY FPS	DISCHARGE GPM	VELOCITY FPS	DISCHARGE GPM	VELOCITY FPS	DISCHARGE GPM	VELOCITY FPS
1¼	–	–	–	–			3.40	1.78
1⅜	–	–	–	–	3.13	1.34	4.44	1.90
1½	–	–	–	–	3.91	1.42	5.53	2.01
1⅝	–	–	–	–	4.81	1.50	6.80	2.12
2	–	–	–	–	8.42	1.72	11.9	2.43
2½	–	–	10.8	1.41	15.3	1.99	21.6	2.82
3	–	–	17.6	1.59	24.8	2.25	35.1	3.19
4	26.7	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137	4.47
6	78.5	1.78	111	2.52	157	3.57	222	5.04
8	170	2.17	240	3.07	340	4.34	480	6.13
10	308	2.52	436	3.56	616	5.04	8721	7.12
12	500	2.83	707	4.01	999	5.67	1413	8.02

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Pressure Drop in Valves and Strainers

Pressure drop calculations can be made for valves and strainers for different fluids, flow rates, and sizes using the C_V values and the following equation:

$$P = \frac{(G)^2 \text{ (specific gravity liquid)}}{(C_V \text{ Factor})^2}$$

Where:

P = Pressure drop in psi
G = Gallons per Minute
C_V = Gallons per minuter per 1 psi pressure drop

To convert psi to feet of head multiply by 2.31 and divide by the specific gravity.

Some manufacturers also prefer to use the following formula to calculate pressure losses through their products:

$$\Delta P = \left[\frac{Q}{C_V} \right]^2$$

Where:

ΔP = Pressure Drop
Q = Flow in GPM
C_V = Flow Coefficient

Table 22 TYPICAL C_v FACTORS FOR PLASTIC VALVES AND STRAINERS IN GPM

Item	¼"	⅜"	½"	¾"	1"	1¼"	1-½"	2"	2½"	3"	4"
Full Port Ball Valve	1.0	7.7	14	29	47	72	155	190	365	410	610
Ball Check Valves	—	—	15	20	25	—	40	50	—	80	100
Y-Check Valves	—	—	.08	3.0	9.0	26	45	26	75	110	240
Swing Check Valve	—	—		20	25	—	40	50	65	80	100
3-way Ball Valve "L" Port	—	—	7.4	10	23	—	43	59	—	130	160
Double "L" Port	—	—	6.3	8.5	20	—	36	45	—	99	200
Diaphragm Valves	—	—	4.8	5.3	8.5	11	26	43	85	115	185
Butterfly Valves full open	—	—	—	—	—	—	71	120	250	300	470
Needle Valves	5.0	7.5	8.0	—	—	—	—	—	—	—	—
Angle Valve	1.0	—	5.0	10	16	—	45	70	—	—	—
Globe Valve	—	—	4.1	6.4	9.7	18	22	29	57	78	115
Gate Valve	—	—	—	—	—	—	130	180	415	470	690
Y-Strainer	—	—	5.2	7.5	14	—	34	50	—	110	165
Simplex Basket Strainer	—	—	15	18	20	55	58	60	290	300	350
Duplex Basket Strainer	—	—	12	13	14	40	15	48	—	200	230

FLOW OF FLUIDS AND HEAD LOSS CALCULATIONS

Tables, flow charts, or a monograph may be used to assist in the design of a piping system depending upon the accuracy desired. In computing the internal pressure for a specified flow rate, changes in static head loss due to restrictions (valves, orifices, etc.) as well as flow head loss must be considered.

The formula in Table 23 can be used to determine the head loss due to flow if the fluid viscosity and density and flow rate are known. The head loss in feet of fluid is given by:

$$h = \frac{:186\, fLV}{d^2}$$

f, the friction factor, is a function of the Reynolds number, a dimensionless parameter which indicates the degree of turbulence.

The Reynolds number is defined as: $f = \frac{dVW}{12U}$

Figure 4 on the next page, shows the relationship between the friction factor, f, and the Reynolds number, R. It is seen that three distinct flow zones exist. In the laminar flow zone, from Reynolds numbers 0 to 2000, the friction factor is given by the equation:

$$f = \frac{64}{R}$$

Substituting this in the equation for the head loss, the formula for laminar flow becomes:

$$h = \frac{143\, ULV}{Wd}$$

Flow in the critical zone, Reynolds numbers 2000 to 4000, is unstable and a surging type of flow exists. Pipelines should be designed to avoid operation in the critical zone because head losses cannot be calculated accurately in this zone. In addition, the unstable flow results in pressure surges and water hammer which may be excessively high. In the transition zone, the degree of turbulence increases as the Reynolds number increases; however, due to the smooth inside surface of plastic pipe, complete turbulence rarely exists. Most pipe systems are designed to operate in the transition zone.

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Table 23

FORMULAS FOR HEAD LOSS CALCULATIONS

$$R = \frac{dVw}{12\,u}$$

$$R = \frac{3160\ G}{kd}$$

$$R = \frac{2220B}{kd}$$

$$R = 22{,}735\ \frac{Qw}{zd}$$

When R = 4000:

$$h = .186\ \frac{fLV^2}{d}$$

$$h = .0311\ \frac{fLG^2}{d^5}$$

$$P = \frac{fLB^2\ W}{9450d^2}$$

$$P = 43.5\ \frac{fLQ^2\ W}{d^5}$$

SYMBOL	QUANTITY	UNITS
B	flow rate	barrels/hour
d	inside diameter	inches
f	friction factor	dimensionless
G	flow rate	gallons/minute
h	head loss	feet of fluid
k	kinematic viscosity	centistokes
L	length of pipe	feet
P	pressure drop	lbs/in^2
Q	flow rate	ft^3/sec.
R	Reynolds number	dimensionless
u	absolute viscosity	lb/ft-sec.
V	velocity	ft./sec.
w	density	lbs/ft^3
z	absolute viscosity	centipoises

Velocity

Thermoplastic pipe is not subject to erosion caused by high velocities and turbulent flow, and in this respect is superior to metal piping systems, particularly where corrosive or chemically aggressive fluids are involved. The Plastics Pipe Institute has issued the following policy statement on water velocity:

The maximum safe water velocity in a thermoplastic piping system depends on the specific details of the system and the operating conditions. In general, 5 feet per second is considered to be safe. Higher velocities may be used in cases where the operating characteristics of valves and pumps are known so that sudden changes in flow velocity can be controlled. The total pressure in the system at any time (operating plus surge or water hammer) should not exceed 150 percent of the pressure rating of the system.

Harrington Industrial Plastics recommends sizing all plastic piping systems to operate at velocities of (approximately) 5 feet per second or less.

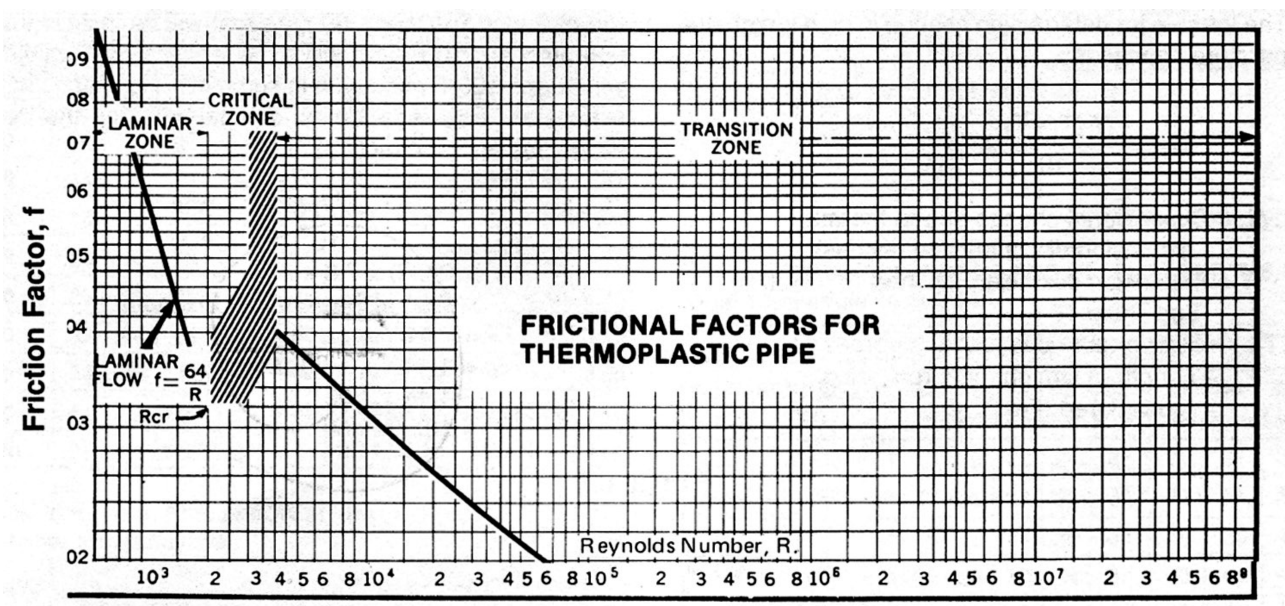


Figure 4

WATER HAMMER & HYDRAULIC SHOCK

Surge pressures due to water hammer are a major factor contributing to pipe failure in liquid transmission systems. A column of moving fluid within a pipeline, owing to its mass and velocity, contains stored energy.

Since liquids are essentially incompressible, this energy cannot be absorbed by the fluid when a valve is suddenly closed. The result is a high momentary pressure surge, usually called water hammer or hydraulic shock. The five factors that determine the severity of water hammer are:

1. Velocity (The primary factor in excessive water hammer: see discussion of "Velocity" above and "Safety Factor" on page 41.
2. Modulus of elasticity of material of which the pipe is made.
3. Inside diameter of pipe.
4. Wall thickness of pipe.
5. Valve closing time.

Maximum pressure surges caused by water hammer can be calculated by using the equation below. This surge pressure should be added to the existing line pressure to arrive at a maximum operating pressure figure.

$$Ps = V \left(\frac{Et\ 3960}{Et + (3 \times 10^5\, Di)} \right)^{1/2}$$

Where:

Ps = Surge Pressure, in psi
V = Liquid Velocity, in feet per second
Di = Inside Diameter of Pipe, in inches
E = Modulus of Elasticity of Pipe Material, psi
t = Wall Thickness of Pipe, in inches

Calculated surge pressure, which assumes instantaneous valve closure, can be calculated for any material using the values for E (Modulus of Elasticity) found in the properties chart, pages 4-5.

The most commonly used surge pressure tables for IPS pipe sizes are provided on the next page.

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Table 24 Surge Pressure, in psi at 73°F

WATER VELOCITY (FT/SEC)	NOMINAL PIPE SIZE											
	½"	¾"	1"	1¼"	1 ½"	2"	3"	4"	6"	8"	10"	12"
SCHEDULE 40 PVC & CPVC												
1	27.9	25.3	24.4	22.2	21.1	19.3	18.9	17.4	15.5	14.6	13.9	13.4
2	55.8	50.6	48.8	44.4	42.2	38.6	37.8	34.8	31.0	29.2	27.8	26.8
3	83.7	75.9	73.2	66.6	63.3	57.9	56.7	52.2	46.5	43.8	41.7	40.2
4	111.6	101.2	97.6	88.8	84.4	77.2	75.6	69.6	62.0	58.4	55.6	53.6
5	139.5	126.5	122.0	111.0	105.5	96.5	94.5	87.0	77.5	73.0	69.5	67.0
6	167.4	151.8	146.4	133.2	126.6	115.8	113.4	104.4	93.0	87.6	83.4	80.4
SCHEDULE 80 PVC & CPVC												
1	32.9	29.9	28.7	26.2	25.0	23.2	22.4	20.9	19.4	18.3	17.3	17.6
2	65.6	59.8	57.4	52.4	50.0	46.4	44.8	41.8	38.8	36.6	35.6	35.2
3	98.7	89.7	86.7	78.6	75.0	69.6	67.2	62.7	58.2	59.9	53.4	52.8
4	131.6	119.6	114.8	104.8	107.0	92.8	89.6	83.6	77.6	73.2	71.2	70.4
5	164.5	149.5	143.5	131.0	125.0	116.0	112.0	104.5	97.0	91.5	89.0	88.0
6	197.4	179.4	172.2	157.2	150.0	133.2	134.4	125.4	116.4	109.8	106.8	105.6
SCHEDULE 80 POLYPROPYLENE												
1	23.5	20.9	20.0	18.1	17.1	15.9	15.2	14.1	13.1	12.2	11.9	11.8
2	47.0	41.8	40.0	36.2	34.2	31.6	30.4	28.0	26.2	24.4	23.8	23.6
3	70.5	62.7	60.0	54.3	51.3	47.4	45.6	42.3	39.3	36.6	35.7	35.4
4	94.0	83.6	80.0	72.4	68.4	63.2	60.8	56.4	52.4	48.8	47.6	47.2
5	117.5	104.5	100.0	90.5	85.5	79.0	76.0	70.5	65.5	61.0	59.5	59.0
6	141.0	125.4	120.0	108.6	102.6	94.8	91.2	84.6	78.6	73.2	71.4	70.8
SCHEDULE 80 PVDF												
1	25.2	22.6	21.6	19.5	18.5	17.1	16.5	15.3	14.2	13.3	12.9	12.8
2	50.4	45.2	43.2	39.0	37.0	34.2	33.0	30.6	28.9	26.6	25.8	25.6
3	75.6	67.8	64.8	58.5	55.5	51.3	49.5	45.9	42.6	39.9	38.7	38.4
4	100.8	90.4	86.4	78.0	74.0	68.4	66.0	61.2	56.8	53.2	51.6	51.2
5	126.0	118.0	108.0	97.5	92.5	86.5	92.5	76.5	71.0	66.5	64.5	64.0
6	151.2	135.6	129.6	117.0	111.0	102.6	99.0	91.8	85.2	79.8	77.4	76.8
PURAD™												
1	22.3	19.8	19.6	17.4	17.1	15.5	18.4	12.6	12.5	12.4	12.4	12.4
2	44.5	39.7	39.1	34.7	34.2	30.9	24.8	25.2	24.9	24.8	24.9	24.8
3	66.8	59.5	58.7	52.1	51.4	46.4	37.2	37.7	37.4	37.2	37.3	37.3
4	89.1	79.4	78.3	69.5	68.5	61.8	49.7	50.3	49.9	49.6	49.8	49.7
5	111.3	99.2	97.9	86.9	85.6	77.3	62.1	62.9	62.3	62.0	62.2	62.1
6	133.6	119.0	117.4	104.2	102.7	92.8	74.5	75.5	74.8	74.4	74.6	74.5
PROLINE PRO 150												
1	15.3	14.1	12.9	12.6	12.8	12.8	12.7	12.7	12.8	12.7	12.7	12.7
2	30.7	28.2	25.9	25.3	25.6	25.6	25.5	25.4	25.5	25.5	25.5	25.5
3	46.0	42.3	38.8	37.9	38.4	38.4	38.2	38.2	38.3	38.2	38.2	38.2
4	61.4	56.4	51.8	50.5	51.2	51.2	51.0	50.9	51.0	50.9	51.0	50.9
5	76.7	70.5	64.7	63.2	64.0	64.0	63.7	63.6	63.8	63.7	63.7	63.7
6												
PROLINE PRO 45												
1	-	-	-	-	-	7.1	7.0	7.1	7.1	7.0	7.1	7.1
2	-	-	-	-	-	14.2	14.1	14.3	14.2	14.1	14.1	14.1
3	-	-	-	-	-	21.3	21.1	21.4	21.2	21.1	21.2	21.1
4	-	-	-	-	-	28.4	28.1	28.6	28.3	28.2	28.2	28.2
5	-	-	-	-	-	35.5	35.2	35.7	35.4	35.2	35.3	35.3
6	-	-	-	-	-	42.5	42.3	42.8	42.5	42.2	42.4	42.3

WATER HAMMER (Continued)

However, to keep water hammer pressures within reasonable limits, it is common practice to design valves for closure times considerably greater than 2L/C.

$$T_C > \frac{2L}{V_s}$$

Where:

T_C = Valve Closure time, sec.
L = Length of Pipe run, ft.
V_s = Sonic Velocity of the Pressure Wave = 4720 ft/sec.

Another formula that closely predicts water hammer effects is:

$$Ps = CV$$

Where:

Ps = maximum surge pressure, psi
V = fluid velocity in feet per second
C = surge wave constant for water at 73°F

It should be noted that the surge pressure (water hammer) calculated here is a maximum pressure rise for any fluid velocity, such as would be expected from the instant closing of a valve. It would therefore yield a somewhat conservative figure for use with slow closing actuated valves, etc.

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Table 25 **Surge Wave Constant, C**

PIPE SIZE (IN.)	PVC		CPVC		PP SCH 80	PVDF SCH 80
	SCH 40	SCH 80	SCH 40	SCH 80		
¼	31.3	34.7	33.2	37.3	—	—
⅜	29.3	32.7	31.0	34.7	—	—
½	28.7	31.7	30.3	33.7	25.9	28.3
¾	26.3	29.8	27.8	31.6	23.1	25.2
1	25.7	29.2	27.0	30.7	21.7	24.0
1¼	23.2	27.0	24.5	28.6	19.8	—
1½	22.0	25.8	23.2	27.3	18.8	20.6
2	20.2	24.2	21.3	25.3	17.3	19.0
2½	20.8	23.1	22.2	26.0	—	—
3	19.5	23.2	20.6	24.5	16.6	—
4	17.8	21.8	18.6	22.9	15.4	—
6	15.7	20.2	16.8	21.3	—	—
8	14.8	18.8	15.8	19.8	—	—
10	14.0	18.3	15.1	19.3	—	—
12	13.8	18.1	14.7	19.2	—	—
14	13.7	18.1	14.4	19.2	—	—
16	13.7	17.9	12.7	16.7		
18	13.7	17.8	12.7	16.6		
20	13.3	17.7	12.4	16.5		
24	13.1	17.6	12.2	16.3		

Note: The constants shown in this table are based on average wall thicknesses and average I.D. of pipe from various manufacturers and should not be construed as exact.

For fluids heavier than water, the following correction should be made to the surge wave constant C

$$C^1 = \frac{(S.G. - 1)\,C + C}{2}$$

Where:

C^1 = Corrected Surge Wave Constant
S.G. = Specific Gravity of Liquid

For example, for a liquid with a specific gravity of 1.2 in 2" Schedule 80 PVC pipe, from Table 26 = 24.2

$$C^1 = \frac{(1.2 - 1)}{2}(24.2) + 24.2$$

$$C^1 = 2.42 + 24.2$$

$$C^1 = 26.6$$

Proper design when laying out a piping system will eliminate the possibility of water hammer damage.

The following suggestions will help in avoiding problems:

1. In a plastic piping system, a fluid velocity not exceeding 5ft/sec will minimize water hammer effects, even with quickly closing valves, such as solenoid valves.
2. Using actuated valves that have a specific closing time will eliminate the possibility of someone inadvertently slamming a valve open or closed too quickly. With pneumatic and air-spring actuators, it may be necessary to place a valve in the air line to slow down the valve operation cycle.
3. If possible, when starting a pump, partially close the valve in the discharge line to minimize the volume of liquid which is rapidly accelerating through the system. Once the pump is up to speed and the line completely full, the valve may be opened.
4. Check the anticipated velocity at the discharge port of any pump before startup. Most centrifugal pumps require an immediate increase in pipe size to obtain a proper velocity of 5 ft/sec or less.

Note: The total pressure at any time in a pressure-piping system (operating plus surge or water hammer) should not exceed 150 percent of the pressure rating of the system.

SAFETY FACTOR

As the duration of pressure surges due to water hammer is extremely short - seconds, or more likely, fractions of a second in determining the safety factor the maximum fiber stress due to total internal pressure must be compared to some very short-term strength value. Referring to Figure 3, shown on page 23, it will be seen that the failure stress for very short time periods is very high when compared to the hydrostatic design stress.

The calculation of safety factor may thus be based very conservatively on the 20-second strength value given in Figure 3, shown on page 23 (8470 psi for PVC Type 1).

A sample calculation is shown below, based upon the listed criteria:

Pipe = 1¼" Schedule 80 PVC
OD = 1.660
Wall = 0.191
HDS = 2000 psi

The calculated surge pressure for 1¼" Schedule 80 PVC pipe at a velocity of 1 ft/sec is 26.2 psi/ft/sec. (taken from table 25 on page 40).

Water Velocity = 5 ft/sec.
Static Pressure in System = 300 psi
Total System Pressure = Static Pressure + Surge Pressure:

$$Pt = P \times Ps$$
$$= 300 + 5 \times 26.2$$
$$= 431.0 \text{ psi}$$

Maximum circumferential stress is calculated from a variation of the ISO Equation:

$$S = \frac{Pt\,(Do\text{-}t)}{2t} = \frac{431(1.660 - .191)}{2 \times .191} = 1657.4$$

$$\text{Safety Factor} = \frac{\text{20 second strength}}{\text{Maximum stress}} = \frac{8470}{1657} = 5.11$$

Table 26 on the next page, gives the results of safety factor calculations based upon service factors of 0.5 and 0.4 for the 1¼" PVC Schedule 80 pipe of the example shown above using the full pressure rating calculated from the listed hydrostatic design stress. In each case, the hydrostatic design

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

SAFETY FACTOR (Continued)

basis = 4000 psi, and the water velocity = 5 feet per second. Comparing safety factor for this 1-¼" Schedule 80 pipe at different service factors, it is instructive to note that changing from a service factor of 0.5 to a more conservative 0.4 increases the safety factor only by 16%.

$$100 \times \left(\frac{1 - 3.38}{4.03}\right) = 16\%$$

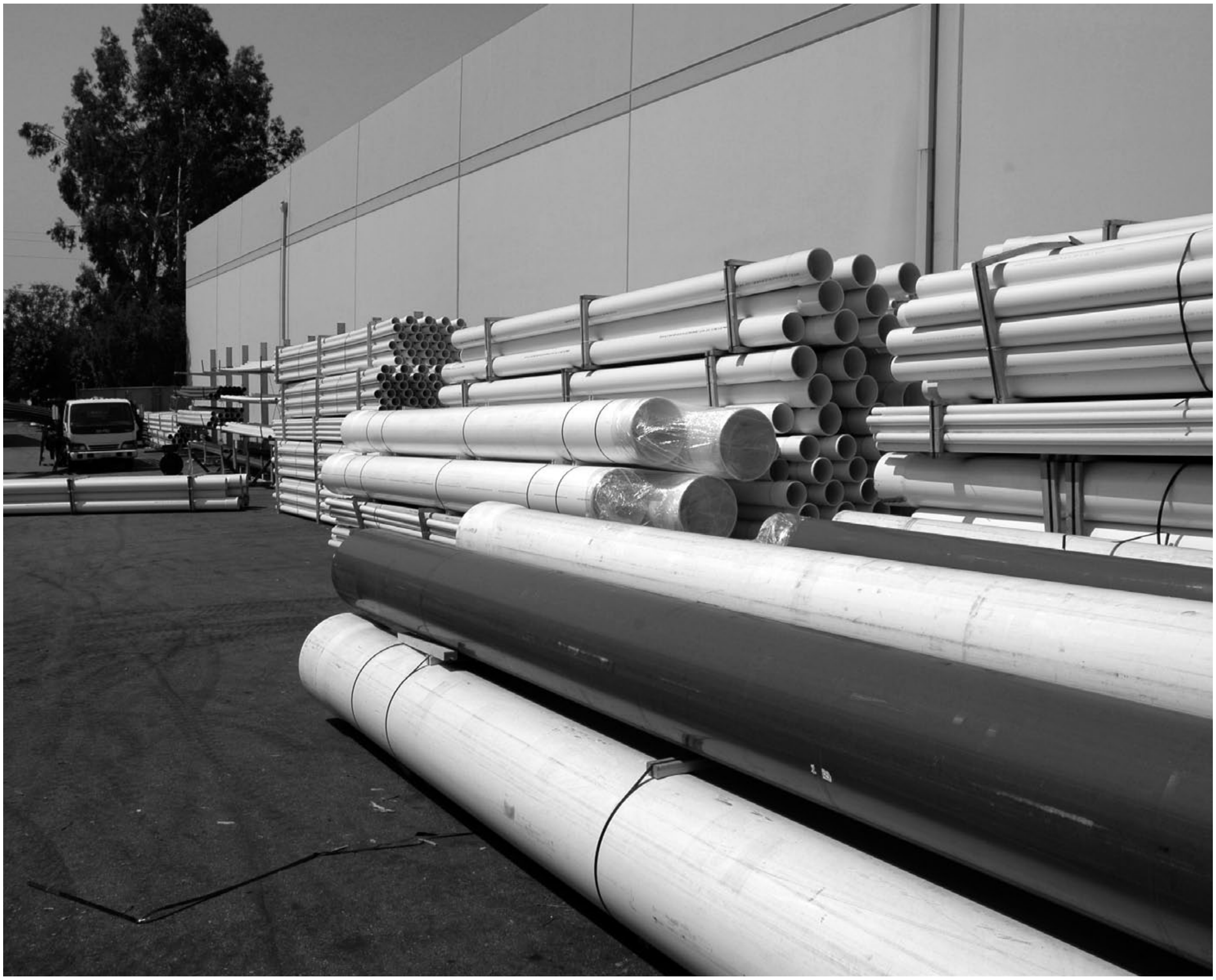
In the same way, changing the service factor from 0.4 to 0.35 increases the safety factor only by 9%. Changing the service factor from 0.5 to 0.35 increases the safety factor by 24%.

From these comparisons it is obvious that little is to be gained in safety from surge pressures by fairly large changes in the hydrostatic design stress resulting from choice of more conservative service factors

Pressure rating values are for PVC pipe, and for most sizes are calculated from the experimentally determined long-term strength of PVC extrusion compounds. Because molding compounds may differ in long term strength and elevated temperature properties from pipe compounds, piping systems consisting of extruded pipe and molded fittings may have lower pressure ratings than those shown here, particularly at the higher temperatures. Caution should be exercised in design operating above 100°F.

Table 26 SAFETY FACTORS VS. SERVICE FACTORS - PVC, TYPE 1 THERMOPLASTIC PIPE

PIPE CLASS	SERVICE FACTOR	HDS PSI	PRESSURE RATING PSI	SURGE PRESSURE AT 5 FT/SEC	MAXIMUM PRESSURE PSI	MAXIMUM STRESS PSI	SAFETY FACTOR
1¼" Sch 80	0.5	2000	520	131.0	651.0	2503.5	3.38
1¼" Sch 80	0.4	1600	416	131.0	547.0	2103.5	4.03



ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

EXPANSION AND CONTRACTION OF PLASTIC PIPE

Plastics, like other piping materials, undergo dimensional changes as a result of temperature variations above and below the installation temperature. In most cases, **piping should be allowed to move unrestrained in the piping support system** between desired anchor points without abrasion, cutting or restriction of the piping. Excessive piping movement and stresses between anchor points must be compensated for and eliminated by installing expansion loops, offsets, changes in direction or Teflon bellows expansion joints. (See Figures 5, 6, and 7 for installed examples.)

If movement resulting from these dimensional changes is restricted by adjacent equipment, improper pipe clamping and support, inadequate expansion compensation, or by a vessel to which the pipe is attached, the resultant stresses and forces may cause damage to the equipment or piping.

CALCULATING LINEAR MOVEMENT CAUSED BY THERMAL EXPANSION

The rate of movement (change in length) caused by thermal expansion or contraction can be calculated as follows:

$$\Delta L = 12yl\ (\Delta T)$$

Where:

ΔL = expansion or contraction in inches
y = coefficient of linear expansion of piping material selected (see Relative Properties on pages 4- 5.
l = length of piping run in feet
ΔT = $(T_1 - T_2)$ temperature change in degrees fahrenheit.

Where:

T_1 = maximum service temperature of system and
T_2 = temperature at time of installation (or difference between lowest system temperature and maximum system temperature, whichever is greater)

Example 1: Calculate the change in length for a 100 foot straight run of 2" Schedule 80 PVC pipe operating at a temperature of 73°F; installed at 32°F.

$$\Delta L = 12yl\ (\Delta T)$$

Where:

ΔL = expansion or contraction in inches
y = 2.9 x 10-5 in/in/°F
l = 100 ft.
ΔT = 41°F (73°F - 32°F)
ΔL = 12 in/ft x 0.000029in/in/ft x 100 ft x 41°F
ΔL = 1.43"

In this example the piping would expand approximately 1-½" in length over a 100 ft straight run once the operating temperature of 73°F was obtained.

Example 2: Calculate the change in length for a 100 foot straight run of 2" Schedule 80 CPVC pipe operating at a temperature of 180°F; installed at 80°F.

$$\Delta L = 12yl\ (\Delta T)$$

Where:

ΔL = expansion or contraction in inches
y = 3.4×10^{-5} in/in/°F
l = 100 ft.
ΔT = 100°F (180°F - 80°F)
ΔL = 12 in/ft x 0.000034in/in/ft x 100 ft x 100°F
ΔL = 4.08"

In example 2, the piping would expand approximately 4" in length over a 100 ft straight run once the operating temperature of 180°F was obtained .

The following tables have been prepared to assist in determining typical thermal expansion.

TABLE 27 - THERMAL EXPANSION ΔL (IN.) - PVC Type 1

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
30	0.11	0.22	0.32	0.43	0.54	0.65	0.76	0.86	0.97	1.08
40	0.14	0.29	0.43	0.58	0.72	0.86	1.01	1.15	1.30	1.44
50	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.40	1.62	1.80
60	0.22	0.43	0.65	0.86	1.08	1.30	1.51	1.72	1.94	2.16
70	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.02	2.30	2.52
80	0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.30	2.59	2.88
90	0.32	0.65	0.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100	0.36	0.72	1.03	1.44	1.80	2.16	2.52	2.88	3.24	3.60

Caution: Not all manufacturers formulate their resins the same; as a result the coefficient of linear expansion may be different from those used here. In critical applications, consult the manufacturer's published physical properties data.

TABLE 28 - THERMAL EXPANSION ΔL (IN.) - CPVC Schedule 80

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
20	0.09	0.18	0.27	0.36	0.46	0.55	0.64	0.73	0.82	0.91
30	0.14	0.27	0.41	0.55	0.68	0.82	0.96	1.09	1.23	1.37
40	0.18	0.36	0.55	0.73	0.91	1.09	1.28	1.46	1.64	1.82
50	0.23	0.46	0.68	0.91	1.14	1.37	1.60	1.82	2.05	2.28
60	0.27	0.55	0.82	1.09	1.37	1.64	1.92	2.19	2.46	2.74
70	0.32	0.64	0.96	1.28	1.60	1.92	2.23	2.55	2.87	3.19
80	0.36	0.73	1.09	1.46	1.82	2.19	2.55	2.92	3.28	3.65
90	0.41	0.82	1.23	1.64	2.05	2.46	2.87	3.28	3.69	4.10
100	0.46	0.91	1.37	1.82	2.28	2.74	3.19	3.65	4.10	4.56

TABLE 29 -THERMAL EXPANSION ΔL (IN.) Copolymer Polypropylene

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
20	0.15	0.29	0.44	0.59	0.73	0.88	1.02	1.17	1.32	1.46
30	0.22	0.44	0.66	0.88	1.10	1.32	1.54	1.76	1.98	2.20
40	0.29	0.59	0.88	1.17	1.46	1.76	2.05	2.34	2.64	2.93
50	0.37	0.73	1.10	1.46	1.83	2.20	2.56	2.93	3.29	3.66
60	0.44	0.88	1.32	1.76	2.20	2.64	3.07	3.51	3.95	4.39
70	0.51	1.02	1.54	2.05	2.56	3.07	3.59	4.10	4.61	5.12
80	0.59	1.17	1.76	2.34	2.93	3.51	4.10	4.68	5.27	5.86
90	0.66	1.32	1.98	2.69	3.29	3.95	4.61	5.27	5.93	6.59
100	0.73	1.46	2.20	2.93	3.66	4.39	5.12	5.86	6.59	7.32

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

TABLE 30 THERMAL EXPANSION ΔL (IN.) - PVDF Schedule 80

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
30	0.19	0.38	0.58	0.77	0.96	1.15	1.34	1.54	1.73	1.92
40	0.38	0.77	1.15	1.54	1.92	2.30	2.69	3.07	3.46	3.84
50	0.48	0.96	1.44	1.92	2.40	2.88	3.36	3.84	4.32	4.80
60	0.58	1.15	1.73	2.30	2.88	3.46	4.03	4.61	5.18	5.76
70	0.67	1.34	2.02	2.69	3.36	4.03	4.70	5.38	6.05	6.72
80	0.77	1.54	2.30	3.07	3.84	4.61	5.38	6.14	6.91	7.68
90	0.86	1.73	2.59	3.46	4.32	5.18	6.05	6.91	7.78	8.64
100	0.96	1.92	2.88	3.84	4.80	5.76	6.72	7.68	4.64	9.60

COMPENSATING FOR MOVEMENT CAUSED BY THERMAL EXPANSION AND CONTRACTION

In most piping applications the effects of thermal expansion/contraction are usually absorbed by the system at changes of direction in the piping. Long, straight runs of piping are more susceptible to experiencing measurable movement with changes in temperature. As with other piping materials, the installation of an expansion joints, expansion loops or offsets is required on long, straight runs. This will allow the piping system to absorb the forces generated by expansion/contraction without damage.

Once the change in length (AL) has been determined, the length of an offset, expansion loop, or bend required to compensate for this change can be calculated as follows:

$$\ell = \sqrt{\frac{3ED(\Delta L)}{2S}}$$

Where:

- ℓ = Length of expansion loop in inches
- E = Modulus of Elasticity
- D = Average outside diameter of pipe
- ΔL = Change in length of pipe due to temperature change
- S = Working stress at maximum temperature

Example: 2" Schedule 80 CPVC pipe operating temperature 180°F; installed at 80°F where ΔL = 4.08"

$$\ell = \sqrt{\frac{3ED(\Delta L)}{2S}}$$

$$\ell = \sqrt{\frac{3 \times 360{,}000 \times 2.375 \times 4.08}{2 \times 500}}$$

$$\ell = 102.29"$$

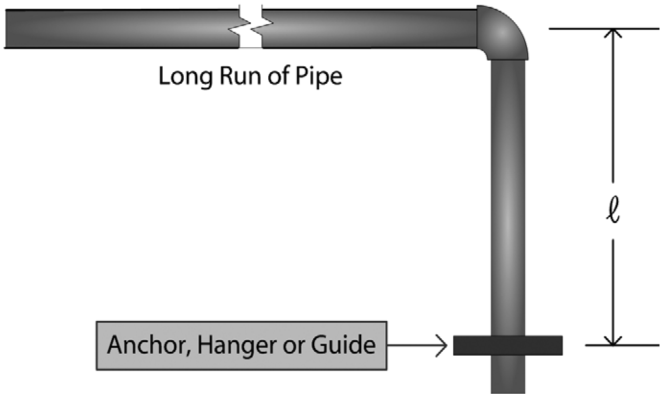


Figure 5 Bend or Change in Direction

Hangers or guides should only be placed in the loop, offset, or change of direction as indicated above and must not compress or restrict the pipe from axial movement. Piping supports should restrict lateral movement and should direct axial movement into the expansion loop configuration. Do not restrain "change in direction" configurations by butting up against joists, studs, walls or other structures. Use only solvent-cemented connections on straight pipe lengths in combination with 90° elbows to construct the expansion loop, offset or bend. The use of threaded components to construct the loop configuration is not recommended. Expansion loops, offsets, and bends should be installed as nearly as possible at the midpoint between anchors. Concentrated loads, such as valves, should not be installed in the developed length. Calculated support guide spacing distances for offsets and bends must not exceed recommended hanger support spacing for the maximum anticipated temperature. If that occurs, the distance between anchors will have to be reduced until the support guide spacing distance is equal to or less than the maximum recommended support spacing distance for the appropriate pipe size at the temperature used.

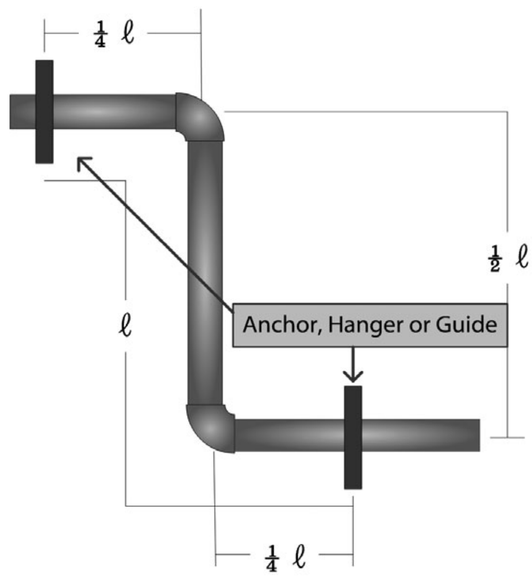


Figure 6 Typical Offset

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

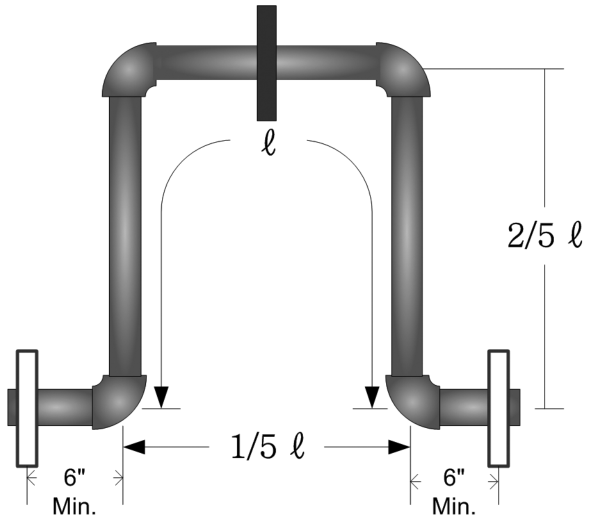


Figure 7 Typical Expansion Loop

The following expansion loop and offset lengths have been calculated based on stress and modulus of elasticities at the temperature shown below each chart.

TABLE 31 EXPANSION LOOPS AND OFFSET LENGTHS, PVC Type 1, Schedule 40 & 80

NOM. PIPE SIZE	AVERAGE O.D.	LENGTH OF RUN IN FEET									
		10	20	30	40	50	60	70	80	90	100
		LENGTH OF LOOP "ℓ" IN INCHES									
½	0.840	11	15	19	22	24	27	29	31	32	34
¾	1.050	12	17	21	24	27	30	32	34	36	38
1	1.315	14	19	23	27	30	33	36	38	41	43
1¼	1.660	15	22	26	30	34	37	40	43	46	48
1½	1.900	16	23	28	33	36	40	43	46	49	51
2	2.375	18	26	32	36	41	45	48	52	55	58
3	3.500	22	31	38	44	49	54	58	63	66	70
4	4.500	25	35	43	50	56	61	66	71	75	79
6	6.625	30	43	53	61	68	74	80	86	91	96
8	8.625	35	49	60	69	78	85	92	98	104	110
10	10.750	39	55	67	77	87	95	102	110	116	122
12	12.750	42	60	73	84	94	103	112	119	126	133

Note: Table based on stress and modulus of elasticity at 130°F
ΔT = 50°F, S = 600 psi, E = 3.1 x 10 psi

Caution: Not all manufacturers formulate their resins the same; as a result the modulus of elasticity may be different from those used here. In critical applications, consult the manufacturer's published physical properties data.

TABLE 32 EXPANSION LOOPS AND OFFSET LENGTHS, CPVC Schedule 80

NOM. PIPE SIZE	AVERAGE O.D.	LENGTH OF RUN IN FEET									
		10	20	30	40	50	60	70	80	90	100
		LENGTH OF LOOP "ℓ" IN INCHES									
½	0.840	15	21	26	30	33	37	39	42	45	47
¾	1.050	17	22	27	31	34	38	40	43	46	48
1	1.315	19	26	32	37	42	46	49	53	56	59
1¼	1.660	21	30	36	42	47	52	56	59	63	67
1½	1.900	23	32	39	45	50	55	59	64	67	71
2	2.375	25	35	43	50	56	62	67	71	75	80
3	3.500	31	43	53	61	68	75	81	86	91	97
4	4.500	35	49	60	69	77	85	92	98	103	109
6	6.625	42	59	73	84	94	103	111	119	125	133
8	8.625	48	67	83	96	107	118	127	135	143	152
10	10.750	54	75	93	107	119	131	142	151	160	169
12	12.750	59	82	101	116	130	143	154	164	174	184

Note: Table based on stress and modulus of elasticity at 160°F.
ΔT = 100°F, S = 750 psi, E = 2.91 x 10 psi

TABLE 33 EXPANSION LOOPS AND OFFSET LENGTHS, Copolymer Polypropylene

NOM. PIPE SIZE	AVERAGE O.D.	LENGTH OF RUN IN FEET									
		10	20	30	40	50	60	70	80	90	100
		LENGTH OF LOOP "ℓ" IN INCHES									
½	0.840	18	25	31	36	40	44	47	50	54	57
¾	1.050	20	28	35	40	45	49	53	56	60	63
1	1.315	22	32	39	45	50	55	59	63	67	71
1¼	1.660	25	35	43	50	56	62	66	71	75	79
1½	1.900	27	38	46	54	60	66	71	76	81	85
2	2.375	30	42	52	60	67	74	79	85	90	95
3	3.500	36	52	63	73	81	89	96	103	109	115
4	4.500	41	58	71	83	92	101	109	117	124	131
6	6.625	50	71	87	100	112	123	132	142	151	159
8	8.625	57	81	99	114	128	140	151	162	172	181
10	10.750	64	90	111	128	143	156	169	181	192	202
12	12.750	69	98	121	139	155	170	184	197	209	220

Note: Table based on stress and modulus of elasticity at 160°F.
ΔT = 100°F, S = 240 psi, E = 0.83 x 10 lb/in.

TABLE 34 EXPANSION LOOPS AND OFFSET LENGTHS, PVDF Schedule 80

NOM. PIPE SIZE	AVERAGE O.D.	LENGTH OF RUN IN FEET									
		10	20	30	40	50	60	70	80	90	100
		LENGTH OF LOOP "ℓ" IN INCHES									
½	0.840	10	15	18	20	23	25	27	29	31	32
¾	1.050	11	16	20	23	26	28	30	32	34	36
1	1.315	13	18	22	26	29	31	34	36	38	40
1¼	1.660	14	20	25	29	32	35	38	41	41	45
1½	1.900	15	22	27	31	34	38	41	44	44	49
2	2.375	17	24	30	34	38	42	46	49	49	54

Note: Table based on stress and modulus of elasticity at 160°F.
ΔT = 100°F, S = 1080 psi, E = 1.04 x 10 psi

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

These tables are based on the formula:

F = AS = restraining force, lbs.

Where:

A = Cross sectional wall area, in.^{2}
S = e(ΔT)E
e = Coefficient of the linear expansion*
E = Modulus of elasticity*
ΔT = Temperature change, °F

* All values are available from the relative properties chart on page 4-5

TABLE 35 RESTRAINT FORCE "F" (Lb.)
PVC, Type 1, Schedule 40 and 80

PIPE SIZE	SCHEDULE 40 PVC			SCHEDULE 80 PVC		
	CROSS-SECTIONAL WALL AREA (IN.)	ΔT = 50°F S = 630 PSI	ΔT = 100°F S = 1260 PSI	CROSS SECTIONAL WALL AREA (IN.)	ΔT = 50°F S = 630 PSI	ΔT = 100°F S = 1260 PSI
½	.250	155	310	.320	200	400
¾	.333	210	420	.434	275	550
1	.494	310	622	.639	405	810
1¼	.669	420	840	.882	555	1,110
1½	.800	505	1,010	1.068	675	1,350
2	1.075	675	1,350	1.477	930	1,860
3	2.229	1,405	2,810	3.016	1,900	3,860
4	3.174	2,000	4,000	4.407	2,775	5,550
6	5.581	3,515	7,030	8.405	5,295	10,590
8	8.399	5,290	10,580	12.763	8,040	16,080
10	11.908	7,500	15,000	18.922	11,920	23,840
12	15.745	9,920	19,840	26.035	16,400	32,800

TABLE 36 - RESTRAINT FORCE "F" (Lb.)
CPVC Schedule 80

PIPE SIZE	CROSS-SECTIONAL WALL AREA (IN.)	ΔT = 50°F S = 805 PSI	ΔT = 100°F S = 1610 PSI
½	.320	260	520
¾	.434	350	700
1	.639	515	1,030
1¼	.882	710	1,420
1½	1.068	860	1,720
2	1.477	1,190	2,380
3	3.016	2,430	4,860
4	4.407	3,550	7,100
6	8.405	6,765	13,530
8	12.763	10,275	20,550
10	18.922	15,230	30,460
12	26.035	20,960	41,920

TABLE 37 RESTRAINT FORCE "F" (Lb.)
Copolymer Polypropylene Schedule 80

PIPE SIZE	CROSS-SECTIONAL WALL AREA (IN.)	ΔT = 50 °F S = 550 PSI	ΔT = 100°F S = 1110 PSI
½	.320	147	294
¾	.434	199	398
1	.639	293	586
1¼	.882	404	808
1½	1.068	489	978
2	1.477	663	1,325
3	3.016	1,381	2,276
4	4.407	2,018	4,036
6	8.405	3,899	7,698
8	12.763	5,895	11,690
10	18.922	8,666	17,332
12	26.035	11,929	23,848

TABLE 38 RESTRAINT FORCE "F" (Lb.)
PVDF Schedule 80

PIPE SIZE	CROSS-SECTIONAL WALL AREA (IN.)	ΔT = 50°F S = 850 PSI	ΔT = 100°F S = 1700 PSI
½	.320	270	540
¾	.434	370	740
1	.639	540	1,080
1¼	.882	750	1,500
1½	1.068	905	1,810
2	1.477	1,255	2,510
3	3.016	2,565	5,130
4	4.407	3,745	7,490

Caution: Not all manufacturers formulate their resins the same; as a result the modulus of elasticity and coefficient of linear expansion may be different from those used here. In critical applications, consult the manufacturer's published physical properties data.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

THRUST

Thrust forces can occur at any point in a piping system where the directional or cross-sectional area of the waterway changes or where additional structural loads such as valves are installed. These forces must be reduced by means of anchors, risers, restraining hangers, thrust blocks or encasement. The method chosen will depend on whether the system is buried or above ground.

The size or need for reinforcements should be based on the design engineer's evaluation of flow velocities and pressure increases due to the fluid's momentum. Note that the thrust created at unrestrained fittings can be considerable (as shown in Table 39 and should be addressed during installation. For more detail regarding estimating and compensating for thrust forces, refer to engineering textbooks such as the *Uni-Bell Handbook of PVC Pipe*.

Table 39

Thrust at Fittings in pounds Per 100 psi (internal pressure)

Pipe Size (in.)	Blank ends & junctions	90° Bends	45° Bends	22½° Bends	11¼° Bends
½	60	85	50	25	15
¾	90	130	70	35	20
1	140	200	110	55	30
1¼	220	320	170	90	45
1	300	420	230	120	60
2	450	630	345	180	90
2½	650	910	500	260	130
3	970	1,360	745	385	200
4	1,600	2,240	1,225	635	320
6	3,450	4,830	2,650	1,370	690
8	5,850	8,200	4,480	2,320	1,170
10	9,100	12,750	6,980	3,610	1,820
12	12,790	17,900	9,790	5,080	2,550
14	15,400	21,500	11,800	6,100	3,080
16	20,100	28,150	15,400	7,960	4,020
18	25,400	35,560	19,460	10,060	5,080
20	31,400	43,960	24,060	12,440	6,280
24	45,300	63,420	34,700	17,940	9,060

Additionally, the calculation for thrust due to static pressure is:

$$Thrust = \frac{((Average\ I.D.)^2 \mu)}{4} \text{ X (Working Pressure) X (z)}$$

Where: z = 1.0 for Tees, 60° Elbows, Plugs and Caps
= .390 for 22½° Bends
= 764 for 45° Elbows
= 1.414 for 90° Elbows

GENERAL PRINCIPLES OF SUPPORT

Adequate support for any piping system is a matter of great importance. In practice, support spacing is a function of pipe size, its weight and contents, plus operating temperatures, and the location of heavy valves or fittings. The mechanical properties of the pipe material must also be taken into consideration.

To ensure satisfactory operation of a thermoplastic piping system, the location and type of hangers must be carefully planned. The principles of design for steel piping systems (simple and continuous beam calculations) are generally applicable to thermoplastic piping systems. Proper design will prevent stress concentration areas as a result of weight loading, bending stresses, the effects of thermal expansion/contraction and limit pipe displacement (sag). The following considerations are critical to proper support, design and a successful project.

Concentrated loads (i.e. valves, flanges, etc.) should be supported directly to eliminate high stress concentrations on the pipe. Should this be impractical, the pipe must then be supported immediately adjacent to any extra load.

Valves should be braced against operating torque. Heavy metal valves should be supported so as not to induce additional stress on the thermoplastic piping system.

In systems where large fluctuations in temperature occur, allowance must be made for expansion and contraction of the piping system. Since changes in direction in the system are usually sufficient to allow expansion and contraction, hangers must be placed so proper movement is not restricted.

Note that in some instances it may be desirable to use a clamp-type hanger to direct thermal expansion or contraction in a specific direction. When using a clamp-type hanger, the hanger should not deform the pipe when it has been tightened.

Since thermoplastic piping is somewhat notch sensitive, hangers should provide as much bearing surface as possible. Sharp supports or sharp edges on supports should not be used with thermoplastic piping because they will cause mechanical damage if and when the pipe moves

Changes in direction (e.g., 90° elbows) should be supported as close as practical to the fitting to avoid introducing excessive tensional stresses into the system.

When a thermoplastic piping is designed to operate at or near maximum recommended temperature limits, it may be more economical to provide continuous support for the system. Consider using structural angle or channel that is free from rough or sharp edges.

Always consult local building, mechanical, and plumbing codes before installation. Check with all local authorities having jurisdiction over the installation.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

HANGERS, ANCHORS & GUIDES

Proper selection and location of pipe supports are critical to the life of any piping system. The use of improper supports can generate excessive sag resulting in failure of the piping system. Many hangers designed for use with metallic piping are suitable for thermoplastic piping systems too; however, selected hangers, anchors and guides must be free of rough or sharp edges that could damage the piping system. It is also extremely important that all supports provide an adequate load bearing surface to handle the weight loading and all stress plus movement of the piping system caused be thermal expansion and contraction. Increase in temperature will require additional supports and in some cases it may be more economical to provide continuous support for the system via structural angle or channel. Regardless of the method chosen the support system must allow axial movement while prohibiting transverse or lateral movement. Sleeving plastic pipe at horizontal support points with one pipe size larger which allows unrestricted movement is recommended.

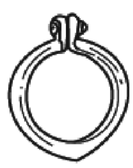
Vertical lines must also be supported at proper intervals so that the fitting at the lower end is not overloaded. The supports should not exert a compressive strain on the pipe such as the double-bolt type. Riser clamps squeeze the pipe and are not recommended. If possible, each clamp should be located just below a coupling or other fitting so that the shoulder of the coupling provides bearing support to the clamp.

Anchors are utilized to direct movement of the piping by providing restraint at key points in the system. Their use may be required to control the effects of movement caused by expansion and contraction, forces generated by pressure surges, vibration, and other transient conditions. Anchors and guides are typically installed on long straight runs, at changes in direction of the system, and where expansion joints and other methods of thermal compensation are utilized. Guides are necessary to help direct movement between anchors by allowing longitudinal movement while restricting lateral movement. Since guides act as support they should have the same load bearing surface and other requirements of hangers designed for the system. Guides must be rigidly attached to the structure to prevent lateral movement, but should not restrict longitudinal movement of the pipe through the guide. Anchors and guides must be engineered and installed such a manor to perform adequately without point loading the system.

RECOMMENDED PIPE HANGERS FOR THERMOPLASTIC PIPING SYSTEMS

PIPE RING

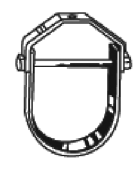
Adj. Swivel Ring
Split Ring type
¾" to 8" pipe



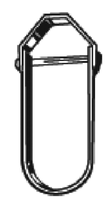
Split Ring
⅜" - 8" pipe

Adj. Ring
½" - 8" pipe

Adj. Swivel Ring
½" - 8" pipe

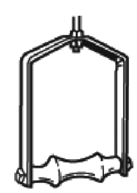


Adj. Clevis - Standard
½" - 30" pipe

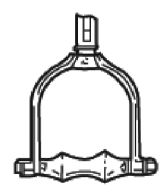


Adj. Clevis For Insulated Lines
¾" - 12" pipe

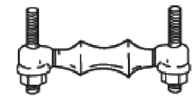
PIPE ROLLERS



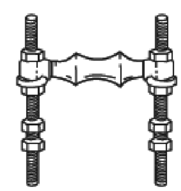
Adj. Steel Yoke Pipe Roll
2½" - 20" pipe



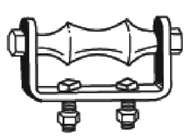
Adj. Swivel Pipe Roll
2½" - 12" pipe



Single Pipe Roll
1" - 30" pipe

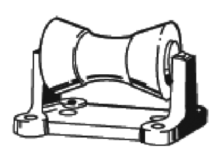


Adj. Pipe Roll Support
1" - 30" pipe



Roller Chair
2" - 12" pipe

Pipe Roll and Plate
2" - 24" pipe

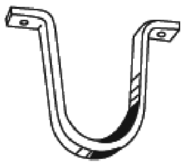


Pipe Roll Stand Complete
2" - 42" pipe

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

HANGERS, ANCHORS & GUIDES

PIPE STRAPS AND HOOKS

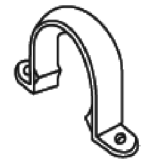


Wrought Strap Short
½" - 4" pipe

One Hole Clamp
⅜" - 4" pipe

Tin Strap
½" - 2" pipe

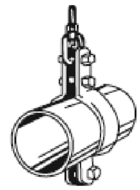
IPEX Cobra Pipe Clip -
Polyethylene ⅜" - 4" pipe



Saddle Clip - PVC or
Polypropylene ⅜" - 4" pipe

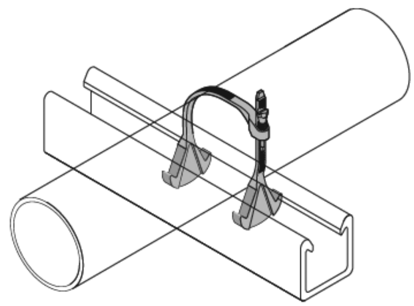
PIPE CLAMPS

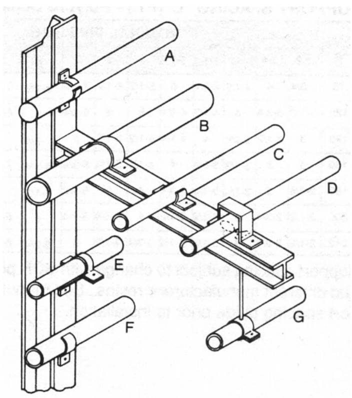
Pipe Clamp Medium
½" - 24" pipe

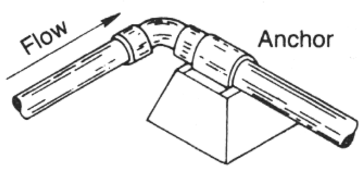


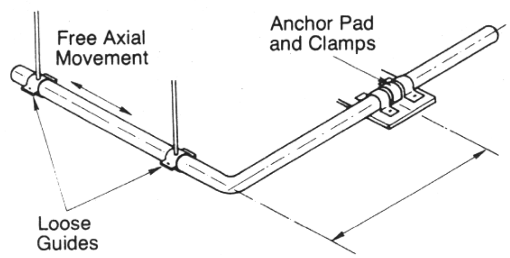
Double Bolt Pipe Clamp
¾" - 36" pipe

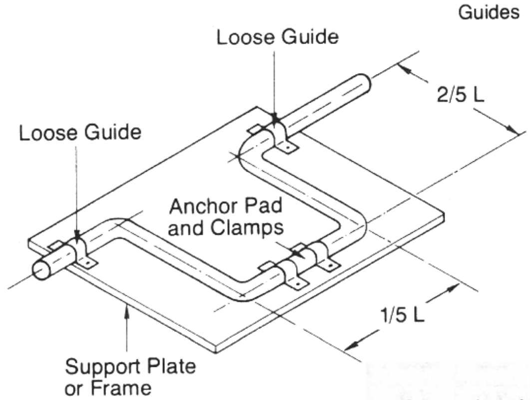
PIPE ADJUSTABLE CLAMPS

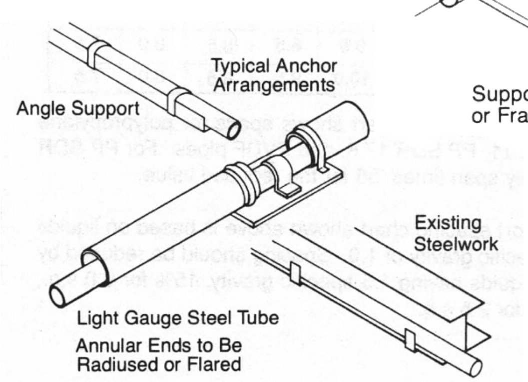


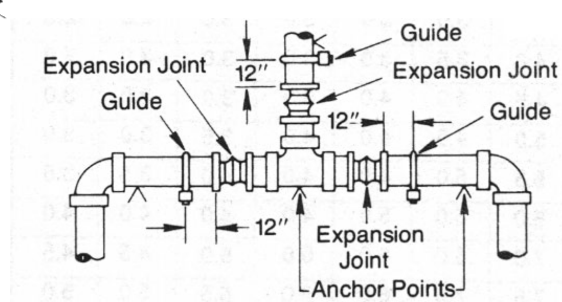












ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

SUPPORT SPACING OF PLASTIC PIPE

When thermoplastic piping systems are installed above ground, they must be properly supported to avoid unnecessary stresses and possible sagging. Horizontal runs require the use of hangers spaced approximately as indicated in the tables for individual material show below. Note that additional support is required as temperatures increase. Continuous support can be accomplished by the used of a smooth structural angle or channel. Where the pipe is exposed to impact damage, protective shields should be installed. Tables are based on the maximum deflection of a uniformly loaded, continuously supported beam calculated from:

$$y = .00541 \frac{wL^4}{EI}$$

Where:

- y = Deflection or sag, in.
- w = Weight per unit length, lb/in.
- L = Support spacing, in.
- E = Modulus of elasticity at given temp. lb/in.^{2}
- I = Moment of inertia, in.^{4}

If 0.100 inch is chosen arbitrarily as the permissible sag (y) between supports then:

$$L^4 = 18.48 \frac{EI}{W}$$

Where:

W = Weight of Pipe + Weight of Liquid, lb./in.

For a pipe $I = \frac{\pi}{64} (Do^4 - Di^4)$

Where :

Do = Outside diameter of the pipe
Di = Inside diameter of the pipe

Then:

$$L = .907 \frac{E}{W} (Do^4 - Di^4)^{1/4} = .976 \frac{E}{W} (Do^4 - Di^4)$$

Table 40 SUPPORT SPACING "L" (FT.)Polypropylene Sch 80

PIPE SIZE	TEMPERATURE (°F)					
	73	120	140	160	180	200
½	3.75	3.50	3.0	3.0	2.75	2.5
¾	4.0	3.75	3.5	3.0	3.0	2.75
1	4.5	4.0	3.75	3.5	3.25	3.0
1¼	4.75	4.5	4.0	3.75	3.5	3.5
1½	5.0	4.75	4.25	4.0	3.75	3.5
2	5.5	5.0	4.5	4.25	4.0	4.0
3	6.5	6.0	5.5	5.25	5.0	4.75
4	7.25	6.75	6.0	5.75	5.5	5.25
6	8.5	8.0	7.25	6.75	6.5	6.0
8	9.5	8.75	8.0	7.5	7.0	6.75
10	10.5	9.75	8.75	8.25	7.75	7.5
12	11.25	10.5	9.5	9.0	8.25	8.0

Table 41 SUPPORT SPACING "L" (FT.) PVDF Sch 80

PIPE SIZE	TEMPERATURE (°F)						
	68	120	160	200	240	260	280
½	3.5	3.0	2.75	2.5	2.25	2.25	2.0
¾	3.75	3.25	3.0	2.75	2.50	2.50	2.25
1	4.25	3.75	3.5	3.0	2.75	2.75	2.25
1¼	4.5	4.0	3.75	3.5	3.0	3.0	2.75
1½	4.75	4.25	4.0	3.5	3.25	3.25	3.0
2	5.25	4.75	4.25	4.0	3.5	3.5	3.25
3	6.5	5.75	5.25	4.75	4.25	4.0	4.0
4	7.0	6.25	5.75	5.25	4.75	4.5	4.25
6	8.5	7.5	6.75	6.25	5.5	5.5	5.25
8	9.5	8.25	7.5	7.0	6.25	6.0	5.75
10	10.5	9.25	8.5	7.75	7.0	6.75	6.5
12	11.25	10.0	9.0	8.25	7.5	7.25	7.0

Note: The preceding tables for Schedule 80 Polypropylene and PVDF are based in 100 inch SAG between supports.

CAUTION:
Support spacing subject to change with SDR Polypropylene and PVDF piping systems from different manufacturers' using different resins. See manufacturers support spacing guide prior to installation.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

Support Spacing (Continued)

In years past, support system spacing data for PVC and CPVC was a little simpler as most manufacturers used the same resin formulations and processing techniques. However today many suppliers formulate their own resins, all within the same ASTM standard, but resulting in slightly different physical properties. Therefore, Harrington recommends specifying a particular manufacturer and using their support spacing recommendations throughout the complete system. For example, the recommendations of two different manufacturers are shown below for comparison purposes.

Table 42 Recommended Maximum Support Spading in feet by two manufacturers

Manufacturer A

Manufacturer B*

PIPE SIZE (IN.)	SCHEDULE 40 PVC						SCHEDULE 80 PVC					
	60°F		100°F		140°F		60°F		100°F		140°F	
¼	4	N/A	3.5	N/A	2	N/A	4	N/A	3.5	N/A	2	N/A
⅜	4	N/A	3.5	N/A	2	N/A	4.5	N/A	4	N/A	2.5	N/A
½	4.5	3.0	4	2.9	2.5	2.6	5	3.1	4.5	3.0	2.5	2.7
¾	5	3.4	4	3.2	2.5	3	5.5	3.5	4.5	3.4	2.5	3.1
1	5.5	3.9	4.5	3.7	2.5	3.4	6	4.0	5	3.9	3	3.6
1¼	5.5	4.3	5	4.2	3	3.9	6	4.6	5.5	4.4	3	4.1
1½	6	4.7	5	4.5	3	4.1	6.5	5	5.5	4.8	3.5	4.4
2	6	5.2	5	5	3	4.6	7	5.6	6	5.4	4	5
2½	7	N/A	6	N/A	3.5	N/A	7.5	N/A	6.5	N/A	4	N/A
3	7	6.7	6	6.4	3.5	5.9	8	7.2	7	6.9	4.5	6.4
3½	7.5	N/A	6.5	N/A	4	N/A	8.5	N/A	7.5	N/A	4.5	N/A
4	7.5	7.6	6.5	7.3	4	6.7	9	8.2	7.5	7.9	5	7.3
5	8	N/A	7	N/A	4	N/A	9.5	N/A	8	N/A	5	N/A
6	8.5	9.3	7.5	8.9	4.5	8.2	10	10.3	9	9.9	5	9.2
8	9	10.7	8	10.2	4.5	9.5	11	12	9.5	11.5	5.5	10.6
10	10	12	8.5	11.5	5	10.7	12	13.7	10	13.1	6	12.1
12	11.5	13.2	9.5	12.7	5.5	11.8	13	15.2	10.5	14.6	6.5	13.5
14	12	14	10	13.5	6	12.4	13.5	16.2	11	15.6	7	14.4
16	12.5	15.3	10.5	14.7	6.5	13.6	14	17.6	11.5	16.9	7.5	15.7
18	13	16.6	11	15.9	7	14.7	14.5	19	12	18.3	9	16.9
20	14	17.5	11.5	16.8	8.5	15.5	15.5	20	12.5	19.5	9.5	18.1
24	15	19.6	12.5	18.8	9.5	17.4	17	20	14	20	10.5	20

*Manufacturer B states "based on a sag limit of 0.2% span length that is well within the bending stress limits of the material. This conservative calculation is also intended to accommodate expansion and contraction, pressure surges and entrained air. Bearing surfaces of supports should be at least 2" wide."
N/A = Data not available at time of printing

All recommendations shown above are based on handling solutions with a specific gravity of 1.0. When the fluid has a specific gravity greater than water (S.G. 1.0) the hanging distance must be decreased by dividing the recommended support distance by the fluid's specific gravity.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

Table 43 Recommended Maximum Support Spading in Feet by Two Manufacturers

Manufacturer A

Manufacturer B*

PIPE SIZE (IN.)	SCHEDULE 80 CPVC													
	73°F		100°F		120°F		140°F		160°F		180°F		200°F	
½	5.5	3.1	5	3	4.5	2.9	4.5	2.8	3	2.7	2.5	2.7	NOT PUBLISHED BY THIS SUPPLIER	2.5
¾	5.5	3.5	5.5	3.4	5	3.3	4.5	3.2	3	3.1	2.5	3		2.8
1	6	4.1	6	3.9	5.5	3.8	5	3.7	3.5	3.6	3	3.5		3.3
1¼	6.5	4.6	6	4.5	6	4.4	5.5	4.2	3.5	4.1	3	4		3.7
1½	7	5.0	6.5	4.8	6	4.7	5.5	4.6	3.5	4.4	3.5	4.3		4
2	7	5.6	7	5.5	6.5	5.3	6	5.2	4	5	3.5	4.9		4.5
2½	8	6.5	7.5	6.3	7.5	6.1	6.5	5.9	4.5	5.7	4	5.6		5.2
3	8	7.2	8	7	7.5	6.8	7	6.6	4.5	6.4	4	6.2		5.8
3½	8.5	N/A	8.5	N/A	8	N/A	7.5	N/A	5	N/A	4.5	N/A		N/A
4	8.5	8.3	9	8.1	8.5	7.8	7.5	7.6	5	7.4	4.5	7.1		6.7
6	10	10.4	9.5	10.1	9	9.8	8	9.5	5.5	9.2	5	9		8.4
8	11	12.1	10.5	11.7	10	11.4	9	11	6	10.7	5.5	10.4		9.7
10	11.5	13.8	11	13.4	10.5	13	9.5	12.6	6.5	12.3	6	11.9		11.1
12	12.5	15.4	12	15	11.5	14.5	10.5	14.1	7.5	13.7	6.5	13.3		12.4
14	15	16.4	13.5	15.9	12.5	15.4	11	15	9.5	14.5	8	14.1		13.2
16	16	17.8	15	17.3	13.5	16.8	12	16.3	10	15.4	8.5	14.9		14.3

*Based on a sag limit of 0.2% of span length. Greater than 200°F requires continuous support. Bearing surfaces of support should be at least 2" wide.

Table 44

PIPE SIZE (IN.)	SCHEDULE 40 CPVC													
	73°F		100°F		120°F		140°F		160°F		180°F		200°F	
½	5	3	4.5	2.9	4.5	2.8	4	2.7	2.5	2.7	2.5	2.6	NOT PUBLISHED BY THIS SUPPLIER	2.4
¾	5	3.4	5	3.3	4.5	3.2	4	3.1	2.5	3	2.5	2.9		2.7
1	5.5	3.9	5.5	3.8	5	3.7	4.5	3.5	3	3.4	2.5	3.3		3.1
1¼	5.5	4.4	5.5	4.3	5.5	4.1	5	4	3	3.9	3	3.8		3.5
1½	6	4.7	6	4.6	5.5	4.4	5	4.3	3.5	4.2	3	4		3.8
2	6	5.3	6	5.1	5.5	5	5	4.8	3.5	4.7	3	4.5		4.2
2½	7	6.1	7	5.9	6.5	5.7	6	5.6	4	5.4	3.5	5.2		4.9
3	7	6.7	7	6.5	7	6.3	6	6.1	4	6	3.5	5.8		5.4
3½	7.5	N/A	7.5	N/A	7	N/A	6.5	N/A	4	N/A	4	N/A		N/A
4	7.5	7.7	7.5	7.4	7	7.2	6.5	7	4.5	6.8	4	6.6		6.2
6	8.5	9.4	8	9.1	7.5	8.8	7	8.6	5	8.3	4.5	8.1		7.5
8	9.5	10.8	9	10.5	8.5	10.2	7.5	9.9	5.5	9.6	5	9.3		8.7
10	10.5	12.2	10	11.8	9.5	11.5	8	11.1	6	10.8	5.5	10.5		9.8
12	11.5	13.4	10.5	13	10	12.7	8.5	12.3	6.5	11.9	6	11.5		10.6
14	12	14.2	11	13.8	10	13.4	9	13	8	12.6	6	12.2		11.3
16	13	15.5	12	15.1	11	14.6	9.5	14.2	8.5	18.8	7	13.4		12.1

*Based on a sag limit of 0.2% of span length. Greater than 200°F requires continuous support. Bearing surfaces of support should be at least 2" wide.

All recommendations shown above are based on handling solutions with a specific gravity of 1.0. When the fluid has a specific gravity greater than water (S.G. 1.0) the hanging distance must be decreased by dividing the recommended support distance by the fluid's specific gravity.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

Table 45

PIPE SIZE (IN.)	ASAHI/AMERICA PROLINE PRO 150 SUPPORT SPACING IN FEET						
	68°F	86°F	104°F	122°F	140°F	158°F	176°F
	20°C	30°C	40°C	50°C	60°C	70°C	80°C
½	3	2.5	2.5	2	2	2	2
¾	3	3	2.5	2.5	2.5	2.5	2
1	3.5	3	3	3	3	2.5	2.5
1½	4	3.5	3	3	3	3	3
2	4.5	4	4	3.5	3	3	3
2½	5	4.5	4	4	3.5	3	3
3	5.5	5	4	4	4	3.5	3.5
4	6	5	5	4	4	4	4
6	7	6	6	5	5	4.5	4.5
8	7.5	7	6	6	5.5	5	5
10	8.5	7.5	7	6.5	6	6	5.5
12	9.5	8.5	8	7	7	6.5	6
14	10	8.5	8	7.5	7	6.5	6.5
16	10.5	9.5	8.5	8	7.5	7	6.5
18	11.5	10	9	8.5	8	7.5	7

PIPE SIZE (IN.)	ASAHI/AMERICA PROLINE PRO 45 SUPPORT SPACING IN FEET						
	68°F	86°F	104°F	122°F	140°F	158°F	176°F
	20°C	30°C	40°C	50°C	60°C	70°C	80°C
2	2.5	2.25	2.25	2	1.5	1.5	1.5
2½	2.75	2.5	2.25	2.25	2	1.5	1.5
3	3.5	2.75	2.75	2.25	2.25	2.25	2.25
6	4	3.5	3.5	2.75	2.75	2.5	2.5
8	4	4	3.5	3.5	3	2.75	2.75
10	4.5	4	4	3.5	3.5	3.5	3
12	5	4.5	4.5	4	4	3.5	3.5
14	5.5	4.5	4.5	4	4	3.5	3.5
16	6	5	4.5	4	4	4	3.5
18	6.5	5.5	5	4.5	4.5	4	4
20	6.5	6	5	4.5	4.5	4.5	4
24	7.5	6.5	5.5	4.5	4.5	4.5	4

PIPE SIZE (IN.)	ASAHI/AMERICA PROLINE PRO 150 SUPPORT SPACING IN FEET						
	68°F	86°F	104°F	122°F	140°F	158°F	176°F
	20°C	30°C	40°C	50°C	60°C	70°C	80°C
½	3	2.5	2.5	2	2	2	2
¾	3	3	2.5	2.5	2.5	2.5	2
1	3.5	3	3	3	3	2.5	2.5
1½	4	3.5	3	3	3	3	3
2	4.5	4	4	3.5	3	3	3
2½	5	4.5	4	4	3.5	3	3
3	5.5	5	4	4	4	3.5	3.5
4	6	5	5	4	4	4	4
6	7	6	6	5	5	4.5	4.5
8	7.5	7	6	6	5.5	5	5
10	8.5	7.5	7	6.5	6	6	5.5
12	9.5	8.5	8	7	7	6.5	6

*Above values are based on water with a specific gravity of 1.0. Correction factors must be used when handling higher specific gravities as follows: 0.90 for S.G. = 1.5, 0.85 for S.G. = 2.0, 0.8 for S.G. = 2.5

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

AIR RELIEF

All piping systems will trap air or other gases at high points in the system. It is recommended that air release valves ¼ of line size be placed at all high points in a piping system. Trapped gases are a common cause of greatly reduced flows and broken plastic pipe and fittings during a hydro test and while the system is being operated. Tests have shown that air moving under pressure multiplies the applied pressure 15 times. Trapped gases are usually stationary at the high point and act as a partially open valve to liquid trying to pass. Gases readily compress compared to a liquid. When pressure is applied to a liquid being pumped, the trapped gas is compressed and stores energy. Surges created by opening and closing valves or starting and stopping pumps will cause the gas to suddenly move downstream, releasing its stored energy, and creating pressure surges far greater than the piping system is designed for. Gases in small amounts go into and come out of solution while a system is being operated. These gases will continue to cause operating problems and possible piping damage unless automatic air release valves are used which are capable of releasing air while the valve is in contact with the liquid being pumped.

OZONE

Ozone is a form of oxygen. In its pure form it is an unstable blue gas with a pungent odor. It is formed naturally in the air from lighting and is seen as a blue halo effect. Ozone, $0_{3.}$ is used as a bactericide in deionized water systems in low concentrations of 0.04 to 5 PPM and presents no problem to plastic piping in aqueous form. In high concentrations. Ozone acts as a strong oxidizer. Pigments and resin additives will be leached out of PVC, CPVC, and polypropylene. Polypropylene will stress crack. PVDF or Teflon should be used for gaseous ozone.

Ozone deteriorates rubber in trace amounts, and with its increasing use to sterilize high-purity water systems, the elastomers used for seats and seals become a matter for concern. Commercial mixtures are ordinarily 2% ozone and are produced by electronic irradiation of air. It is usually manufactured on the spot, as it is too expensive to ship.

Butyl rubber (EPDM) has good resistance to ozone as does Fluorine rubber FKM (Viton) and chlorine sulphonyl polyethylene (Hypalon). Neoprene and Buna-N or Nitrile are severely attacked. On the plastics, PVDF holds up best; but PVC is marginally acceptable. The polyolefins, i.e, polypropylene and polyethylene are attacked.

You might wish to review your ozone application with the Technical Services staff at Harrington.

PRESSURE REGULATION AND PRESSURE RELIEF

Pressure regulators are usually installed near a pump to maintain constant downstream pressure. All pressure regulators are capable of failure due to a ruptured diaphragm, seal, or lodging of debris. When a pressure regulator fails, full pump or line pressure is transferred downstream causing a potentially catastrophic failure to piping. Pressure relief valves should be installed on the downstream side of all pressure regulators and discharge into the suction side of the pump or into a storage tank. In general, a pressure relief valve should be sized to ¼ of line size.

SUNLIGHT WEATHERING AND PAINTING

Plastic pipe and fittings have varying resistance to weathering. PVC, CPVC, and Polypropylene undergo surface oxidation and embrittlement by exposure to sunlight over a period of several years. The surface oxidation is evident by a change in pipe color from gray to white. Oxidized piping does not lose any of its pressure capability. It does, however, become much more susceptible to impact damage. PVDF is unaffected by sunlight but is translucent when unpigmented.

PVC and CPVC pipe and fittings can be easily protected from ultraviolet oxidation by painting with a heavily pigmented, exterior water base latex paint. The color of the paint is of no particular importance, as the pigment acts as an ultraviolet screen and prevents sunlight damage. White or some other light color is recommended as it helps reduce pipe temperature. The latex paint must be thickly applied as an opaque coating on the pipe and fittings that have been cleaned well and very lightly sanded.

Polypropylene and PVDF pipe and fittings are very difficult to paint properly and should be protected by insulation.

ABOVE-GROUND INSTALLATION OF THERMOPLASTIC PIPING

THERMAL EFFECTS ON PLASTICS

The physical properties of thermoplastic piping are significantly related to the operating temperature. As the operating temperature falls, the pipe's stiffness and tensile strength increases, increasing the pipe's pressure capacity and its ability to resist earth-loading deflection. With a drop in temperature, impact strength is reduced.

With an increase in temperature, there is a decrease in pipe tensile strength and stiffness and a reduction in pressure capability, as outlined in the Temperature-Pressure charts on page 25.

THERMAL CONDUCTIVITY, HEAT TRACING AND INSULATION

Plastic piping, unlike metal, is a very poor conductor of heat. Thermal conductivity is expressed as BTU/hr/sq/ft/°F/in. where BTU/hr or British Thermal Unit per hour is energy required to raise temperature of one pound of water one degree Fahrenheit in one hour. Square foot refers to one square foot where heat is being transferred. Inch refers one inch of pipe wall thickness. As pipe wall increases, thermal conductivity decreases.

A comparison to steel, aluminum, and copper can be seen on pages 4-5. Copper, a good conductor of heat, will lose 2,610 BTU/hr per square foot of surface area with a wall thickness of one inch. PVC will lose only 1.2 BTU/hr! If wall thickness is reduced to 0.250 inches, the heat loss increases four times.

Although plastics are poor conductors of heat, heat tracing of plastic piping may be necessary to maintain a constant elevated temperature of a viscous liquid, prevent liquid freezing, or to prevent a liquid, such as 50% sodium hydroxide, from crystallizing in a pipeline at 68°F. Electric heat tracing with self-regulating, temperature-sensing tape such as Raychem Chemelex Autotrace will maintain a 90°F temperature to prevent sodium hydroxide from freezing. The tape should be S-pattern wrapped on the pipe to allow pipe repairs and to avoid deflection caused by heating one side of the pipe. Heat tracing should be applied directly on the pipe within the insulation and must not exceed the temperature-pressure-chemical resistance design of the system.

Insulation to further reduce plastic piping heat loss is available in several different forms from several manufacturers. The most popular is a two-half foam insulation installed within a snap together with aluminum casing. Insulation can also provide weathering protection and fireproofing to plastic piping and is discussed later.

ULTRA VIOLET(UV) LIGHT STERILIZATION

UV sterilizers for killing bacteria in deionized water are becoming common. The intense light generated will stress crack PVC, CPVC, polypropylene, and PVDF piping over time. PVDF goes through a cross-linking of H-F causing a discoloration of the fitting and pipe material as well as joint stress cracking.

VIBRATION ISOLATION

Plastic piping will conduct vibration from pumping and other sources of resonance frequencies, such as liquid flow through a partially open valve. Vibration isolation is best accomplished using a flanged, Teflon, or thin rubber bellows expansion joint installed near the pump discharge or source of vibration. **Metallic or thick rubber expansion joints lack the flexibility to provide flange movement and vibration isolation and should not be used in plastic piping systems.** The proper bellows expansion joint will also provide for pipe system flexibility against a stationary mounted pump, storage tank, or equipment to reduce pipe breakage during an earthquake.

PLASTICS AND FIRE

The Uniform Building Code (UBC), 1994 edition, is a construction standard and building plan that is subject to interpretation and approval from local building and fire officials under the law. Section 4202 addresses testing and classification of materials and states: "The classes of materials based upon their flame-spread index shall be as set forth in Table No. 68. The smoke density shall be no greater than 450 when tested in accordance with UBC 42-1 in the way intended for use." Section 4202 (a) states: "The maximum flame-spread class used on interior walls and ceilings shall not exceed that set forth in Table No. 66. Plastic piping is not addressed specifically with regard to UBC 42-1 flame and smoke spread ratings required.

The surface burning characteristics of building materials are based on UBC 42-1 Standards and ASTM E-84 testing to provide flame and smoke spread information of plastic materials. ASTM E-84 is a flame test conducted on both vertical and horizontal plastic material to determine the flame and smoke spread of the particular material being tested for its use in specific areas of construction.

An underwriters lab approved kaolin clay thermal insulation cloth wrap, which fireproofs any plastic piping system to a 0 flame spread and 0 smoke spread, per ASTM E-84 testing has been used effectively to meet fire codes.

There are also new resin formulations of CPVC and PVDF that meet ASTM E-84 for use in all classifications of construction.

BELOW-GROUND INSTALLATION OF THERMOPLASTIC PIPING

INTRODUCTION

Many problems experienced by above-ground plastic piping such as weathering/painting, expansion/contraction, pipe support/hangers, fire, and external mechanical damage are virtually eliminated by proper below-ground installation. The depth and width of trenching, bedding and backfilling, thrust blocking, snaking, air and pressure relief, and size and wall thickness of pipe must be considered.

TRENCHING AND BEDDING DEPTH

In installing underground piping systems, the depth of the trench is determined by the intended service and by local conditions (as well as by local, state and national codes that may require a greater trench depth and cover than are technically necessary).

Underground pipes are subjected to external loads caused by the weight of the backfill material and by loads applied at the surface of the fill. These can range from static to dynamic loads.

Static loads comprise the weight of the soil above the top of the pipe plus any additional material that might be stacked above ground. An important point is that the load on a flexible pipe will be less than on a rigid pipe buried in the same manner. This is because the flexible conduit transfers part of the load to the surrounding soil and not the reverse. Soil loads are minimal with narrow trenches until a pipe depth of 10 feet is attained.

Dynamic loads are loads due to moving vehicles such as trucks, trains and other heavy equipment. For shallow burial conditions live loads should be considered and added to static loads, but at depths greater than ten feet, live loads have very little effect.

Pipe intended for potable water service should be buried at least twelve inches below the maximum expected frost penetration.

WIDTH

The width of the trench should be sufficient to provide adequate room for “snaking” ½ to 2½ inch nominal diameter pipe from side to side along the trench bottom, as described below, and for placing and compacting the side fills. The trench width can be held to a minimum with most pressure piping materials by joining the pipe at the surface and then lowering it into the trench after adequate joint strength has been obtained.

BEDDING

The bottom of the trench should provide a firm, continuous bearing surface along the entire length of the pipe run. It should be relatively smooth and free of rocks. Where hardpan, ledge rock or boulders are present, it is recommended that the trench bottom be cushioned with at least four inches of sand or compacted fine-grained soils.

SNAKING

To compensate for thermal expansion and contraction when laying small diameter pipe in hot weather, the snaking technique of offsetting ½ to 2½ inch nominal diameter pipe with relation to the trench center line is recommended.

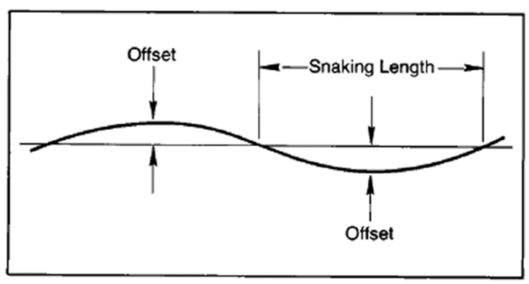
A. **½ inch to 2½ inch nominal diameter**. When the installation temperature is substantially lower than the operating temperature, the pipe should, if possible, be installed with straight alignment and brought up to operating temperature after joints are properly cured but before backfilling. This procedure will permit expansion of the pipe to be accommodated by a “snaking” action.

When the installation temperature is substantially above the operating temperature, the pipe should be installed by snaking in the trench. For example, a 100-foot length of PVC Type 1 pipe will expand or contract about ¾ inch for each 20°F temperature change. On a hot summer day, the direct rays of the sun on the pipe can drive the surface temperature up to 150°F. At night, the air temperature may drop to 70°F. In this hypothetical case, the pipe would undergo a temperature change of 80°F and every 100 feet of pipe would contract 3 inches overnight. This degree of contraction would put such a strain on newly cemented pipe joints that a poorly made joint might pull apart.

A practical and economical method is to cement the line together at the side of the trench during the normal working day. When the newly cemented joint has dried, the pipe is snaked from one side of the trench to the other in gentle alternate curves. This added length will compensate for any contraction after the trench is backfilled. See Figure 8.

B. **3 inch and larger nominal diameter pipes** should be installed in straight alignment. Before backfilling to the extent that longitudinal movement is restricted, the pipe temperature should be adjusted to within 15°F of the operating temperature, if possible.

FIGURE 8



Snaking of thermoplastic pipe within the trench to compensate for thermal expansion and contraction.

The table shown below gives the required loop length in feet and offset in inches for various temperature variations.

Table 46 SNAKE LENGTH VS. OFFSET (IN.) COMPENSATE FOR THERMAL CONTRACTION

SNAKING LENGTH (FT.)	MAXIMUM TEMPERATURE VARIATION (°F) BETWEEN TIME OF CEMENTING AND FINAL BACKFILL									
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
	LOOP OFFSET (IN.)									
20	2.5	3.5	4.5	5.20	5.75	6.25	6.75	7.25	7.75	8.00
50	6.5	9.0	11.0	12.75	14.25	15.50	17.00	18.00	19.25	20.25
100	13.0	18.0	22.0	26.00	29.00	31.50	35.00	37.00	40.00	42.00

BELOW-GROUND INSTALLATION OF THERMOPLASTIC PIPING

DETERMINING SOIL LOADING FOR FLEXIBLE PLASTIC PIPE, SCHEDULE 80

Underground pipes are subjected to external loads caused by the weight of the backfill material and by loads applied at the surface of the fill. These can range from static to dynamic loads.

Static loads comprise the weight of the soil above the top of the pipe plus any additional material that might be stacked above ground. An important point is that the load on a flexible pipe will be less than on a rigid pipe buried in the same manner. This is because the flexible conduit transfers part of the load to the surrounding soil and not the reverse. Soil loads are minimal with narrow trenches until a pipe depth of 10 feet is attained.

Dynamic loads are loads due to moving vehicles such as trucks, trains and other heavy equipment. For shallow burial conditions live loads should be considered and added to static loads, but at depths greater than 10 feet, live loads have very little effect.

Soil load and pipe resistance for other thermoplastic piping products can be calculated using the following formula or using tables 47-48.

$$Wc' = \frac{\Delta X(EI + .061\ E'r^3)80}{r^3}$$

Where:

- Wc' = Load Resistance of the Pipe, lb./ft.
- ΔX = Deflection in Inches @ 5% (.05 x I.D.)
- E = Modulus of Elasticity
- t = Pipe Wall Thickness
- r = Mean Radius of Pipe (O.D. - t)/2
- E' = Modulus of Passive Soil Resistance, psi
- H = Height of Fill Above Top of Pipe, ft.
- I = Moment of Inertia $\frac{t^3}{12}$

Table 47 LIVE LOAD FOR BURIED FLEXIBLE PIPE (LB/L IN/FT.)

PIPE SIZE	H_20 WHEEL LOADS FOR VARIOUS DEPTHS OF PIPE (LB/L IN/FT.)				
	2	4	6	8	10
2	309	82	38	18	16
3	442	118	56	32	21
4	574	154	72	42	27
6	837	224	106	61	40
8	1102	298	141	82	53
10	1361	371	176	101	68
12	1601	440	210	120	78

NOTE: H_20 Wheel load is 16,000 lb/wheel.

Table 48 SOIL LOAD AND PIPE RESISTANCE FOR FLEXIBLE THERMOPLASTIC PIPE

Schedule 40 and 80 PVC Pipe

NOM. SIZE (IN.)	Wc' = LOAD RESISTANCE OF PIPE (LB/FT.)				H (FT.)	Wc = SOIL LOADS AT VARIOUS TRENCH WIDTHS AT TOP OF PIPE (LB/FT.)			
	SCHEDULE 40 PIPE		SCHEDULE 80 PIPE						
	E'=200	E'=200	E'=200	E'=200		2 FT.	3 FT.	4 FT.	5 FT.
1½	1084	1282	2809	2993	10	106	125	136	152
					20	138	182	212	233
					30	144	207	254	314
					40	—	214	269	318
2	879	1130	2344	2581	10	132	156	170	190
					20	172	227	265	291
					30	180	259	317	392
					40	—	267	337	398
2½	1344	1647	3218	3502	10	160	191	210	230
					20	204	273	321	352
					30	216	306	377	474
					40	—	323	408	482
3	1126	1500	2818	3173	10	196	231	252	280
					20	256	336	392	429
					30	266	366	384	469
					40	—	394	497	586
3½	1021	1453	2591	3002	10	223	266	293	320
					20	284	380	446	490
					30	300	426	524	660
					40	—	450	568	670
4	969	1459	2456	2922	10	252	297	324	360
					20	328	432	540	551
					30	342	493	603	743
					40	—	503	639	754
5	896	1511	2272	2861	10	310	370	407	445
					20	395	529	621	681
					30	417	592	730	918
					40	—	625	790	932
6	880	1620	2469	3173	10	371	437	477	530
					20	484	636	742	812
					30	503	725	888	1093
					40	—	745	941	1110
8	911	1885	2360	3290	10	483	569	621	690
					20	630	828	966	1057
					30	656	945	1156	1423
					40	—	970	1225	1445
10	976	2198	2597	3764	10	602	710	774	860
					20	785	1032	1204	1317
					30	817	1177	1405	1774
					40	—	1209	1527	1801
12	1058	2515	2909	4298	10	714	942	919	1020
					20	931	1225	1429	1562
					30	969	1397	1709	2104
					40	—	1434	1811	2136

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

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

BELOW-GROUND INSTALLATION OF THERMOPLASTIC PIPING

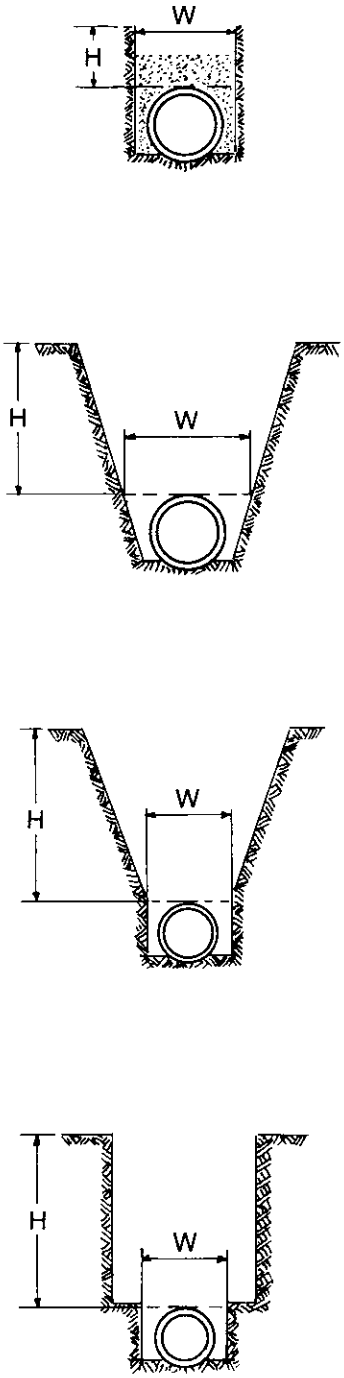


Figure 9

H = Height of fill above top of pipe, ft.
W = Trench width at top of pipe, ft.

HEAVY TRAFFIC

When plastic pipe is installed beneath streets, railroads, or other surfaces that are subjected to heavy traffic and resulting shock and vibration, it should be run within a protective metal or concrete casing.

Plastic pipe is not designed to provide structural strength beyond sustaining internal pressures up to its designed hydrostatic pressure rating and normal soil loads. Anchors, valves, and other connections must be independently supported to prevent added shearing and bending stresses on the pipe.

RISERS

The above piping design rule applies also where pipe is brought out of the ground. Above-ground valves or other connections must be supported independently. If pipe is exposed to external damage, it should be protected with a separate, rigidly supported metal pipe sleeve at the danger areas. Thermoplastic pipe should not be brought above ground where it is exposed to high temperatures. Elevated temperatures can lower the pipes pressure rating below design levels.

LOCATING BURIED PIPE

The location of plastic pipelines should be accurately recorded at the time of installation. Since pipe is a non-conductor, it does not respond to the electronic devices normally used to locate metal pipelines. However, a copper or galvanized wire can be spiraled around, taped to, or laid alongside or just above the pipe during installation to permit the use of a locating device, or use marker tape.

NOTE: For additional information see ASTM D-2774, *Underground Installation of Thermoplastic Pressure Piping.*

TESTING THERMOPLASTIC PIPING SYSTEMS

We strongly recommend that all plastic piping systems be hydrostatically tested (as described below) before being put into service. Water is normally used as the test medium.

Note: Do not pressure test with compressed air or gas!

Severe damage or bodily injury can result.

The water is introduced through a pipe of 1-inch diameter or smaller at the lowest point in the system. An air relief valve should be provided at the highest point in the system to bleed off any air that is present.

The piping system should gradually be brought up to the desired pressure rating using a pressure bypass valve to assure against over pressurization. The test pressure should in no event exceed the rated operating pressure of the lowest rated component in the system such as a 150-pound flange.

INITIAL LOW-PRESSURE TEST

The initial low-pressure hydrostatic test should be applied to the system after shallow backfilling which leaves joints exposed. Shallow backfilling eliminates expansion/contraction problems. The test should last long enough to determine that there are no minute leaks anywhere in the system.

HYDROSTATIC PRESSURE TESTING

PRESSURE GAUGE METHOD

Where time is not a critical factor, the reading of a regular pressure gauge over a period of several hours will reveal any small leaks. If the gauge indicates leakage, that entire run of piping must then be visually inspected, paying special attention to the joints–to locate the source of the leak.

VISUAL INSPECTION METHOD

After the line is pressurized, it can be visually inspected for leaks without waiting for the pressure gauge to reveal the presence or absence of a pressure drop.

Even though no leaks are found during the initial inspection, however, it is recommended that the pressure be maintained for a reasonable length of time. Checking the gauge several times during this period will reveal any slow developing leaks.

LOCATE ALL LEAKS

Even though a leak has been found and the pipe or joint has been repaired, the low-pressure test should be continued until there is a reasonable certainty that no other leaks are present. Locating and repairing leaks is very much more difficult and expensive after the piping system has been buried. Joints should be exposed during testing.

HIGH-PRESSURE TESTING

Following the successful completion of the low-pressure test, the system should be high-pressure tested for at least 12 hours. The run of pipe should be more heavily backfilled to prevent movement of the line under pressure. Any leaks that may develop probably will occur at the fitting joints, these should be left uncovered.

Solvent-cemented piping systems must be fully cured before pressure testing. For cure times, refer to the solvent cementing instruction tables on page 66.

TEST PRESSURE

The test pressure applied should not exceed: (a) the designed maximum operating pressure, (b) the designed pressure rating of the pipe or (c) the designed pressure rating of any system component, whichever is lowest.

SAFETY PRECAUTIONS

(1) Do not test with fluid velocities exceeding 5 ft./sec. since excessive water hammer could damage the system. (2) Do not allow any personnel not actually working on the high-pressure test in the area, in case of a pipe or joint rupture.

(3) Do not test with air or gas.

TRANSITION FROM PLASTIC TO OTHER MATERIALS

Transitions from plastic piping to metal piping may be made with flanges, threaded fittings, or unions. Flanged connections are limited to 150 psi, and threaded connections are limited to 50% of the rated pressure of the pipe.

NOTE: When tying into a threaded metal piping system, it is recommended that a plastic male thread be joined to a metal female thread. Because the two materials have different coefficients of expansion, the male plastic fitting will actually become tighter within the female metal fitting when expansion occurs.

INSTALLATION OF THERMOPLASTIC PIPING

HANDLING & STORAGE OF PLASTIC PIPING

Normal precautions should be taken to prevent excessive mechanical abuse. When unloading pipe from a truck, for example, it is unwise to drag a length off the tailgate and allow the free end to crash to the ground. Remember too, that **SCRATCHES AND GOUGES ON THE PIPE SURFACE CAN LEAD TO REDUCED PRESSURE-CARRYING CAPACITY.** Standard pipe wrenches should not be used for making up threaded connections since they can deform or scar the pipe. Use strap wrenches instead. When using a pipe vise or chuck, wrap jaws with emery cloth or soft metal.

Pipe should be stored on racks that afford continuous support and prevent sagging or draping of longer lengths. Burrs and sharp edges of metal racks should be avoided. Plastic fittings and flanges should be stored in separate bins or boxes and never mixed with metal piping components. The storage area should be clean and have adequate ventilation. Plastic pipe should not be stored or installed near a steam line or other source of heat that could overheat the pipe.

FIELD STORAGE

Although plastic pipe has excellent resistance to weathering, it is recommended that prolonged storage be under cover so as to maintain its installation suitability. Because of possible heat buildup, it is not recommended that the cover consist only of a tarpaulin.

FIELD STACKING

During prolonged field storage of loose pipe, its stacks should not exceed two feet in height. Bundled pipe may be double-stacked providing its weight is distributed by its packaging boards.

HANDLING

Care should be exercised to avoid rough handling of pipe and fittings. They should not be pushed or pulled over sharp projections, dropped, or have any objects dropped upon them. Particular care should be taken to avoid kinking or buckling the pipe. Any kinks or buckles that occur should be removed by cutting out the entire damaged section as a cylinder. All sharp edges on a pipe carrier or trailer that could come in contact with the pipe should be padded; (e.g., can use old fire hose or heavy rubber strips.) Only nylon or rope slings should be used for lifting bundles of pipe; chains are not to be used.

INSPECTION

Before installation, all lengths of pipe and fittings should be thoroughly inspected for cuts, scratches, gouges, buckling, and any other imperfections which may have been imparted on the pipe during shipping, unloading, storing, and stringing. Any pipe or pre-coupled fittings containing harmful or even questionable defects should be removed by cutting out the damaged section as a complete cylinder

JOINING TECHNIQUES

FOR THERMOPLASTIC PIPING

There are several recommended methods of joining thermoplastic pipe and fittings, each with its own advantages and limitations:

SOLVENT CEMENTING

The most widely used method in Schedule 40 PVC, Schedule 80 PVC and CPVC piping systems as described in ASTM D-2855. The O.D. of the pipe and the I.D. of the fitting are primed, coated with special cement and joined together, (described in detail below.) Knowledge of the principles of solvent cementing is essential to a good job. These are discussed in the Solvent Welding Instructions Section.

NOTE: The single most significant cause of improperly or failed solvent cement joints is lack of solvent penetration or inadequate primer application.

THREADING

Schedule 80 PVC, CPVC, PVDF, and PP can be threaded with special pipe dyes for mating with Schedule 80 fittings provided with threaded connections. Since this method makes the piping system easy to disassemble, repair, and test, it is often employed on temporary or take-down piping systems, as well as systems joining dissimilar materials. Threaded pipe must be derated by 50% from solvent-cemented systems. (Threaded joints are not recommended for PP pressure applications.)

FLANGES

Flanges are available for joining all thermoplastic piping systems. They can be joined to the piping either with solvent-cemented or threaded connections. Flanging offers the same general advantages as threading and consequently is often employed in piping systems that must frequently be dismantled. The technique is limited to 150 psi working pressure.

SOCKET FUSION

This technique is used to assemble PVDF and polypropylene pipe and fittings for high-temperature, corrosive-service applications. (See each manufacturer's data for recommended joining techniques.)

BUTT FUSION

This technique us used to connect all sizes of polypropylene (Proline), PVDF (Purad™) and other larger diameter materials. Butt fusion is an easy, efficient fusion method especially in larger diameters.

IR (INFRARED) Fusion

Improving upon conventional butt fusion, IR welding uses a noncontact method. IR welding uses the critical welding parameters of heat soak time, change over time, and joining force as found with butt fusion. By avoiding direct contact with the heating element, IR fusion produces a cleaner weld with more repeatable and smaller bead sizes. The end result is a superior weld for high-purity applications.

HPF Fusion

The HPF welding technology is an electric socket fusion system that joins Purad™ PVDF piping components, providing a smooth internal surface.

SMOOTH INNER BORE (S.I.B.)

S.I.B. offers state-of-the-art technology for sanitary piping systems construction. The "smooth" interior surface of the weld eliminates all beads, crevices and intrusions into the fluid system. Materials cannot become entrapped, and the possibility of bacterial growth and contamination is virtually eliminated. S.I.B. reduces pressure loss due to friction and improves system hydraulics. Available in Kynar® (PVDF) and polypropylene.

ELECTROFUSION

Electrofusion fittings are manufactured with an integral resistance wire, molded in place using a proprietary manufacturing process. The wire is electrically heated by means of a microprocessor controlled control unit. This results in fusion and bonding of the pipe to the fitting.

MECHANICAL JOINT

Traditionally mechanical joint polypropylene and PVDF drainage systems are used extensively for accessible smaller sized piping areas. The system, as the name implies, is a mechanical sealed joint that consists of a seal-ring and nut. It is quick and easy to install and can be disconnected just as easily. This joining method is most suitable for under sink and under counter piping.

SANITARY MECHANICAL JOINT

The Sani-Tech Division of Saint-Gobain Performance Plastics offers a sanitary mechanical joint similar to the Ladish® tri-clamp sanitary joint systems found in the pharmaceutical, food and beverage industries. This system requires that rigid tubing (pipe) and fittings are formed with a sanitary flange and gasket be joined together with a special mechanical clamp.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF SOLVENT CEMENTING

SAFETY PRECAUTIONS

Cements contain highly volatile solvents which evaporate rapidly. Avoid breathing the vapors. If necessary, use a fan to keep the work area clear of fumes. Avoid skin or eye contact. Do not use near heat, sparks, or open flame. Do not pressure test with compressed air or gas! Severe damage or bodily injury can result.

Solvent cementing is a preferred method of joining rigid PVC (polyvinyl chloride) and CPVC (chlorinated polyvinyl chloride) pipe and fittings providing a chemically fused joint. The solvent-cemented joint is the last vital link in the installation process. It can mean the success or failure of the whole system. Accordingly, it requires the same professional care and attention that is given to the other components of the system. Experience shows that most field failures of plastic piping systems are due to improperly made solvent cemented joints.

There are step-by-step procedures on just how to make solvent cemented joints shown on the following pages; however, we feel that if the basic principles involved are first explained and understood, better quality installation can result with ease. To consistently make good joints, the following basics should be clearly understood by the installer.

The joining surfaces must be clean, then softened and made semi-fluid.

Sufficient cement must be applied to fill the gap between pipe and fittings.

Assembly of pipe and fittings must be made while the surfaces are still wet and fluid.

Joint strength develops as the cement dries. In the tight part of the joint the surfaces will tend to fuse together. In the loose part the cement will bond to both surfaces.

Penetration and softening should be achieved with a suitable primer such as P70. Primer will penetrate and soften the surfaces more quickly than cement alone. Primer also provides a safety factor for the installer, because he can know under various temperature conditions when he has achieved sufficient softening of the material surfaces. For example, in cold weather more time and additional applications of primer will be required.

JOINING EQUIPMENT AND MATERIALS

- Cutting Tool (saw or wheel cutter)
- Deburring Tool (knife or file)
- Purple Primer
- Solvent Cement
- Cement and Primer Applicators
- Applicator Can or Bucket
- Tool Tray
- Rags (nonsynthetic, e.g., cotton)
- Notched Boards

More than sufficient cement to fill the loose part of the joint must be applied. Besides filling the gap, adequate cement layers will penetrate the surface and also remain wet until the joint is assembled. Prove this for yourself. Apply on the top surface of a piece of pipe two separate layers of cement. First, flow on a heavy layer of cement, then alongside it a thin brushed out layer. Test the layers every 15 seconds or so by a gentle tap with your finger. You will note that the thin layer becomes tacky and dries quickly (probably within 15 seconds). The heavy layer will remain wet much longer. Now check for penetration a few minutes after applying these layers. Scrape them with a knife. The thin layer will have achieved little or no penetration, the heavy one much more penetration.

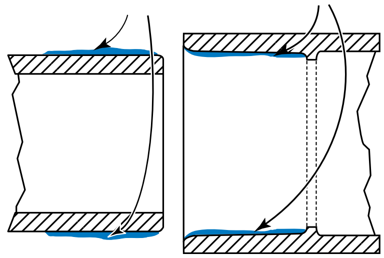


Figure 10

If the cement coating on the pipe and fittings are wet and fluid when assembly takes place, they will tend to flow together and become one cement layer. Also, if the cement is wet the surface beneath them will be soft, and these softened surfaces in the tight part of the joint will tend to fuse together.

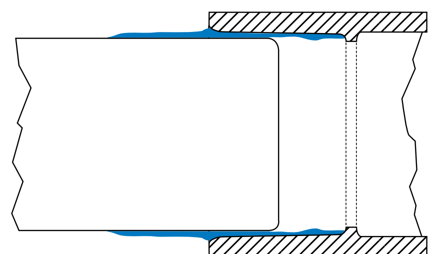


Figure 11

As the solvent dissipates, the cement layer and the softened surfaces will harden with a corresponding increase in joint strength. A good joint will take the required pressure long before the joint is fully dry and final strength is obtained. In the tight (fused) part of the joint, strength will develop more quickly than in the loose (bonded) part of the joint. Information about the development of the bond strength of solvent-cemented joints is available on request.

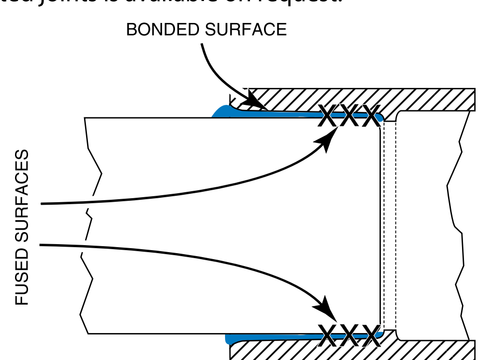


Figure 12

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF SOLVENT CEMENTING

Before beginning, this entire section should be studied and thoroughly understood. It is important that workers making joints be knowledgeable of these instructions and follow them carefully. Do not take shortcuts or omit any of the detailed steps.

KNOW YOUR MATERIAL

There are two general types of rigid vinyl materials, PVC and CPVC. Fitting are made of both materials and in both Schedule 40 and Schedule 80 weights.

Because of the difference in socket dimensions between the Schedule 40 and Schedule 80 fittings, more care must be taken with the Schedule 80 fittings and the cure schedules are different. Determine before proceeding with the job which type of vinyl plastic you are working with and which weight of fitting.

HANDLING CEMENTS AND PRIMERS

Cements and primers contain highly volatile solvents that evaporate rapidly. Avoid breathing the vapors. If necessary, use a fan to keep the work area clear of fumes. Avoid skin or eye contact. Keep cans closed when not actually in use. Solvent cements are formulated to be used "as received" in the original containers. If the cement thickens much beyond its original consistency, discard it. Cement should be free flowing, not jelly-like. Do not attempt to dilute it with thinner, as this may change the character of the cement and make it ineffective. Caution: Solvent cement has limited shelf life, usually one year for CPVC and two years for PVC. Date of manufacture is usually stamped on the bottom of the can. Do not use the cement beyond the period recommended by the manufacturer. Always keep solvent cements and primers out of the reach of children.

SELECTION OF CEMENTS, PRIMERS AND APPLICATORS

1. Obtain the correct primer and solvent cement for the product being installed. (See Harrington's catalog for detailed information on solvent cements and primers.)

PVC

(a) Use #P-70 purple primer for all sizes of PVC pipe and fittings.

(b) Use #710 clear, light-bodied cement with PVC Schedule 40 fittings having an interference fit through 2" size. Do not use on Schedule 80.

(c) Use #705 clear, medium-bodied cement with PVC Schedule 40 fittings having an interference fit though 6" size. Do not use on Schedule 80.

(d) Use #711 gray, heavy-bodied cement with PVC Schedule 80 fittings through 8" and Schedule 40 fittings 6" and 8" size

(e) Use #719 gray, extra-heavy-bodied cement for Schedule 40, 80, and all class or schedule sizes over 8" size.

CPVC

(a) Use #P-70 purple primer for all sizes of CPVC pipe and fit tings except copper tube size CPVC (which requires #P-72 or 729).

(b) Use #714 orange or gray, heavy-bodied cement for all sizes of CPVC pipe and fittings.

2. Obtain the correct primer applicators. (See Harrington's Catalog for applicators.) Generally, the applicator should be about ½ the pipe diameter.

(a) Use #DP-75, ¾" diameter, dauber (Supplied with pint size cans of P-70 primer.) for pipe sizes thru 1¼".

(b) Use #DP-150, 1½" diameter, dauber for pipe sizes through 3".

(c) Use #4020 cotton string mop for pipe sizes 4" and larger. Low VOC 724 cement for hypochlorite service. Weld-on 724 CPVC low VOC cement is a gray, medium bodied, fast setting solvent cement used for joining CPVC industrial piping through 12" diameter, and is specially formulated for services that include caustics and hypochlorites.

3. Obtain the correct solvent cement applicators. Generally, the applicator should be about half the pipe diameter.

(a) Use #DP-75 ¾" diameter dauber or a natural bristle brush for pipe sizes ½" through 1¼".

(b) Use #DP-150 1½" diameter dauber for pipe sizes ¾" through 3". (1" natural bristle brush may be used for pipe sizes up to 2").

(c) Use #3020, 2" diameter, "Roll-A-Weld" roller for 3" through 6" pipe sizes.

(d) Use #7020 7" long roller or #4020 large cotton swab for 6" through 12" pipe sizes.

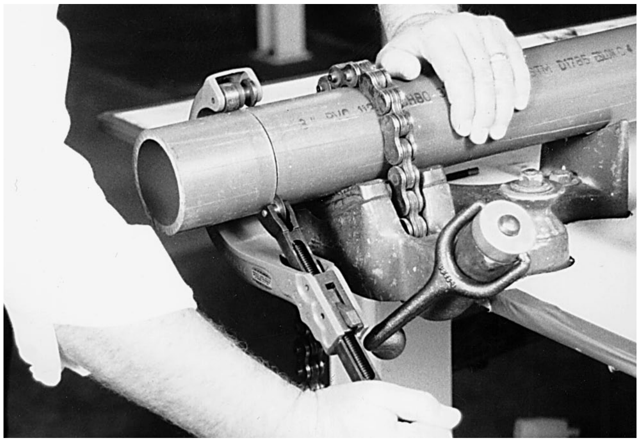
(e) Use extra-large natural bristle paint brush to flow cement onto pipe larger than 12".

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC/CPVC PIPE & FITTINGS

PREPARATION

1. Condition pipe and fittings to the same temperature. Cut pipe square to desired length using a hand saw and miter box or mechanical cutoff saw. A diagonal cut reduces the bonding area in the most effective part of the joint.



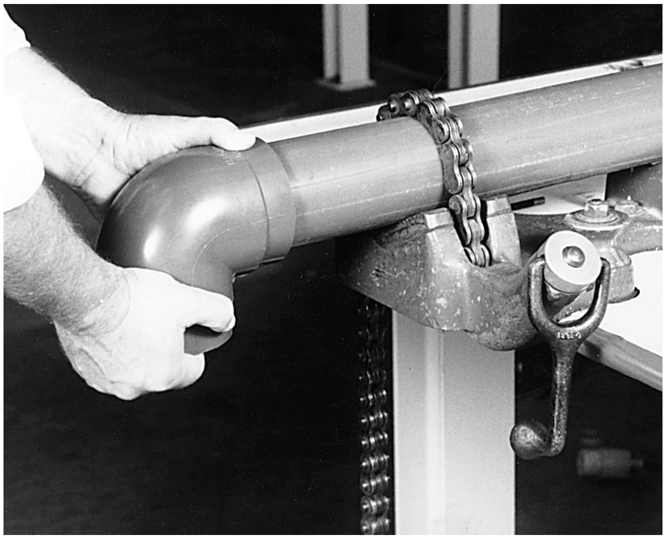
2. Plastic tubing cutters may also be used for cutting plastic pipe; however, most produce a raised bead at the end of the pipe. This must be removed with a file, knife, or beveling tool. A raised bead will wipe the cement away when the pipe is inserted into the fitting.

3. Large diameter pipe should be cut and chamfered with appropriate power tools. See Harrington's products catalog for tools.

4. Chamfer end of the pipe as shown above.

For ⅜" to 8" pipe chamfer 1/16" to 3/32"

For 10" to 30" pipe chamfer ¼" to ⅝"



5. Clean and dry pipe and fitting socket of all dirt, moisture, and grease. Use a clean, dry rag.

Check pipe and fitting for fit (dry) before cementing. For proper interference fit, the pipe must go into the fitting ⅓ to ¾ of the way to the stop. Too tight of a fit is not desirable. The assembler must be able to fully bottom the pipe into the socket after it has been softened with primer. If the pipe and fitting are not out of round, a satisfactory joint can be made if there is a "net" fit. That is, the pipe bottoms in the fitting socket with no interference, but without slope. All pipe and fitting must conform to ASTM or other standards.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC / CPVC PIPE & FITTINGS

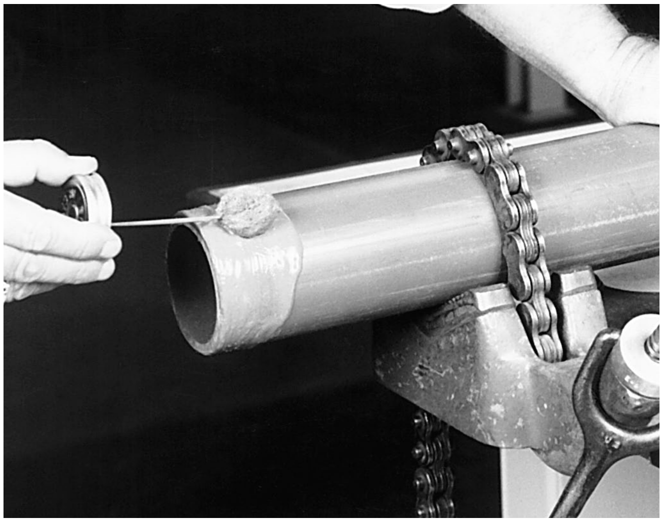
PRIMING

7. The purpose of the primer is to penetrate and soften the surfaces so that they can fuse together. The proper use of the primer and checking of its softening effect provides assurance that the surfaces are prepared for fusion in a wide variety of temperatures and working conditions.

Before starting the installation, we recommend checking the penetration and softening effect of the primer on a scrap piece of the material you will be working with. This should be done where the temperature and environmental conditions are the same as those where the actual installation will take place. The effect of the primer on the surface will vary with both time and temperature. To check for proper penetration and softening, apply primer as indicated in step number 9. After applying primer, use a knife or sharp scraper and draw the edge over the coated surface. Proper penetration has been made if the assembler can scratch or scrape a few thousandths of an inch of the primed surface away.

8. Using the correct applicator as previously mentioned, apply primer freely with a scrubbing motion to the fitting socket, keeping the surface and applicator wet until the surface has been softened. This usually requires 5-15 seconds. More time is needed for hard surfaces (found in belled-end pipe and fittings made from pipe stock) and in cold weather conditions. Redip the applicator in the primer as required.

When the surface is primed, remove any puddles of primer from the socket. Puddles of primer can weaken the pipe and/or joint itself.

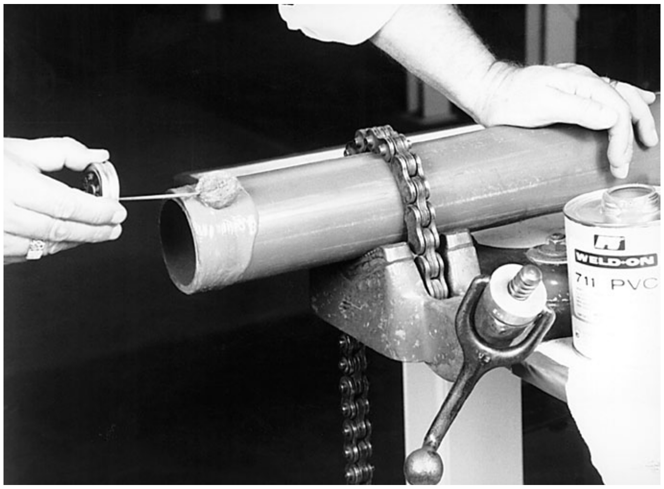


9. Apply the primer to the end of the pipe equal to the depth of the fitting socket. Application should be made in the same manner as was done to the fitting socket. Be sure the entire surface is well dissolved or softened.

10. Apply a second application of primer to the fitting socket and immediately, while the surfaces are still wet, apply the appropriate solvent cement. Time becomes important at this stage. Do not allow cement or primer to dry or start forming film on the surface.

CEMENTING

11. Apply a liberal coat of solvent cement to the male end of the pipe. Flow the cement on with the applicator. Do not brush cement out to a thin paint-type layer that will dry in a few seconds. The amount should be more than sufficient to fill any gap between the pipe and fitting.

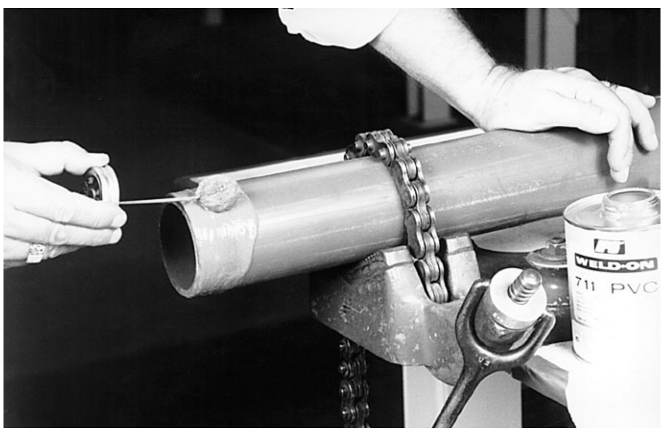


INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC / CPVC PIPE & FITTINGS

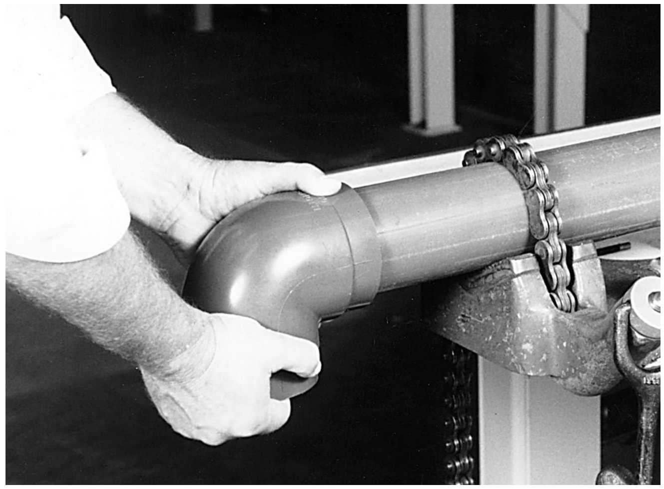
12. Apply a medium layer of solvent cement to the fitting socket; avoid puddling cement in the socket. On bell-end pipe do not coat beyond the socket depth or allow cement to run down in the pipe beyond the bell.

13. Apply a second full, even coat of solvent cement to the male end of the pipe. There must be sufficient cement to fill any gap in the joint. The cement must be applied deliberately but without delay. It may be necessary for two men to work together when cementing 3" and larger pipe.



14. While both the inside of the socket and the outside surface of the male end of the pipe are soft and wet with cement, forcefully bottom the male end of the pipe into the socket. Give the male end of the pipe a one-quarter turn if possible. This will help drive any air bubbles out of the joint. The pipe must go into the bottom of the socket and stay there. Hold the joint together until both soft surfaces are firmly gripped. (Usually less than 30 seconds on small diameter piping, larger sizes will require more time.) Care must be used since the fitting sockets are tapered and the pipe will try to push out of the fitting just after assembly.

When solvent cementing large diameter (8 inch and above) pipe and fittings proper equipment should be used. We recommend using straps and come-alongs as shown. See the tool section of the Harrington catalog.



15. After assembly, a properly made joint will normally show a ring or bead of cement completely around the juncture of the pipe and fitting. Any gaps at this point may indicate a defective assembly job, due to insufficient cement or the use of light bodied cement on larger diameters where heavy bodied cement should have been used.

16. Without disturbing the joint, use a rag and remove excess cement from the pipe at the end of the fitting socket. This includes the ring or bead noted earlier. This excess cement will not straighten the joint and may actually cause needless softening of the pipe and additional cure times.

17. Handle newly assembled joints carefully until initial set has taken place. Recommended setting time allowed before handling or moving is related to temperature. See initial set times in Table 49 on the next page.

18. Allow the joint to cure for adequate time before pressure testing. Joint strength development is very rapid within the first 48 hours. Short cure periods are satisfactory for high ambient temperatures with low humidity, small pipe sizes, and interference-type fittings. Longer cure periods are necessary for low temperatures, large pipe sizes, loose fits, and relatively high humidity. See Table 50 for recommended cure times.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC / CPVC PIPE & FITTINGS

Table 49 **INITIAL SET TIMES**

TEMPERATURE RANGE DURING INITIAL SET TIME	SET TIMES FOR PIPE SIZES ½" TO 1¼"	SET TIMES FOR PIPE SIZES 1½" TO 3"	SET TIMES FOR PIPE SIZES 4" TO 8"	SET TIMES FOR PIPE SIZES 10" TO 14"	SET TIMES FOR PIPE SIZES 16" TO 24"
60° TO 100° F	15 MIN	30 MIN	1 HR	2 HR	4 HR
40° TO 59° F	1 HR	2 HR	4 HR	8 HR	16 HR
0° TO 39° F	3 HR	6 HR	12 HR	24 HRS	48 HR

The following cure schedules are suggested as guides. They are based on laboratory test data and should not be taken to be the recommendation of all cement manufacturers. Individual manufacturers' recommendations for their particular cement should be followed. These cure schedules are based on laboratory test data obtained on net fit joints. (Net-fit—in a dry fit the pipe bottoms snugly in the fitting socket without meeting interference.) If a gap joint is encountered in the system, double the following cure times.

Table 50 **JOINT CURE SCHEDULE FOR PVC /CPVC PIPE & FITTINGS**

RELATIVE HUMIDITY 60% OR LESS TEMPERATURE RANGE DURING ASSEMBLY AND CURE TIME	CURE TIME FOR PIPE SIZES ½" - 1¼"		CURE TIME FOR PIPE SIZES 1½" - 3"		CURE TIME FOR PIPE SIZES 4" - 8"		CURE TIME FOR PIPE SIZES 10" - 14"	CURE TIME FOR PIPE SIZES 16" - 24"
	UP TO 180 PSI	ABOVE 180-370 PSI	UP TO 180 PSI	ABOVE 180-370 PSI	UP TO 180 PSI	ABOVE 180-370 PSI	UP TO 180 PSI	UP TO 100 PSI
60° - 100° F	1 HR	6 HR	2 HR	12 HR	6 HR	24 HR	24 HR	48 - 72 HR
40° - 59° F	2 HR	12 HR	4 HR	24 HR	12 HR	48 HR	72 HR	5 DAYS
0° - 39° F	8 HR	48 HR	16 HR	96 HR	48 HR	8 DAYS	8 DAYS	10 -14 DAYS

TROUBLESHOOTING AND TESTING SOLVENT CEMENT JOINTS

DO NOT TEST WITH AIR OR COMPRESSED GAS.

DO NOT TAKE SHORTCUTS.

Experience has shown that shortcuts from the instructions given above are the cause of most field failures. Don't take a chance.

Solvent cemented joints correctly assembled with good cement under reasonable field conditions should never blow apart when tested, after the suggested cure period under recommended test pressures.

Good solvent cemented joints exhibit a complete dull surface on both surfaces **when cut in half and pried apart.**

Leaky joints will show a continuous or an almost continuous series of shiny spots or channels from the bottom to the outer lip of the fitting. No bond occurred at these shiny spots. The condition can increase to the point where the entire cemented area is shiny, and the fitting can blow off at this point.

Shiny areas can be attributed to one or a combination of the following causes:

1. Cementing surface not properly primed and dissolved prior to applying solvent cement.
2. Use of too small an applicator for primer or cement in comparison to pipe and fitting diameter.
3. Use of a cement that has partially or completely dried prior to bottoming the pipe into the fitting.
4. Use of jelled cement that will not bite into the pipe and fitting surface due to loss of the prime solvent.
5. Insufficient cement or cement applied only to one surface.
6. Excess gap that cannot be satisfactorily filled.
7. Excess time taken to make the joint after start of the cement application. In many of these cases, as well as condition No. 2, examination will show that it was impossible to bottom the fitting because the lubrication effect of the cement had dissipated.
8. Cementing with pipe surfaces above 110°F has evaporated too much of the prime solvent.
9. Cementing with cement that has water added by one means or another, or excess humidity conditions coupled with low temperatures.
10. Joints that have been disturbed and the bond broken prior to the firm set or readjusted for alignment after bottoming.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC / CPVC PIPE & FITTINGS

JOINING PLASTIC PIPE IN HOT WEATHER

There are many occasions when solvent cementing plastic pipe in 95°F temperatures and over cannot be avoided. If special precautions are taken, problems can be avoided. Solvent cements for plastic pipe contain high-strength solvents that evaporate faster at elevated temperatures. This is especially true when there is a hot wind blowing. If the pipe is stored in direct sunlight, surface temperatures may be 20°F to 30°F above the air temperature. Solvents attack these hot surfaces faster and deeper, especially inside the joint. Thus it is very important to avoid puddling inside the socket and to wipe off excess cement outside the joint.

By following our standard instructions and using a little extra care as outlined below, successful solvent cemented joints can be made even in the most extreme hot weather conditions.

JOINING PLASTIC PIPE IN COLD WEATHER

Working in freezing temperatures is never easy, but sometimes the job is necessary. If that unavoidable job includes solvent cementing of plastic pipe, it can be done. **GOOD JOINTS CAN BE MADE AT SUB-ZERO TEMPERATURES.**

By following our standard instructions and using a little extra care and patience, successful solvent cemented joints can be made at temperatures even as low as -15°F. In cold weather, solvents penetrate and soften the surfaces more slowly than in warm weather. Also, the plastic is more resistant to solvent attack. Therefore, it becomes more important to pre-soften the surfaces with primer.

Because solvents evaporate slower in cold weather, a longer cure time will be required. The cure schedule printed in Table 51 already allows a wide margin for safety. For colder weather, simply allow more cure time.

TIPS TO FOLLOW WHEN SOLVENT CEMENTING IN HIGH TEMPERATURES

Store solvent cements and primers in a cool or shaded area prior to use.

If possible, store fittings and pipe, or at least the ends to be solvent cemented, in a shady area before cementing.

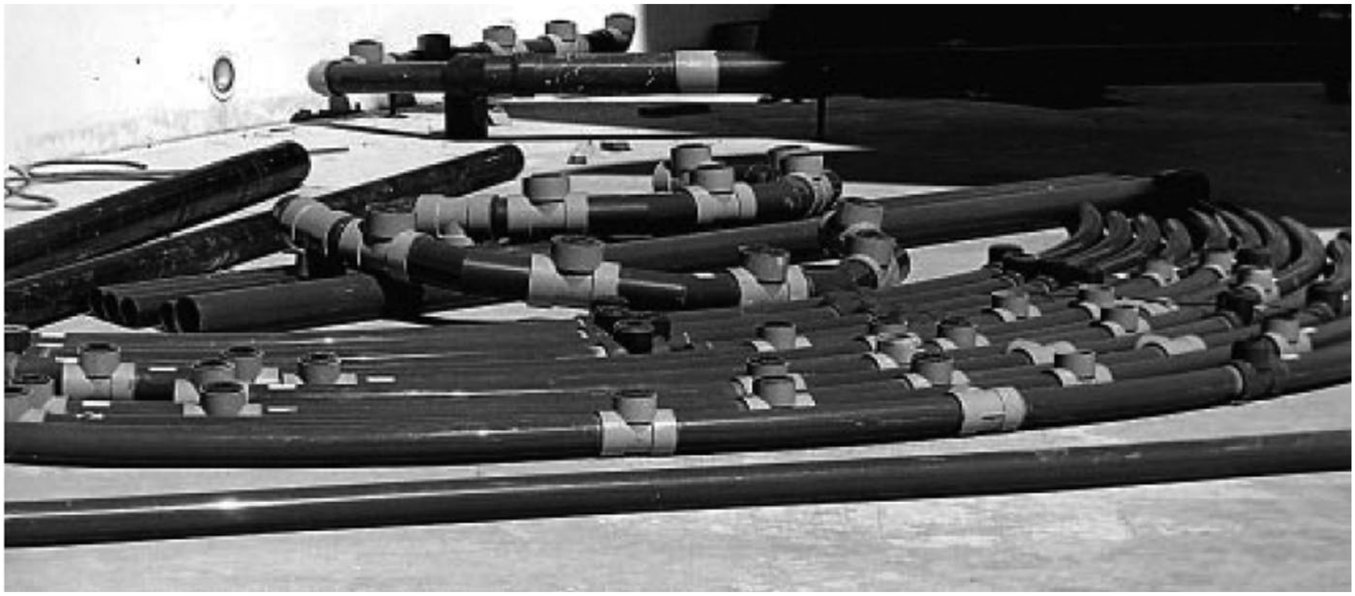
Cool surfaces to be joined by wiping with a damp rag. Be sure that surface is dry prior to applying solvent cement.

Try to do the solvent cementing in the cooler morning hours.

Make sure that both surfaces to be joined are still wet with cement when putting them together. With large-size pipe, more people on the crew may be necessary.

Use one of our heavier bodied, high viscosity cements because they will provide a little more working time.

Be prepared for a greater expansion-contraction factor in hot weather.



25 years in service and still performing well!

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING INSTRUCTIONS FOR PVC / CPVC PIPE & FITTINGS

TIPS TO FOLLOW IN SOLVENT CEMENTING DURING COLD WEATHER:

Prefabricate as much of the system as is possible in a heated working area.

Store cements and primers in a warmer area when not in use and make sure they remain fluid.

Take special care to remove moisture, including ice and snow.

Use extra primer to soften the joining surfaces before applying cement.

Allow a longer initial set and cure period before the joint is moved or the system is tested.

Read and follow all of our directions carefully before installation.

Regular cements are formulated to have well-balanced drying characteristics and to have good stability in sub-freezing temperatures. Some manufacturers offer special cements for cold weather because their regular cements do not have that same stability For all practical purposes, good solvent cemented joints can be made in very cold conditions with our existing products, providing proper care and a little common sense are used.

Table 51

PHYSICAL DATA

P-70 PRIMER FOR PVC AND CPVC

BOILING POINT (°F) Based on first boiling Comp THF.	151°F	SPECIFIC GRAVITY ($H_2$0=1)	0.870 ± 0.010
VAPOR PRESSURE (mm Hg.) THF @ 25	190	PERCENT VOLATILE BY VOLUME (%)	100%
VAPOR DENSITY (AIR = 1) APPROX	2.49	EVAPORATION RATE (BUAC = 1) APPROX	5.5 - 8.0
SOLUBILITY IN WATER 100%			
APPEARANCE AND ODOR - purple color, etheral odor			

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.C.C.) 6°F	FLAMMABLE LIMITS	Left 1.8	Used 11.8
EXTINGUISHING MEDIA Dry chemical, Carbon dioxide - Foam - Ansul "Purple K" National Aero-O-Foam			
SPECIAL FIREFIGHTING PROCEDURES Close or confined quarters require self-contained breathing apparatus. Positive pressure hose mask or airline masks.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Fire hazard because of low flash point, high volatility and heavy vapor.			

PHYSICAL DATA

705 CLEAR OR GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on first boiling Comp THF.	151°F	SPECIFIC GRAVITY ($H_2$0=1)	0.920 ± 0.02
VAPOR PRESSURE (mm Hg) THF @ 25	190	PERCENT VOLATILE BY VOLUME (%)	85% - 90%
VAPOR DENSITY (AIR = 1) APPROX	2.49	EVAPORATION RATE (BUAC = 1) APPROX	5.5 - 8.0
SOLUBILITY IN WATER solvent portion PVC resin & filler, precipates			
APPEARANCE AND ODOR - clear, thin syrupy liquid, etheral odor			

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (method used) (T.C.C.) 6°F	FLAMMABLE LIMITS	Left 1.8	Used 1.8
EXTINGUISHING MEDIA Dry chemical, carbon dioxide, foam, Ansul "Purple K" National Aero-O-Foam			
SPECIAL FIREFIGHTING PROCEDURES Close or confined quarters require self contained breathing apparatus. Positive pressure hose masks or airline masks.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Fire hazard because of low flash point, high volatility and heavy vapor.			

PHYSICAL DATA

711 GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on first boiling Comp THF.	151°F	SPECIFIC GRAVITY ($H_2$0=1)	0.958 ± 0.008
VAPOR PRESSURE (mm Hg) THF @ 25	190	PERCENT, VOLATILE BY VOLUME (%)	90%
VAPOR DENSITY (AIR = 1) APPROX	2.49	EVAPORATION RATE (BUAC = 1) APPROX	5.0 - 8.0
SOLUBILITY IN WATER solvent portion PVC resin & filler, precipates			
APPEARANCE AND ODOR - gray color, medium syrupy liquid, etheral odor			

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.C.C.) 8°F	FLAMMABLE LIMITS	Left 2.0	Used 11.8
EXTINGUISHING MEDIA Dry chemical, carbon dioxide, foam, Ansul "Purple K" National Aero-O-Foam			
SPECIAL FIREFIGHTING PROCEDURES Close or confined quarters require self-contained breathing apparatus. Positive pressure hose mask or airline masks.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Fire hazard because of low flash point, high volatility and heavy vapor.			

PHYSICAL DATA

714 GRAY CEMENT FOR CPVC

BOILING POINT (°F) Based on first boiling Comp. THF.	151°F	SPECIFIC GRAVITY ($H_2$0=1)	0.009 ± 0.004
VAPOR PRESSURE (mm Hg) THF @ 25	190	PERCENT, VOLATILE BY VOLUME (%)	85% - 90%
VAPOR DENSITY (AIR = 1) APPROX	2.49	EVAPORATION RATE (BUAC = 1) APPROX	8.0
SOLUBILITY IN WATER resin precipates			
APPEARANCE AND ODOR - Gray color, medium syrupy liquid, etheral odor			

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) (T.C.C.) 6°F	FLAMMABLE LIMITS	Left 1.8	Used 11.8
EXTINGUISHING MEDIA Dry chemical, carbon dioxide, foam, Ansul "Purple K" National Aero-O-Foam			
SPECIAL FIREFIGHTING PROCEDURES Close or confined quarters require self-contained breathing apparatus. Positive pressure hose masks or airline masks.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Fire hazard because of low flash point, high volatility and heavy vapor.			

Low VOC 724 CEMENT FOR HYPOCHLORITE SERVICE

Weld-On 724 CPVC low VOC cement is a gray, medium-bodied, fast-setting solvent cement used for joining CPVC industrial piping through 12" diameter and is specially formulated for services that include caustics and hypochlorites.

THREADING INSTRUCTIONS PVC - CPVC - PP - PVDF

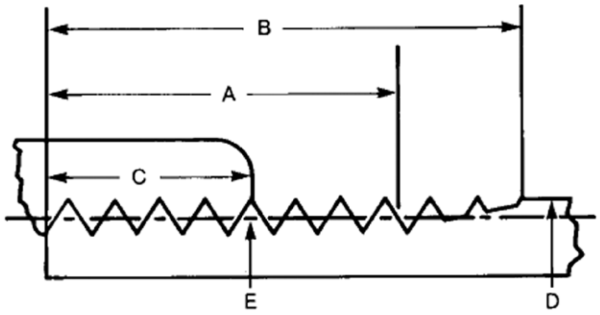


Figure 13

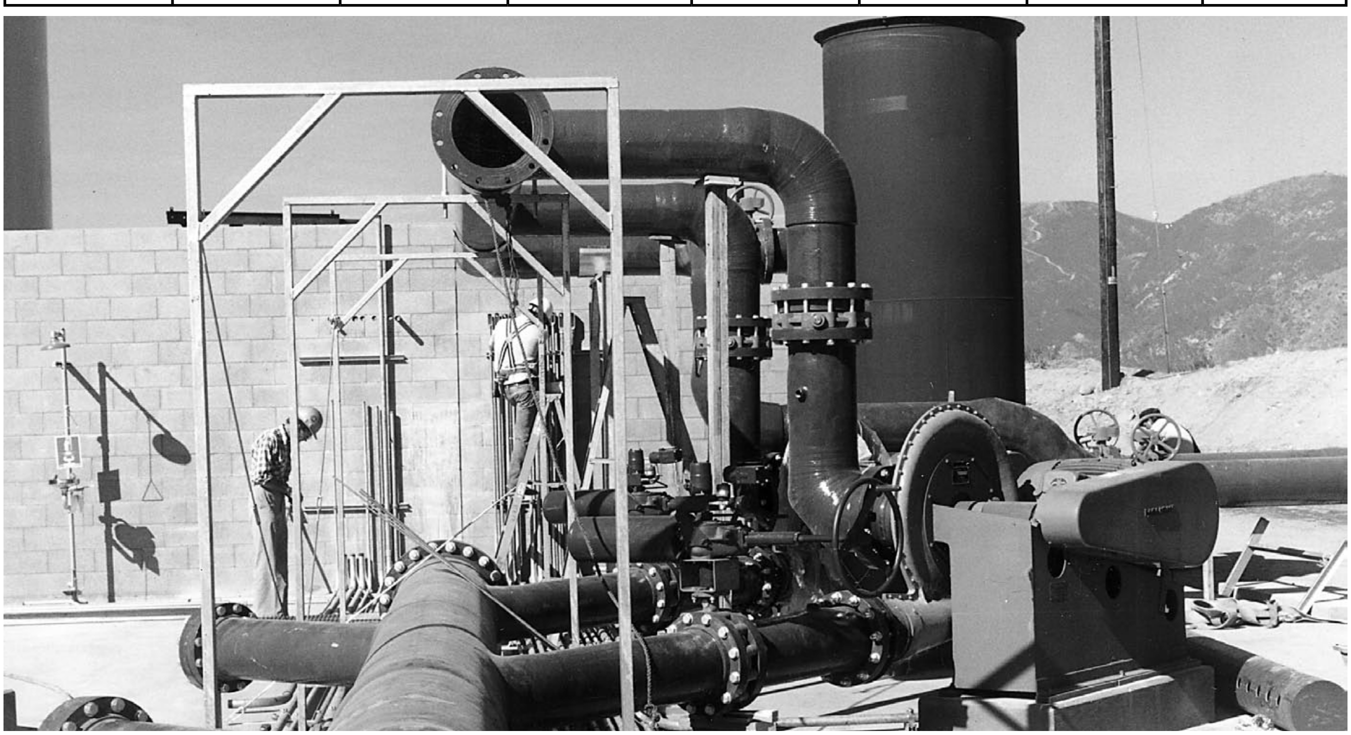
SCOPE

The procedure presented herein covers threading of all IPS Schedule 80 or heavier thermoplastic pipe. The threads are National Pipe Threads (NPT) which are cut to the dimensions outlined in ANSI B2.1 and presented below.

NOTE: DO NOT THREAD SCHEDULE 40 PIPE

Table 52 THREADING DIMENSIONS

PIPE		THREADS					
NOMINAL PIPE SIZE (IN.)	OUTSIDE DIAMETER "D" (IN.)	NUMBER OF THREADS (IN.)	NORMAL ENGAGE-MENT BY HAND "C" (IN.)	LENGTH OF EFFECTIVE THREAD "A" (IN.)	TOTAL LENGTH: END OF PIPE TO VANISH-ING POINT "B" (IN.)	PITCH DIAMETER AT END OF INTER-NAL THREAD "E" (IN.)	DEPTH OF THREAD MAX. (IN.)
¼	0.540	18	.200	0.4018	0.5946	0.48989	.04440
½	0.840	14	.320	0.5337	0.7815	0.77843	.05714
¾	1.050	14	.339	0.5457	0.7935	.98887	.05714
1	1.315	11½	.400	0.6828	0.9845	1.23863	.06957
1¼	1.660	11½	.420	0.7068	1.0085	1.58338	.06957
1½	1.900	11½	.420	0.7235	1.0522	1.82234	.06957
2	2.375	11½	.436	0.7565	1.0582	2.29627	.06957
2½	2.875	8	.682	1.1375	1.5712	2.76216	.10000
3	3.500	8	.766	1.2000	1.6337	3.38850	.10000
4	4.500	8	.844	1.3000	1.7337	4.38713	.10000



THREADING INSTRUCTIONS PVC - CPVC - PP - PVDF

THREADING EQUIPMENT AND MATERIALS

- Pipe dies
- Pipe vise
- Threading ratchet or power machine
- Tapered plug
- Cutting lubricant (soap and water, soluble machine oil and water)
- Strap wrench
- Teflon tape
- Cutting tools
- Deburring tool

PIPE PREPARATION

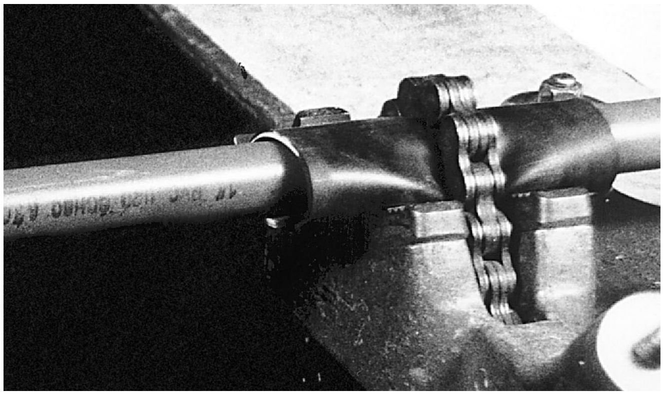
Cut pipe square and smooth and remove burrs or raised edges with a knife or file. To ensure square end cuts, a miter box, hold down, or jig must be used. The pipe can be easily cut with a power or hand saw, circular saw or band saw. Smooth cuts are obtained by using fine-toothed cutting blades (16-18 teeth per inch). A circumferential speed of about 6000 ft./min. is suitable for circular saws; band saw speed should be approximately 3,000 ft/min. Pipe or tubing cutters can also be used to produce square, smooth cuts, however, the cutting wheel should be specifically designed for plastic pipe. Such a cutter is available from your local service center.

If a hold down vise is used when the pipe is cut, the jaws should be protected from scratching or gouging the pipe by inserting a rubber sheet between the vise jaws and the pipe.

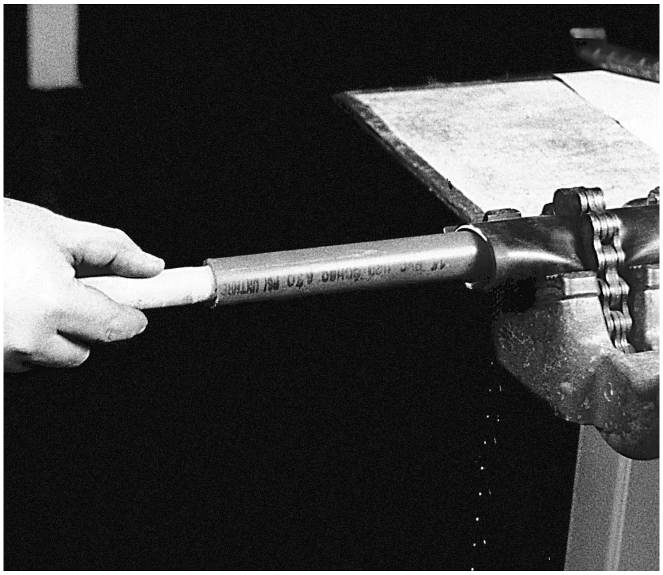
THREADING DIES

Thread-cutting dies should be clean, sharp and in good condition and should not be used to cut materials other than plastics. Dies with a 5° negative front rake are recommended when using power threading equipment, and dies with a 5° to 10° negative front rake are recommended when cutting threads by hand. When cutting threads with power threading equipment, self-opening die heads and a slight chamfer to lead the dies will speed production.

THREADING AND JOINING

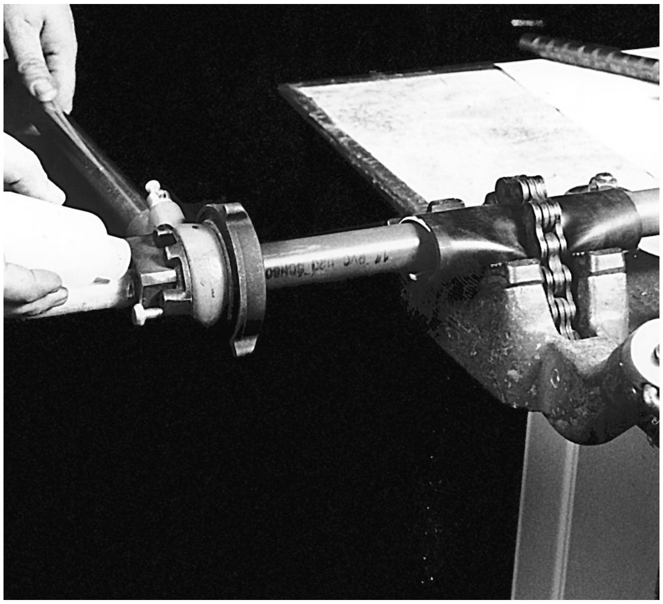


1. Hold pipe firmly in a pipe vise. Protect the pipe at the point of grip by inserting a rubber sheet or other material between the pipe and vise.



2. A tapered plug must be inserted in the end of the pipe to be threaded. This plug provides additional support and prevents distortion of the pipe in the threaded area. Distortion of the pipe during the threading operation will result in eccentric threads, non-uniform circumferential thread depth, or gouging and tearing of the pipe wall.

3. Use a die stock with a proper guide that is free of burrs or sharp edges, so the die will start and go on square to the pipe axis.



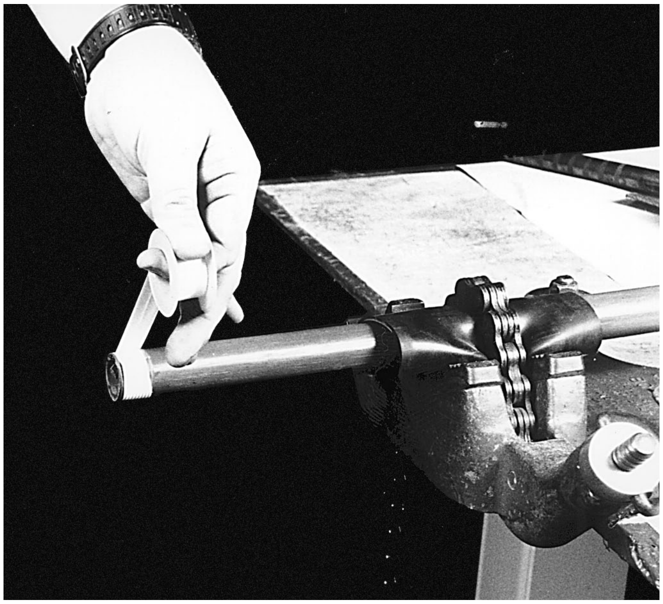
4. Push straight down on the handle avoiding side pressure that might distort the sides of the threads. If power threading equipment is used, the dies should not be driven at high speeds or with heavy pressure. Apply an external lubricant liberally when cutting the threads. Advance the die to the point where the thread dimensions are equal to those listed in Table 52. Do not overthread.

THREADING INSTRUCTIONS PVC - CPVC - PP - PVDF

5. Periodically check the threads with a ring gauge to ensure that proper procedures are being followed. Thread dimensions are listed in Table 52 and the gauging tolerance is +1½ turns.

6. Brush threads clean of chips and ribbons. Then starting with the second full thread and continuing over the thread length, wrap TFE (Teflon®) thread tape in the direction of the threads. Overlap each wrap by one-half of the width of the tape.

7. Screw the fitting onto the pipe and tighten by hand. Using



a strap wrench only, further tighten the connection an additional one to two threads past hand tightness. Avoid excessive torque as this may cause thread damage or fitting damage.

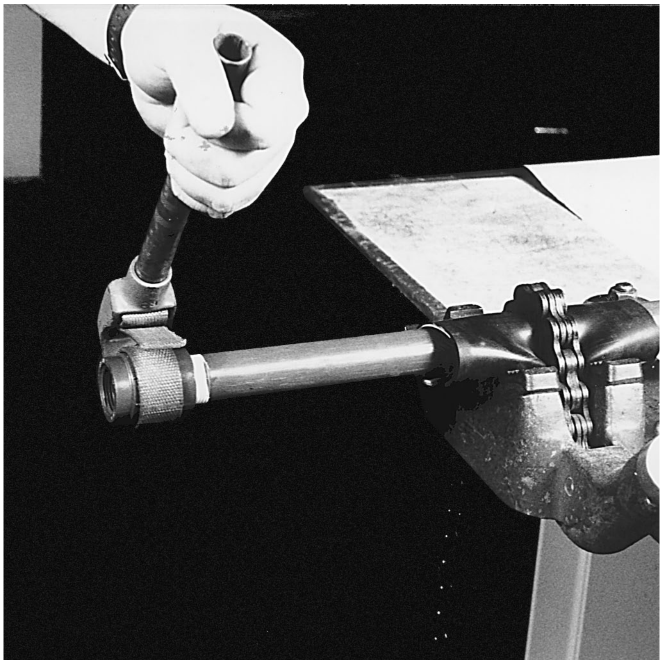


Table 53 REINFORCING PLUG DIMENSIONS*

NOMINAL PIPE SIZE (IN.)	PLUG O.D.
½	0.526
¾	0.722
1	0.935
1¼	1.254
1½	1.475
2	1.913
2½	2.289
3	2.864
4	3.786

*These dimensions are based on the median wall thickness and average outside diameter for the respective pipe sizes. Variations in wall thickness and O.D. dimensions may require alteration of the plug dimensions.

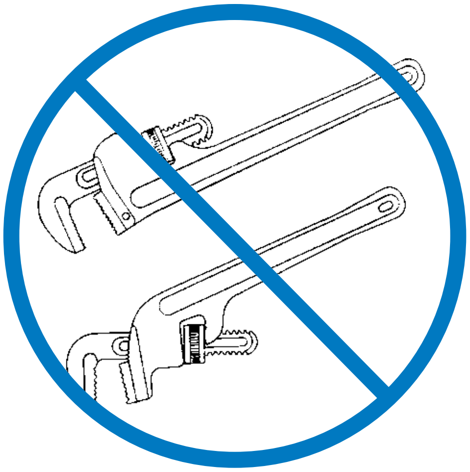
PRESSURE TESTING

Threaded piping systems can be pressure tested up to 50% of the pipe's hydrostatic pressure rating as soon as the last connection is made.

Caution: Air or compressed gas is not recommended and should not be used as a media for pressure testing of plastic piping systems.

Caution: Pressure ratings for threaded systems are reduced drastically. Check your application with your local service center prior to installation.

USE STRAP WRENCH ONLY



FLANGED JOINTS

SCOPE

Flanged joints are recommended extensively for plastic piping systems that require periodic dismantling. Flanges and flanged fittings are available in almost all materials and sizes to meet your requirements. Please consult your local service center for the availability of any flanged fitting not shown in this handbook. Flanges are normally assembled to pipe or fittings by solvent welding, threading, or thermal fusion.

Gasket seals between the flange faces should be an elastomeric, full, flat-faced gasket with a hardness of 50 to 70 durometer. Harrington Industrial Plastics can provide neoprene gaskets in the ½" through 24" range having a ⅛" thickness. For chemical environments too aggressive for neoprene, other more resistant elastomers should be used.

DIMENSIONS

Bolt circle and number of bolt holes for the flanges are the same as 150 lb. metal flanges per ANSI B16.1. Threads are tapered iron pipe size threads per ANSI B2.1. The socket dimensions conform to ASTMD 2467 which describes ½ ″through 8" sizes.

PRESSURE RATING

Maximum pressure for any flanged system is 150 psi. At elevated temperatures the pressure capability of a flanged system must be derated as follows:

Table 54 MAXIMUM OPERATING PRESSURE (PSI)

OPERATING TEMPERATURE				
(°F)	PVC*	CPVC*	PP**	PVDF
100	150	150	150	150
110	135	140	140	150
120	110	130	130	150
130	75	120	118	150
140	50	110	105	150
150	NR	100	93	140
160	NR	90	80	133
170	NR	80	70	125
180	NR	70	50	115
190	NR	60	NR	106
200	NR	50	NR	97
250	NR	NR	NR	50
280	NR	NR	NR	25

NR-not recommended.
*PVC and CPVC flanges sizes 2½, 3 and 4-inch threaded must be back-welded for the above pressure capability to be applicable.
** Threaded PP flanges size ½ through 4" as well as the 6" back weld socket flange are not recommended for pressure applications (drainage only).

SEALING

The faces of flanges are tapered back away from the orifice area at a ½ to 1 degree pitch so that when the bolts are tightened the faces will be pulled together generating a force in the waterway area to improve sealing.

INSTALLATION TIPS

Once a flange is joined to pipe, the method for joining two flanges together is as follows:

Make sure that all the bolt holes of the matching flanges match up. It is not necessary to twist the flange and pipe to achieve this.

Insert all bolts.

Make sure that the faces of the mating flanges are not separated by excessive distance prior to bolting down the flanges.

The bolts on the plastic flanges should be tightened by pulling down the nuts diametrically opposite each other using a torque wrench. Complete tightening should be accomplished in stages and the final torque values in the following table should be followed for the various sizes of flanges. Uniform stress across the flange will eliminate leaky gaskets.

Table 55

FLANGE SIZE (IN.)	RECOMMENDED TORQUE (FT/LB.)*
½-1½	10-15
2-4	20-30
6-8	33-50
10	53-75
12	80-110
14-24	100

*For a well-lubricated bolt.

The following tightening pattern is suggested for the flange bolts.

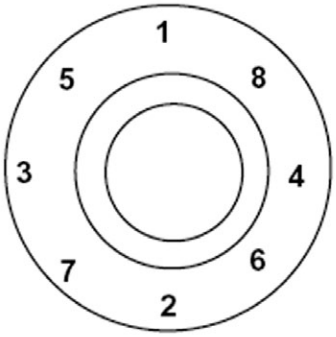


Figure 14

If the flange is mated to a rigid and stationary flanged object, or a metal flange, particularly in a buried situation where settling could occur with the plastic pipe, the plastic flange must be supported to eliminate potential stressing.

Note: Flange gaskets and low-torque gasket sets are available from Harrington Industrial Plastics.

FLANGED JOINTS

Flanging and AV Gaskets

When bolting a flange connection, it is required to tighten the bolts in a specified pattern as well as tighten them to a required specification. Harrington offers a line of low torque AV gaskets in sizes ½" through 12" for single wall pipe connections. These gaskets offer a unique double-convex ring design that gives optimum sealing with one third the torque of a common flat gasket seal. The gaskets are available in the following materials:

- EPDM
- PVDF bonded over EPDM
- Teflon™ over EPDM

They are available in both standard and high-purity grade. PTFE and PVDF bonded gaskets are produced in a proprietary laminating process for bonding to EPDM. The use of the rubber backing provides greater elasticity for lower bonding torques.

Detail of Gasket

When tightening a flange, the torque rating is dependent on the gasket used. For the AV gasket, see Table 56 for the recommended tightness. In addition, when tightening follow the star pattern shown in Figure 14, on the previous page. Conduct two or three passes, tightening the flange uniformly. Finish by doing a circular pass to check the torque values. Always use a torque wrench when tightening a flange. A common mistake when tightening a flange is to squeeze it as tightly as possible. This action will damage the gasket and eventually lead to reduced elasticity and leakage. Do not tighten beyond the rating.

Table 56 **Recommended Bolt Torque for AV Gaskets (IN/LBS.)**

SIZE (IN.)	TEFLON™ - PVDF	EPDM
½	174	157
¾	174	157
1	174	157
1¼	191	165
1½	217	174
2	217	174
2½	304	217
3	304	217
4	304	217
6	348	260
8	435	304
10	435	304
12	522	435

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF SOCKET FUSION

Socket fusion is the oldest and simplest method for assembling thermoplastic materials. Socket fusion used for welding Schedule 80, polypropylene and PVDF in sizes ½" through 4"and the equivalent metric sizes. In socket fusion, material is in direct contact with the heat source. The pipe is inserted into a heated mandrel and the pipe's exterior becomes molten. Fittings are inserted over a mandrel and the interior becomes molten. After proper heat soak time has been accomplished, the two components are forced together until they bottom-out.

Figure 15 **Hand-held socket fusion for 1/2"–2" show left, 1/2"–4" on right**

Socket fusion is fairly tolerant to temperature conditions and is simple to do. Untrained personnel can be trained in a short period of time to make consistent and reliable joints. The disadvantage of socket fusion is that it provides the most uneven weld of all the methods. Beads are formed on the pipe and fitting and final stop position is random, depending on the operator. Mechanically the weld is reliable, but smooth, clean welds are more difficult to achieve consistently. Additionally, weld inspection is limited as the weld area is not visible from the outside.

Socket fusion is ideal for smaller systems and is quite simple and practical for welding ½" through 1". While 1½" and 2" sizes can be welded with the handheld tool, consider using the bench-type socket fusion machine because much more force is required when attempting to bottom-out the pipe in the socket. 3" and 4" socket welds should only be done with the bench type machines. Larger sizes should be joined by IR or butt welding.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF SOCKET FUSION

Socket Fusion with Hand Held Tools

The method described here applies only to thermal welds using manual-type welding equipment.

STEP 1: PREPARATION
Select the heater bushing and the heating spigot of the required diameters, depth for type and brand of material used. Insert and secure the bushings to the heating paddle or mirror.

STEP 2: CLEAN SURFACES
Carefully clean the Teflon® coated contact surfaces. Use only a clean, dry cloth

STEP 3: HEATING TOOL
Set the temperature of the heating tool. To form the joint correctly, the temperature should be set correctly and check with a Tempilstik®. Plug the heater into a grounded 110-volt outlet ensuring that the outlet is protected by circuit breakers or fuses.

CAUTION: Handle the heater bushings carefully. Damage to the Teflon coating on the heater bushings can result in irregular heating resulting in inferior joints.
NOTE: Using other electrical devices on the same power source can cause amperage loss resulting in poor welds.

STEP 4: CUT PIPE
Cut the pipe at right angles and chamfer the newly cut edge at an angle of 15°. Chamfer length to manufacturer's recommendations.

STEP 5: CHECK FIT
Check pipe and fittings for dry fit before fusing together.

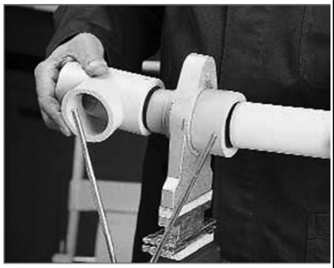
STEP 6: MAKE LONGITUDINAL REFERENCE
Mark a longitudinal reference line on the outside of the pipe and the fitting to show a guideline to prevent the two parts from rotating while the joint is being made.

STEP 7: CLEAN PIPE AND FITTING
Clean the fitting and pipe of any traces of oil or grease on the weld surfaces with an approved cleaning agent such as isopropyl alcohol.

STEP 8: CHECK BUSHINGS TEMPERATURE
Check that the thermostat green light is on steady or, if external conditions require the use of a Tempilstik®, use the correct Tempilstik® to check the bushings temperature.

CAUTION: Do not use the stick on the parts of the bushings that will come in contact with pipe, fittings or valves.
NOTE: Overheating or under-heating of the pipe and fittings may result in a poor joint.

STEP 9: HEAT COMPONENTS
Briefly and simultaneously engage both pipe and fitting with their respective bushing to determine interference. If substantially more resistance is offered by either the pipe or the fitting, begin your insertion with just that one item. Start the insertion of the second item once the first has reached the bushing half point. If the same resistance is observed, start both pipe and fitting insertion simultaneously.
Once the mark on the pipe reaches the edge of the female bushing, and the top of the fitting reaches the stop on the male bushing, apply just enough pressure to prevent "kickback" and hold together



STEP 10: ASSEMBLY
Once the recommended heating time has elapsed, quickly remove the elements from the heater bushings and fit the pipe into the socket for the entire insertion length as determined and marked previously. Do not turn the pipe in the socket.

Ensure the longitudinal reference marks are perfectly aligned.

BASIC PRINCIPLES OF SOCKET FUSION

STEP 11: ASSEMBLY Hold the joint together for the welding time established by the manufacturer. This allows sufficient time for the components to fuse together. Do not twist or move joint for prescribed time.	
Step 12: JOINT SETTING Leave the joint to cool slowly at ambient temperature for the recommended cooling time established by the manufacturer. Allow for proper cooling before pressurizing and testing the system. **NOTE:** Never dip the joint into water or expose it to a forced airstream in order to cool it quickly as this will result in weak joints.	

The bench type machines follow a similar procedure to that described above but provide more consistent joints than are possible by hand.

It is important to remember that each manufacturer's resins will vary slightly, resulting in different heat-soak times, pressures to make the joint and cooling times.

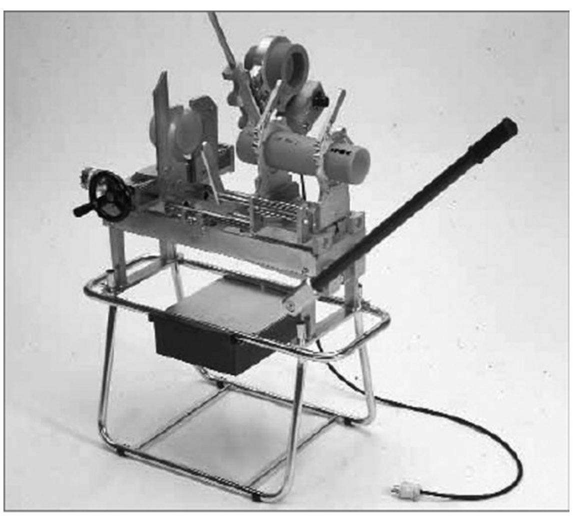


Figure 16 **Bench type Socket Fusion Tool for ½" - 4"**

The Bench Fusion machine is the natural choice when performing larger size socket welds or when completing a large number of welds requiring consistent and maximum accuracy.

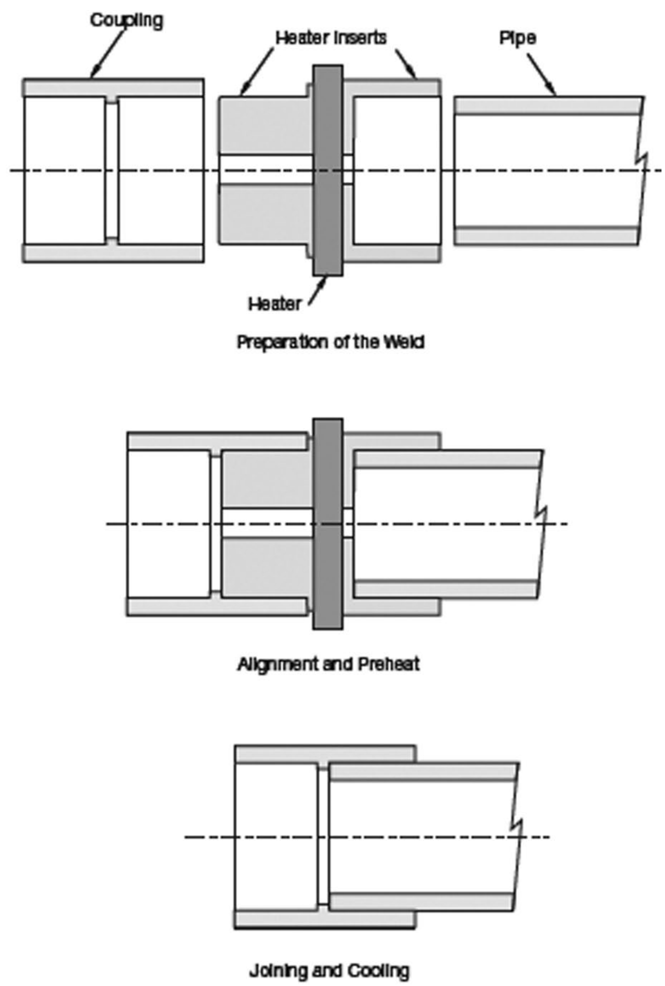


Figure 17 **Socket Fusion Process**

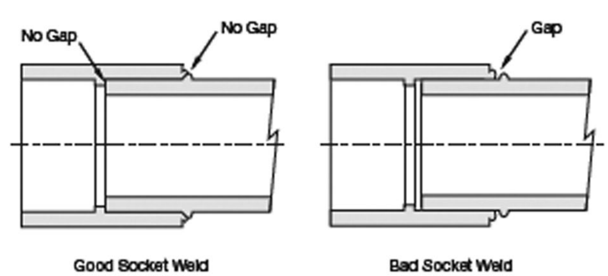


Figure 18 **Socket Fusion Sample Welds**

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF BUTT FUSION

Butt fusion is the second oldest heat fusion technique used for the assembly of thermoplastic pipe and fitting. Initially used for the joining of polyethylene, butt fusion techniques have successfully been used on almost all thermoplastic materials. It is the preferred method of joining larger diameter polypropylene (PP), polyvinylidene fluoride (PVDF), Halar (E-CTFE), and HDPE piping systems. Typical butt fusion systems range in sizes from ½" through 24" and larger.

The principle of butt fusion is to heat two surfaces at the melt temperature, then make contact between the two surfaces and allow the two surfaces to fuse together by application of force. The force causes flow of the melted materials to join. Upon cooling, the two parts are united. Nothing is added or changed chemically between the two components being joined. When fused according to the proper procedures, the joint area becomes as strong as or stronger than the pipe itself in both tensile and pressure properties. Butt fusion does not require solvents or glue to join material.

Butt fusion is recognized as the industry standard, providing high integrity and reliability. It does not require couplings or added material. The procedure, recommended by most manufacturers, conforms to ASTM D-2857 for Joining Practices of Polyolefin Materials, and the recommended practices of the ASME B 31.3 Code (Chemical Plant and Petroleum Refinery Piping).

Welding Process

Once the pipes or fittings have been secured in the proper welding equipment[1], aligned and planed with the facing tool (planer), and the heating element is warmed to the proper temperature, welding proceeds as follows:

Follow the welding parameters (temperature, time, and force) provided by the manufacturer of the butt fusion system that has been selected. Each manufacture will provide specific instructions applicable to their specific resin formulation.

Insert heating element between secured pipes or fittings, making sure full contact is made around surfaces. Visually inspect to ensure there are no gaps seen between material and the heater surface.

Apply full welding pressure, as recommended by the manufacturer or until a maximum 1/64" ridge of melted material is present around the outside circumference of both pipes or fittings. This indicates proper melt flow has been accomplished and further guarantees two parallel surfaces.

Reduce the pressure to the recommended melt pressure and follow the recommended heat soak time for the material selected.

At the end of the heat soak time, in a quick smooth motion, separate the pipe fitting from the heating element, remove the heater, then rejoin the materials applying the recommended weld pressure as prescribed by the manufacturer. It is important to gradually increase pressure to achieve welding pressure. The weld must be performed within the allowable change over time specified. Change over time is the maximum period of time when either the pipes or fittings can be separated from the heating element, yet still retain sufficient heat for fusion.

The heat soak time may need to be increased in cold or windy environments. Several practice welds should be conducted at the installation site to ensure welding can be performed as a test of conditions.

A visual inspection must be performed as well. After joining, a bead surrounding the whole circumference will have been created. A good weld will have two symmetrical beads on both the pipe or fittings almost equally sized and have a smooth surface. Bead size and height will vary with materials and wall thicknesses.

Allow components to cool to the touch or until a fingernail cannot penetrate the bead. This is recommended in ASTM D-2857, Section 9. The pipes or fittings may be removed from the welding equipment at the completion of the specified cooling time.

Do not put components under stress or conduct a pressure test until complete cooling time has been achieved.

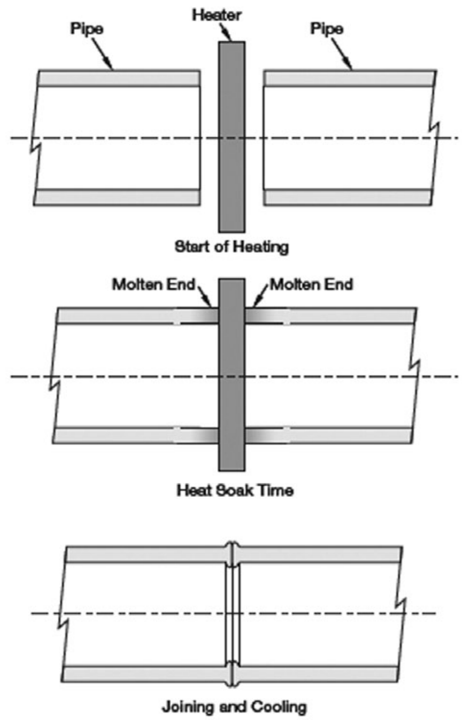


Figure 19 **Butt fusion welding process**

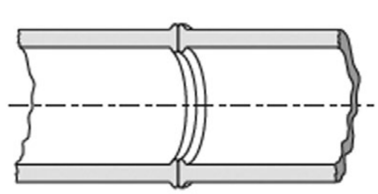


Figure 20 **Example of desired weld**

[1] Harrington offers a full range of butt fusion equipment for sale or for rent. Please see the current catalog for complete details.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF BUTT FUSION

BUTT FUSION (FOR DOUBLE WALL PIPING SYSTEMS)

Installation of several different double containment piping systems involves the use of thermal butt fusion for both the carrier and containment piping. Depending on system design, the size, material, and layout will determine the required equipment.

Harrington and our suppliers offer all the necessary sizes and styles of equipment for any installation type.

Systems that are fully restrained and consist of the same carrier and containment materials can take advantage of the simultaneous butt-fusion method. Simultaneous fusion allows for the quickest and easiest installation by conducting the inner and outer weld all at once. For designs that consist of dissimilar materials or require the inner (carrier) piping to be loose for thermal expansion, use the staggered welding procedure discussed later in this handbook. Staggered welding consists of welding the inner carrier pipe first and the containment piping second. Finally, if a leak detection cable system is required, special heating elements or procedures are provided to accommodate for pull ropes.

The basic installation techniques for double containment piping systems follow the principles that apply to ordinary plastic piping applications.

Simultaneous Butt Fusion Method

The object of simultaneous fusion is to prepare both the carrier and containment pipe so that both pipes are fixed to each other and thus can be welded at the same time. In some systems, simultaneous fusion can only be performed due to their design. The net result of the simultaneous method is a substantial reduction of labor and equipment requirements.

As previously discussed, simultaneous fusion is only applicable for welding installations having the same carrier and containment material. In addition, simultaneous fusion is used for systems that are completely restrained. Prior to using the simultaneous method, an analysis based on operating conditions is required to determine the suitability of a restrained design. Contact your local Harrington branch for assistance in this area.

Equipment

For simultaneous welding, standard butt-fusion equipment used for single wall systems is used. No special heating elements are required. For some systems, hot air or extrusion welding equipment is necessary to weld the support discs and spider clips to the pipes. Hot air welding is not recommended or used for any pressure rated components.

Fittings

Fittings used for simultaneous fusion are either molded or prefabricated at the factory with the necessary support discs. Prefabricated fittings greatly reduce the amount of hot air welding required in the field and, in turn, reduce labor time. If an installation is pipe intensive, labor costs may be reduced by ordering prefabricated pipe spools in longer dimensions.

WELDING PROCEDURE

Welding theory for double containment is the same as for the single wall pipe. Most manufacturers have developed welding tables for the appropriate heating times and forces required for simultaneous fusion of their products. The following procedure outlines the necessary steps for simultaneous fusion.

Double Wall Pipe Assembly

Pipe and fittings in a simultaneous double wall system are generally prefabricated at the factory and supplied to a job site ready for butt fusion; however, when varying lengths are required, in-the-field assembly is necessary. Staggered welding procedures discussed later in this section may be required in some situations. Additionally some systems will require the use of hand-held hot air welding and/or extrusion welding. Only personnel proficient in thermoplastic welding should be employed for the task of assembling systems that require custom fabrication on site.

The following procedures are designed to prepare customer lengths and fittings for simultaneous butt fusion:

A good weld requires proper preparation of the material. The pipe should be free of any impurities such as dirt, oil, etc. Additionally, some thermoplastics develop a thin layer of oxidized molecules on the surface that require scraping or grounding of the material. Another effect, especially with HDPE, is the migration of unchained lower density molecules to the surface caused by internal pressure of the material. This gives the usually "waxy" surface appearance of HDPE. Grinding or scraping is required. Wipe off any dust with a clean cloth. Do not use solvents or cleaners; they introduce chemicals with unknown and likely negative effects.

Place the molded or fabricated support spider clips or centralizers, with tops aligned, on the carrier pipe, and then hot gas (PP) or extrusion weld (HDPE) the clips into place as shown in Figure 21. Be sure to use the required amount of clips on the full lengths of the carrier pipe. Proper spacing should be determined by the manufacturer's recommendations.

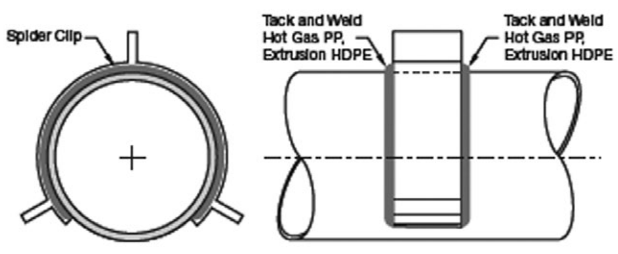


Figure 21 **Spider clip or centralizer attached to carrier pipe**

Insert carrier pipe into containment pipe. Be sure the two pipes have been stored in the same environment for equal expansion or contraction to occur before welding end centralizers into place.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF BUTT FUSION

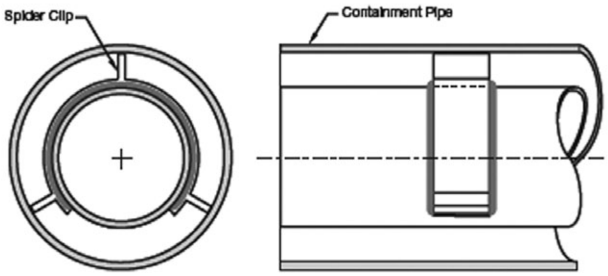


Figure 22 **Carrier pipe and spider clips inserted into containment pipe**

For simultaneous welding, end centralizers, known as support discs, are hot air or extrusion welded to the carrier and containment pipes. This prevents any movement of the carrier pipe during the butt-fusion process. The alignment must match that of the spider supports for the installation of leak detection cables as well as for leak flow. In fitting assemblies, install end centralizers only. All centralizers are installed approximately 1" from the ends using a four milimeter welding rod.

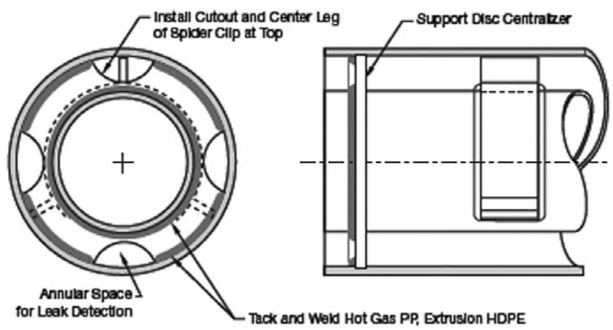


Figure 23

Support disc attached to carrier and containment pipes.

The pipe and fitting with support discs are now ready for simultaneous butt fusion using the recommended ASTM D-2857 joining practices.

Harrington highly recommends a complete review of the manufacturer's installation instructions by all installation crew members, prior to the start of any new installation project.

BUTT FUSION PROCEDURE FOR DOUBLE WALL PIPE WITHOUT LEAK DETECTION CABLE SYSTEMS

The principle of butt fusion is to heat two surfaces at a fusion temperature, then make contact between the two surfaces and allow the two surfaces to fuse together by application of force. After cooling, the original interfaces are gone and the two parts are united. Nothing is added or changed chemically between the two pieces being joined.

Butt fusion is recognized in the industry as a cost effective joining method of very high integrity and reliability. The procedure recommended by Harrington conforms to ASTM D-2857 for Joining Practices of Polyolefin Materials, and the recommended practices of the ASME B 31.3 Code (Chemical Plant and Petroleum Refinery Piping).

The procedure is outlined as follows: Once the pipes or fittings have been secured in the proper welding equipment with the tops and annular space aligned and the heating element warmed to the proper temperature, welding should proceed as follows:

Follow the welding parameters outlined by the manufacturer of the selected system.

To ensure the carrier pipe is planed and flush with the containment pipe, put 4 marks on the end of the carrier pipe at 3, 6, 9 and 12 o'clock prior to planing. If the outer pipe is completely planed and the marks on the carrier have been removed, planing is complete. With experience, visual inspection can determine the planing process is complete. Remove all shavings and recheck alignment. For Poly-Flo, the pipes should be installed in the machines so that the ribs do not align, thereby allowing any fluid to flow to the low point of the annular space in the event of a leak.

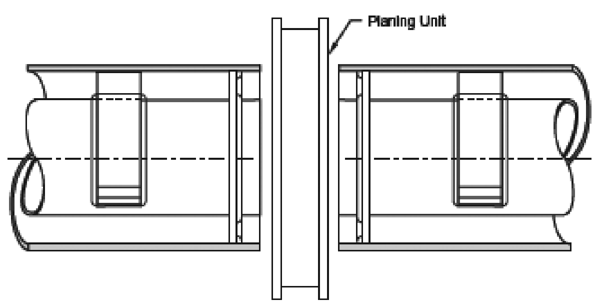


Figure 24 **Plane carrier pipe flush with containment pipe.**

Insert heating element between secured pipes or fittings, making sure full contact is made around surfaces.

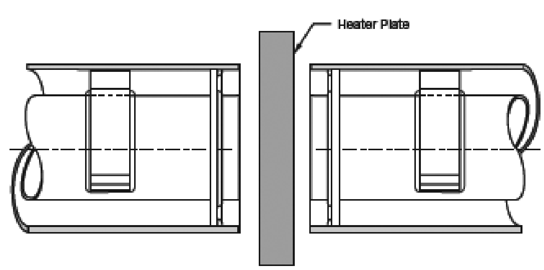


Figure 25 **Insert heating element between pipe ends.**

BASIC PRINCIPLES OF BUTT FUSION

Apply full welding pressure until a maximum 1⁄64" ridge of melted material is noticed around the outside circumference of the components. This indicates proper melt flow has been accomplished and further guarantees two parallel surfaces

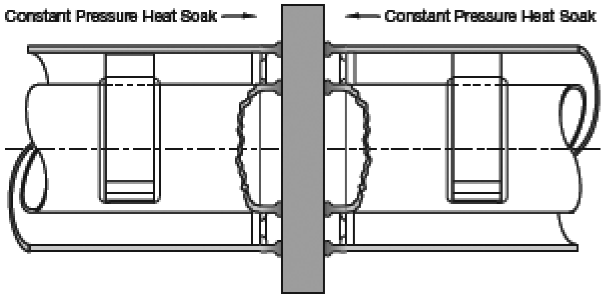


Figure 26 Apply welding pressure to the heating element.

Reduce the pressure to the recommended melt pressure recommended by the manufacturer and begin timing for recommended heat soak time

At the end of the heat soak time, in a quick smooth motion, separate either the pipes or fittings, remove the heating element, then apply weld pressure recommended by the manufacturer. It is important to gradually increase pressure to achieve welding pressure. The weld must be performed quickly and within the allowable change-over time. Change-over time is the maximum period of time when either the pipes or fittings can be separated from the heating element, yet still retain sufficient heat for fusion. Bring the melted end together to its welding pressure.

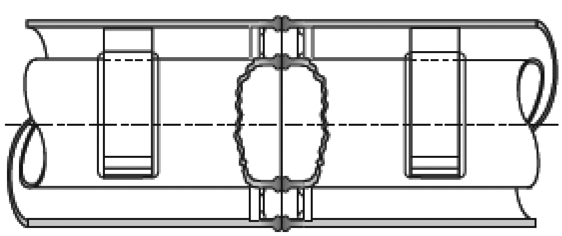


Figure 27 Bring pipe ends together and apply welding pressure.

The heat soak time should be increased if the environment is cold or windy or if either the pipes or fittings are cold. As a test of environmental conditions, several practice welds should be done at the installation site to ensure welding can be performed.

A visual inspection must be performed as well. After joining, a bead surrounding the whole circumference must have been created. A good weld will have a symmetrical bead on both pipes or fittings and will have a smooth surface.

Allow components to cool to the touch or until a fingernail cannot penetrate the bead. This is recommended in ASTM D-2857, Section 9. The pipes or fittings may be removed from the welding equipment at this time.

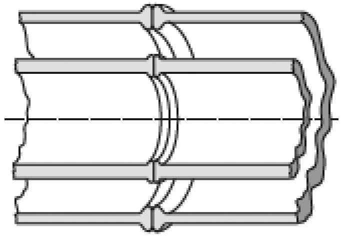
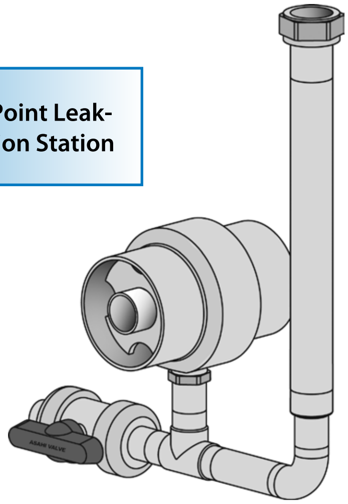
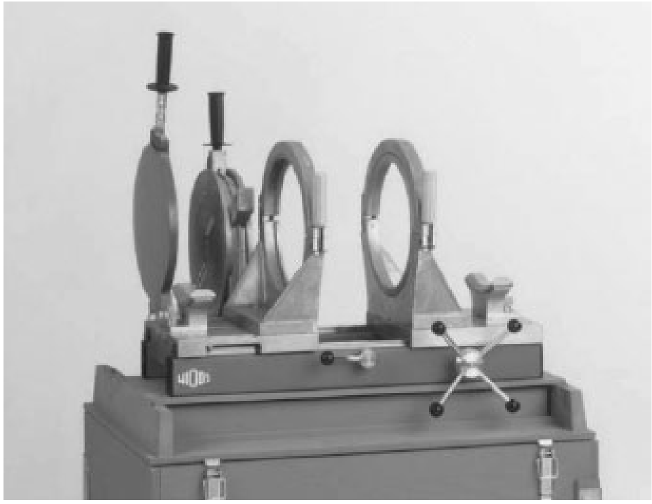


Figure 28 Inspect test welds for uniform beads.

Do not put pipe or fittings under any type of stress or conduct a pressure test until complete cooling time (as recommended by the manufacturer) has been achieved.

Low-Point Leak-Detection Station





Asahi/America's Shop 12 (for 1½" – 12" Butt Fusion)

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF BUTT FUSION

BUTT FUSION PROCEDURE FOR DOUBLE WALL PIPE WITH LEAK DETECTION CABLE SYSTEMS

Split-leak detection heating elements allow both the carrier and containment pipes to be welded simultaneously, with a pull cable in place. The mirror design, as shown in Figure 29, is capable of splitting apart and wrapping around a wire. The small hole centered at the bottom of the heater allows a pull wire to be in place during the fusion process. Once the pipe is heated, the heating element is split apart and removed, leaving the wire in place for the final pipe joining.

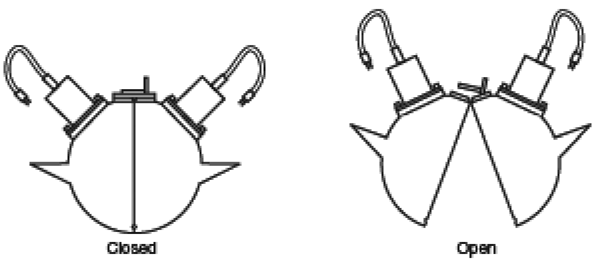


Figure 29 Split heating elements for leak detection system.

A short piece of wire is attached to the pull rope on both ends after planing. The wire runs through the heater during welding in order to prevent damaging or melting the pull rope (see Figures 30 to 33). After each section is complete, the wire is pulled down to the next joint to be welded. The installation of pull rope is at the six o'clock position. A continuous pull rope, free from knots and splices, should be pulled through as the system is assembled.

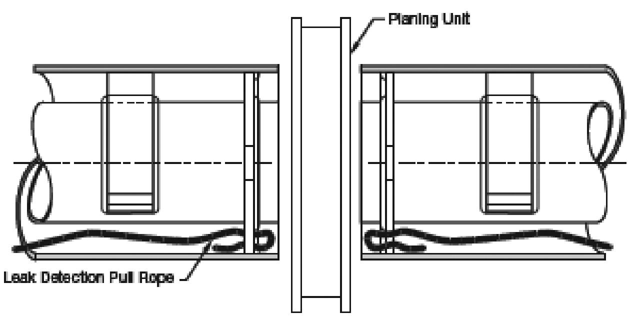


Figure 30 Planing ends with pull rope installed

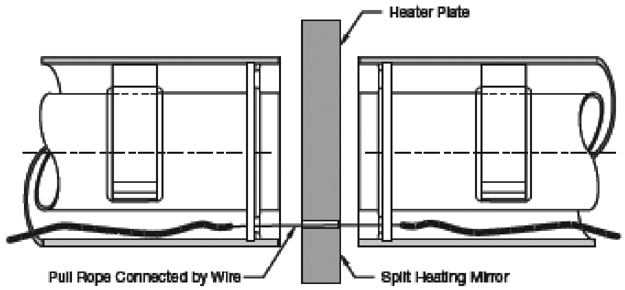


Figure 31 Pull rope connected by wire through heating element

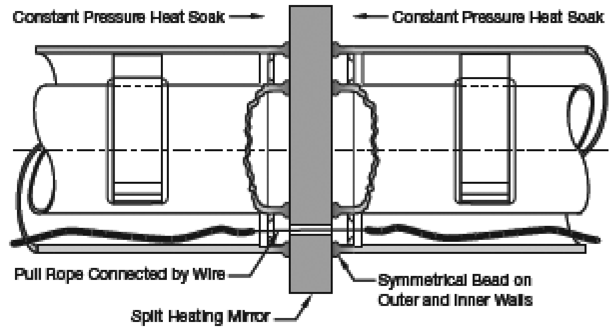


Figure 32 Pipe ends heated with pull rope installed

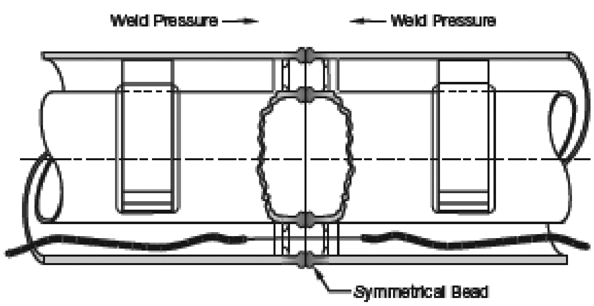


Figure 33 Welding complete with pull rope installed

Follow standard butt-fusion procedure for welding. Other methods for welding with a solid heating element are available that will accommodate a leak detection cable system.

Asahi/America's Field Machine (for 3" – 12" Butt Fusion)

BASIC PRINCIPLES OF BUTT FUSION

Staggered Butt-Fusion Method

Using the staggered fusion procedure to assemble a system is more complicated and labor intensive than simultaneous fusion. It offers the ability to install a double containment system with a flexible inner pipe or with different carrier and containment materials.

In staggered welding, the carrier pipe is welded first, followed by the containment pipe. In a staggered system there are no end support discs. This allows for movement of the carrier components. It is important to plan which welds will be made and in what order. Enough flexibility is required to move the inner pipe out from the outer pipe to perform a carrier weld.

In long straight runs the procedure is simple, due to significant carrier pipe movement. In systems that are fitting intense, the procedure becomes more difficult, because the pipe movement is limited to the amount of annular space between the carrier and containment fittings (see Figure 34).

Welding Procedure

Begin by attaching spider clips to the carrier pipe (follow steps previously shown in double wall pipe assemblies).

Insert carrier pipe or fittings into the appropriate containment line. At the start of a system, it may be easier to weld the carrier first and then slide the containment pipe over the carrier pipe; however, as the installation moves along, this will not be possible. Note: If containment piping has been roughly cut, make sure to plane it prior to welding the carrier pipe. Once the carrier is welded, the containment pipe cannot be planed.

In the machine, use the two innermost clamps to hold the carrier pipe for welding. Use the outer clamps to hold containment pipe in place. In cases where movement is limited, fitting clamps will be necessary to hold the carrier pipe.

Once all pieces are locked in place, weld the carrier pipe using standard butt-fusion techniques (see Figures 34 A and 34 B).

Once the carrier weld is complete, remove the inner clamps and pull the containment pipe together for welding (see Figures 34 C and 34 D). At this point, switch all clamps to containment sizing. It may be preferable to use two machines to eliminate the constant changing of clamps. Also, in some designs, two machines may be required to weld the two different diameter pipes.

To weld the containment pipe, a split annular mirror is required (see Figure 34 F). The mirror is hinged to let it wrap around the carrier pipe while welding the containment pipe.

It is important to ensure the mirror is properly centered so it does not rest on and melt the carrier pipe.

Once the mirror is in place, the welding procedure is the same as standard single wall butt fusion.

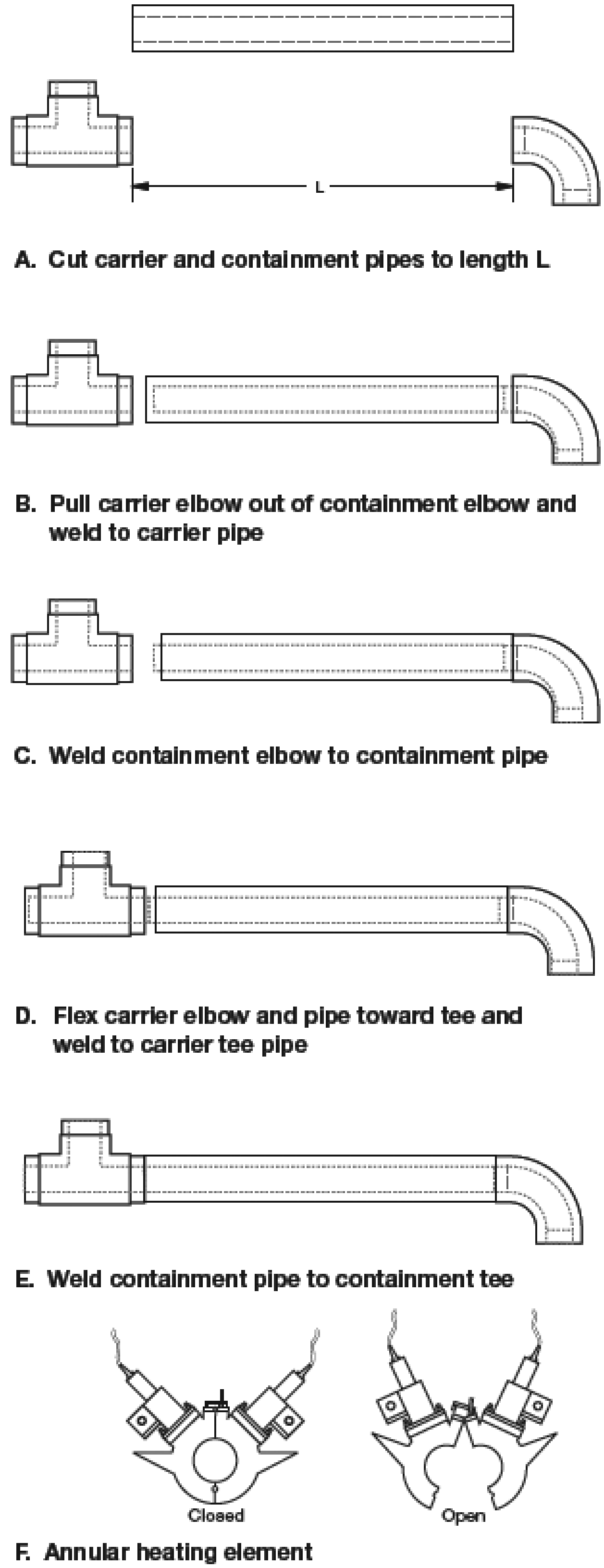


Figure 34 Staggered Butt Fusion

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF IR (INFRARED) FUSION

IR Fusion

Improving upon conventional butt fusion, IR welding uses a noncontact method. IR welding uses the critical welding parameters of heat soak time, change over time, and joining force as found with butt fusion. By avoiding direct contact with the heating element, IR fusion produces a cleaner weld with more repeatable and smaller bead sizes. The end result is a superior weld for high-purity applications.

The graph in Figure 36 outlines the forces applied during the non-contact joining process. Notice that the ramp up force to full joining pressure is a smooth curve where force is gradually ascending over time. Even force build-up is critical to join material without creating a cold joint.

Welding Process

Material is prepared for IR fusion by preparing smooth, clean surfaces on the ends to be joined. Butting the material against an internal planer acts as a centering and leveling device. The planer is then used to cut a clean and smooth surface. The material should then be checked for vertical and horizontal alignment. Welding machines should allow for minor adjustments to the vertical and horizontal orientation of the material.

Once alignment has been verified, the material is heated by close proximity to the heating source. Through radiant heat and proper heat soak time, the material becomes molten to allow physical bonding between the two pieces.

After the heating source has been removed, the material should be joined together in a steady manner, slowly ramping up the force until the desired joining force has been achieved

Ramping up and monitoring the force is critical for repeatable and successful IR welding. This ensures the molten material has joined at the right force and prevents against cold welds, which are caused by the molten material being pushed to the inside and outside of the weld zone.

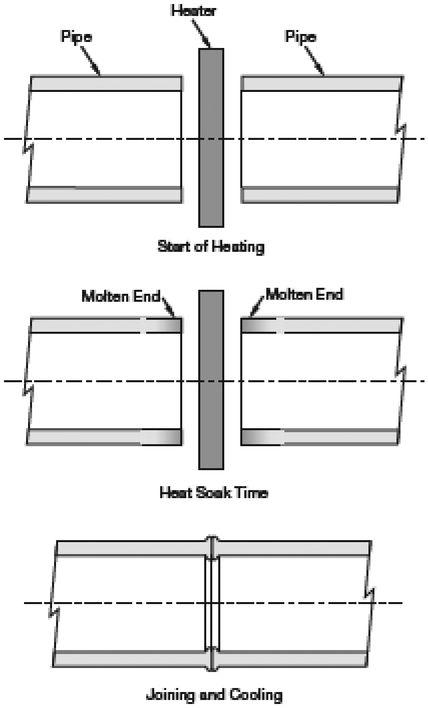


Figure 35 IR fusion welding process

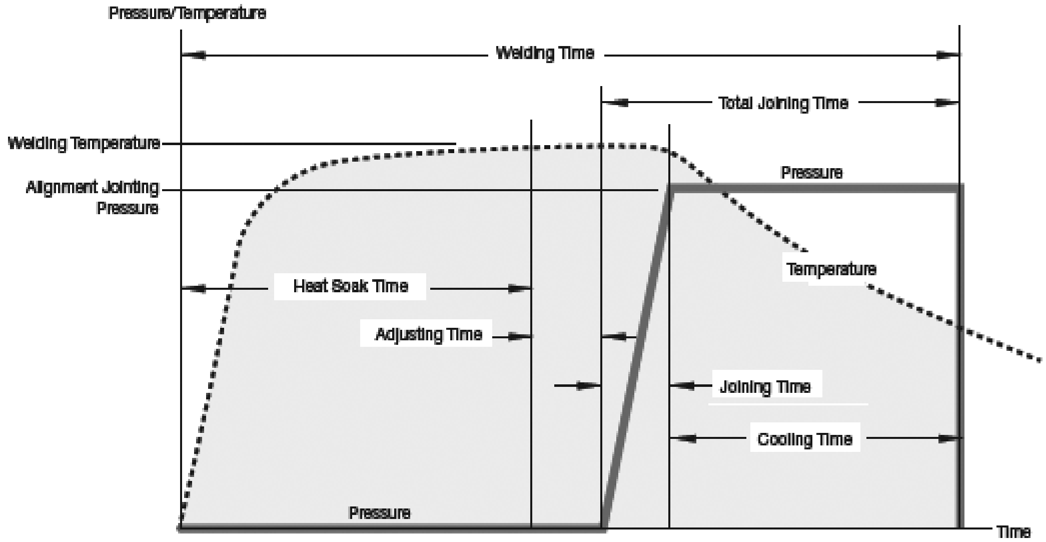


Figure 36 IR fusion timing diagram

BASIC PRINCIPLES OF HPF FUSION

HPF Fusion

The HPF welding technology is an electric socket fusion system that joins Purad® PVDF piping components, providing a smooth internal surface.

Welding Process

Pipes and/or fittings are to be planed except standard 90s, which are planed at the factory. The HPF coupling is placed in the wide mounting clamp. Using the mechanical stop on the clamp, the pipe is centered in the coupling. The pipe or fitting ends should be tight against each other without a gap.

Once the components are fixed in the clamp, the leads are connected and the proper welding times and voltage are scanned through a bar code reader. The entire welding process from this point is automatic and controlled by the HPF unit.

HPF provides a weld without any internal obstruction or any outside contamination. Because the coupling is the heating element and is closed to the external environment, contamination is avoided during the fusion process.

HPF uses most butt-fusion fittings. Extended leg fittings are not required.

HPF welding is capable of being conducted with or without an internal balloon. With the balloon, the joint is completely smooth without any bead or seam. Without the balloon, the joint is still beadless. The advantage of HPF is that all joints within its size range can be conducted without the need of a union, flange, or alternative welding method. See the manufacturer's HPF operation manual for further details on weld procedures.

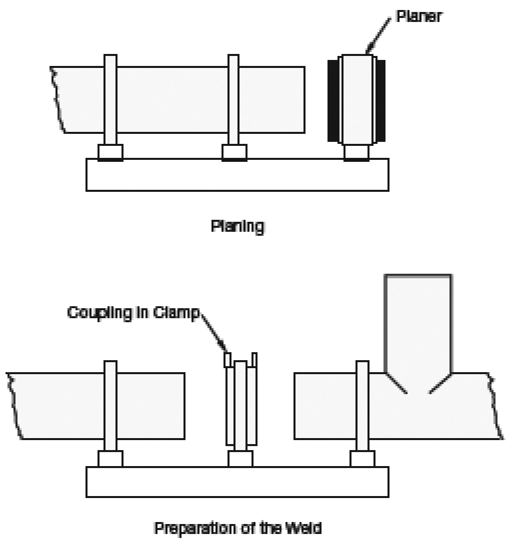


Figure 37 HPF fusion welding preparation

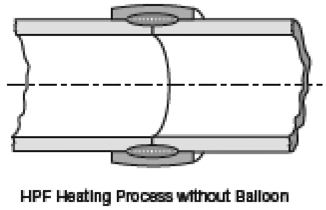


Figure 38 HPF fusion heating process without balloon

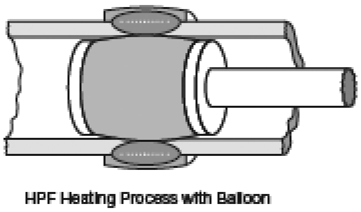


Figure 39 HPF fusion heating process with balloon

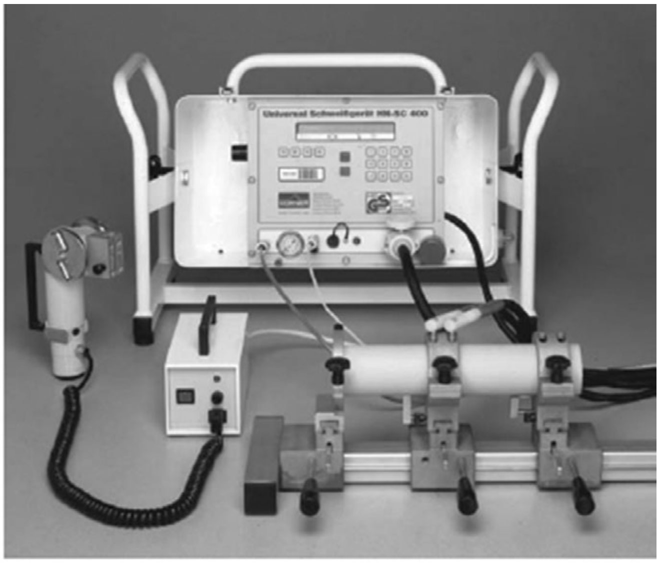


Figure 40 HPF fusion equipment

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF SMOOTH INNER BORE (S.I.B.) WELDING

The Sani-Tech® Smooth Inner Bore 2 Welding System (Sani-Tech® S.I.B.® 2) is a semiautomatic system designed to provide heat and pressure in order to perform a localized smooth circumferential weld without welding beads, crevices, or other potential bacteria traps. When weld are made properly, the inside of the pipe joint remains as smooth or smother than the original pipe. However, this technique and tool only works with Sani-Pro® Kynar® PVDF and Sani-Pro® T, polypropylene tubing. The microprocessor based user interface consists of a power switch, vacuum/pressure switch, E-Stop and color LCD touch screen. This special user interface allows an operator to store and modify weld recipes (parameters) for Sani-Pro® Kynar® PVDF and Sani-Pro® Polypropylene tubing in four different sizes: Mini, Maxi, 1½ and 2 inch sizes. This system also includes an interchangeable welding head for each tubing size.

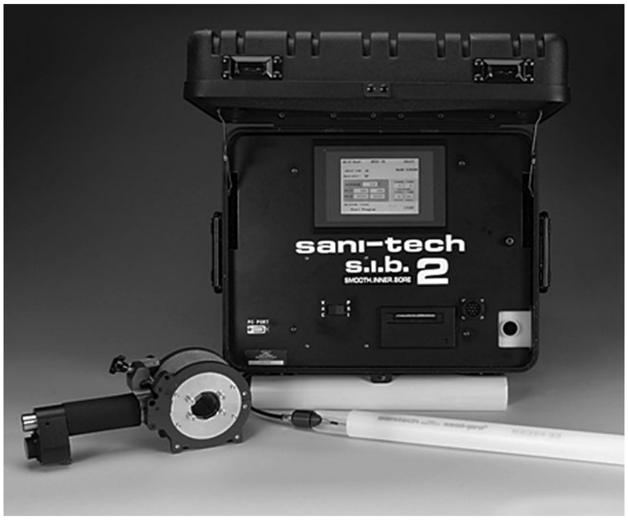


Table 57

Sani-Pro® Kynar® PVDF	Sani-Pro® T POLYPRO-PYLENE	NOMINAL SIZE (IN.)	INNER DIAMETER	
Maximum Operating Pressure in psi @ 72° F	Maximum Operating Pressure in psi @ 72° F		IN.	MM.
230	150	¾	0.560	14.2
230	150	1	0.856	21.7
230	150	1½	1.356	34.4
230	125	2	1.856	47.1
150	75	2½	2.356	59.8
150	75	3	2.856	72.5

Table 58

Temperature correction factors Multiply maximum operating pressures shown above times correction factors shown below.			
° F	° C	Sani-Pro® Kynar® PVDF	Sani-Pro® T POLYPROPYLENE
100	38	0.90	0.85
125	52	0.80	0.65
175	80	0.60	*NR

*NR = not recommended.

Welding Procedure:

Assemble machine and inspect all components (see checklist packaged with machine)

a. Attach the appropriate bladder to the system's control unit
b. Attach the welder to the system's control unit
c. Attach the hose to the welding head

Energize electric system and check machine for faults or alarms.

Cut tubing square and clean with wheel cutter only. Do not use ratchet cutter.

Place tubing in facing tool and prepare fresh, clean, smooth ends in accordance with manufacturers instructions.

Tubing must be cleaned using isopropyl alcohol to remove any remaining oil, grease, or plastic shavings. Do not touch end of pipe or fitting to be joined after cleaning.

Insert bladder through the length of tubing to be joined and let it extend halfway out of side to be welded.

Push tubing together in welding head so the area to be joined is centered and aligned in the welding die.

Tighten clamps per manufacturer's instructions while making sure bladder does not slide.

Press "Start" on the touchscreen or the remote start button (located on the welding tool handle) to begin welding cycle.

During the welding cycle, do not move tubing or machine. Check microprocessor's readout per manufacturer's instructions. Weld cycle may be aborted at any time by pressing the "Abort" button and responding to the confirmation screen.

Upon start of cooling cycle, the machine will beep once. When cooling cycle is complete the machine's display will return to the "Start Program" and the RUN button will turn green.

The material will still feel hot to the touch, but the clamps may be loosened, the bladder removed, and the joint removed from the welding tool.

Print complete information on the completed weld.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF ELECTROFUSION FOR THERMOPLASTIC PIPE

Electrofusion is a method of joining several of the different thermoplastic materials including polypropylene (PP), polyvinylidene fluoride (PVDF), and polyethylene. Electrofusion provides a simple and safe alternative to other fusion techniques and it lends itself well to field installations, repairs and double containment system installations especially in tight quarters.

While each manufacturer offers a slightly different technique to the joining process, each electrofusion system depends on an electrical wire being fit between the exterior pipe wall and a female socket-type fitting. Frequently the manufacturer will embed this wire into the female socket during the manufacturing process similar to those shown below:

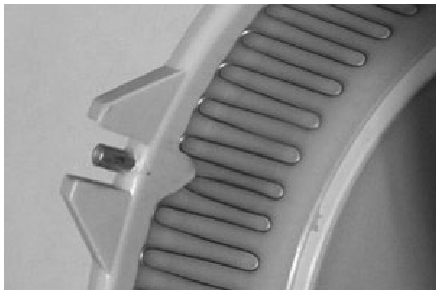


Figure 41 Enfield fusion coil shown with its adapter pin connector

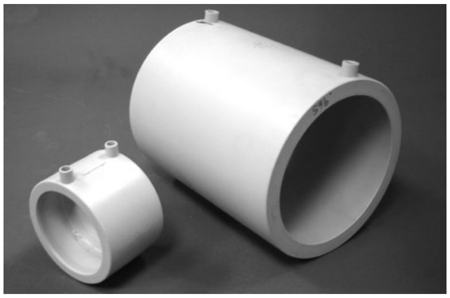


Figure 42 PowerGuard couplings, the totally encapsulated fusion coils

In the Enfield fitting shown above, natural polypropylene is molded over the conductive wire protecting it from damage during shipment and installation.

Joining is achieved by inserting the pipe into the socket and applying a controlled electrical current to the wire for a prescribed amount of time, which generates sufficient heat to melt the adjoining materials. Some manufacturers will specify an external clamp be applied ensure a positive contact between the pipe and fitting. Other manufacturers will recommend external clamps to ensure proper pipe alignment. Once the joint is heated, molten material adheres to both the pipe and the fitting rendering a leak-free joint. Proper time and temperature is required to join most systems and microprocessor fusion control boxes are required for each system. These controls are not interchangeable between manufacturers and their various systems.

Welding Equipment

Electrofusion welding equipment is available for rent or sale from Harrington Industrial Plastics. Please see the complete catalog for details.

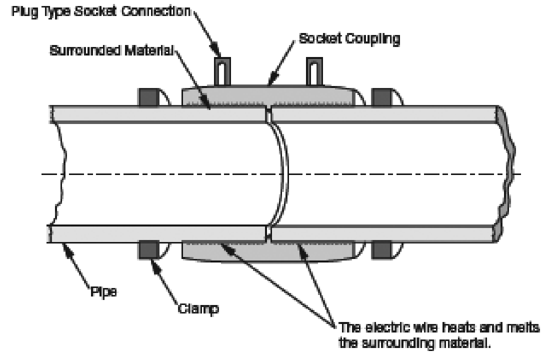


Figure 43 Typical electrofusion joint with external pipe alignment clamps

Typical Electrofusion Procedure:

Using a pipe cutter with a wheel designed for plastic (saw and miter box can also be used as an alternative), cut the pipe square making sure to remove all burrs and loose material. Do not chamfer.

Using a 60-grit emery cloth, prepare the end of the pipe by removing dirt and oil (important to obtain a good bonding) and roughing up an area equal to 1.5 times the fitting's socket depth. Clean the roughed up area with ethyl or isopropyl alcohol to ensure complete removal of grease and residue. Some manufacturers will recommend using a hand operated or mechanical scrapper to clean the O.D. of the pipe. These manufacturers usually recommend avoiding emery cloth, rasp or sand paper during the cleaning operation. Once cleaned or treated do not handle this area of the pipe or allow it to get dirty.

Completely inspect and ready the electrofusion machine for use following the manufacturers instructions.

Insert the pipe all the way to the stop at the bottom of the socket. If the pipe does not bottom against the pipe stop it may create excessive purge or leak paths.

Some machines will allow for simultaneous welding of multiple joints. If so, follow that manufacturer's recommendations.

Loosely fit supplied clamps only over the hubs of the socket to be fused if recommended by the manufacturers. Other manufacturers will recommend securing pipe in support clamps ensuring proper alignment.

When using compressive clamps on fittings, tighten the clamp(s) until it is not possible to rotate the pipe inside the fitting. A tight clamp is essential to the quality of the fusion cycle in some systems.

Turn the machine on and observe all the messages being displayed because most machines run a self-diagnostic test.

Following the manufacturers instructions, connecting fusion coil to the machine output leads. If required, connect linking cable for multiple fusions.

It is important to set the proper pipe size in most machines. This process may be done automatically by the machine, through external bar code readers or by internal resistance readings. Generally once the pipe size is determined within the machine, proper fusion times and temperatures are set.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

BASIC PRINCIPLES OF ELECTROFUSION FOR THERMOPLASTIC PIPE

Once the correct size is selected, press the START button. Temperature and welding time may be displayed. Many machines include a count down timer automatically counting down to zero.

Upon completion of the fusion cycle, an audible alarm will usually sound and the machine may display a message indicating the fusion is complete.

Usually a 30-second rest period or more should be observed to allow the joint(s) to cool before disconnecting the leads.

Allow five additional minutes before removing the clamps so that the joint can sufficiently cool and properly cure.

Figure 44 Enfield Electrofusion Acid Waste System

PROPER ASSEMBLY OF ENFIELD MECHANICAL JOINT ACID WASTE SYSTEM

The Procedure

The procedure applies to both Labline and Plenumline mechanical joint piping systems.

Ensure each fitting is supplied with the correct number of Elastolive® (sealing rings) and nuts. **YELLOW LABLINE AND BLUE PLENUMLINE ELASTOLIVES ARE NOT INTERCHANGEABLE.**

Verify the grooving tool is sharp.

Cut the pipe to the desired length using a tubing cutter fitted with a wheel designed for plastic pipe. A handsaw and miter box may also be used. **Ensure pipe ends are square and trimmed free of burrs.** The pipe end should be clean and there should be no deep longitudinal grooves in it.

Examine the grooving tool to ensure that the cutting blade is fully retracted. Insert the pipe into the grooving tool.

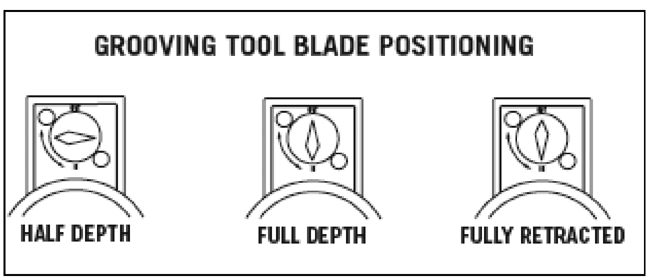


Figure 45 Adjustment for grooving tool

Set the grooving blade at the half-depth position and rotate the tool in a counter-clockwise direction. After one complete turn, set the blade at the full-depth position and again rotate the tool one full turn counterclockwise. Fully retract the blade and remove the tool from the pipe. A shallow groove has now been formed around the pipe as in Figure 46. Any material left as a feather edge in the groove should be removed. Care should be taken not to damage the square edge (shoulder) of the groove, particularly at the edge near the spigot end of the pipe as this is the primary sealing surface.

Feathered or rounded edges may indicate a worn tool and possible leakage. Make sure the groove shoulders are sharp.

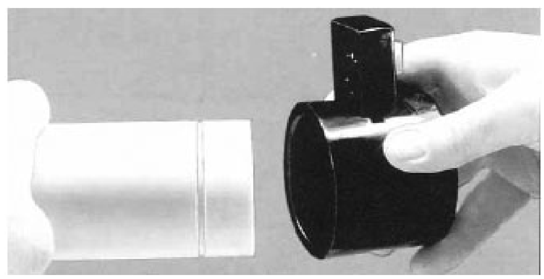


Figure 46 Properly grooved Labline piping

Place the nut onto the pipe with the threaded side to the spigot end of the pipe. Take the elastolive, stretch it, and pull it over the pipe with the thick edge first and the taper pointing to the spigot-end of the pipe. Slide it down the pipe and onto the groove. Once on the groove "work it" a bit to make sure that the rib on the underside of the elastolive engages the full circumference of the groove.

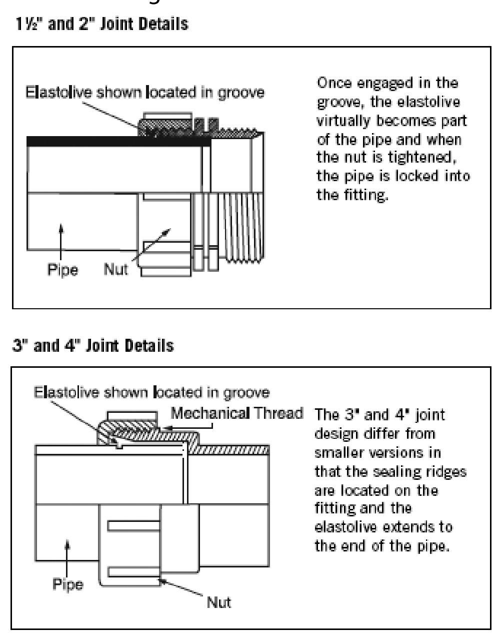


Figure 47

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

PROPER ASSEMBLY OF ENFIELD MECHANICAL JOINT ACID WASTE SYSTEM

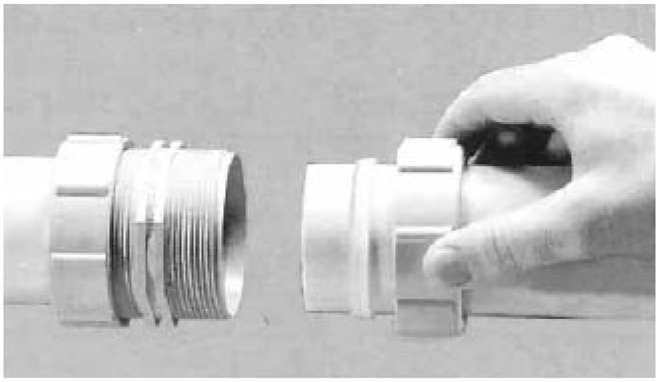


Figure 48

Apply a nonhydrocarbon base lubricant to both the thread and the elastolive, then push the pipe squarely into the fitting. The lubrication permits easy take up of the nuts and allows the pipe with the elastolive to glide smoothly into position against the fitting sealing area. Hand-tighten the nut, then tighten ¼ to ½ turn using a spanner wrench.

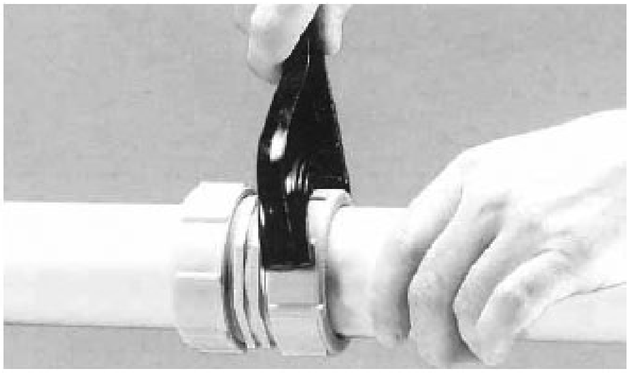


Figure 49 The joint is now ready for testing.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

PROPER ASSEMBLY OF ROLL GROOVED OR RADIUS CUT GROOVED PVC PIPE

PVC pipe can be roll or cut-grooved at each end for quick connection using mechanical couplings specifically designed for PVC pipe. Because PVC is a notch sensitive material, Harrington recommends a radius groove to reduce any point of stress concentration on the piping. This method can be used in any application where PVC pipe is acceptable and where it is desirable to have a means for quick assembly under adverse conditions.

Installation Guidelines

Always use a grooved coupling that is designed and recommended for use with PVC pipe. See below for recommended piping systems for above ground assemblies.

The following piping materials are recommended grooved joints:

- PVC Sch 40 (2″–8″) Roll or radius cut
- PVC Sch 80 (2″– 2″) Roll or radius cut
- PVC SDR 26 (6″–12″) Roll or radius cut
- PVC SDR 21 (4″–12″) Roll or radius cut
- PVC 14″ *May be cut grooved
- PVC 16″ *May be cut grooved
- PVC 18″ *May be cut grooved
- PVC 24″ *May be cut grooved

*Consult individual manufacturers for detailed design

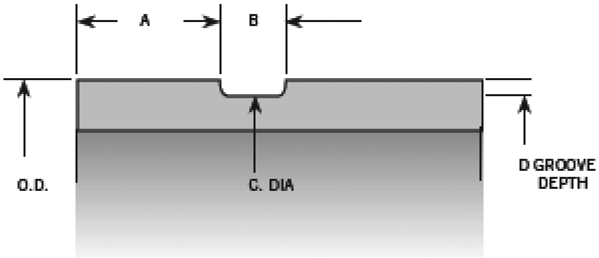


Table 59 Grooved Joint Dimensions

Pipe Size (IN.)	O.D. (IN.)	A ±0.031 (IN.)	B ±0.031 (IN.)	C Average (IN.)	D* (IN.)
2	2.375	0.625	0.312	2.250±0.015	0.062
2½	2.875	0.625	0.312	2.720±0.018	0.078
3	3.500	0.625	0.312	3.344±0.018	0.078
4	4.500	0.625	0.375	4.334±0.020	0.083
6	6.625	0.625	0.437	6.455±0.022	0.085
8	8.625	0.750	0.437	8.441±0.025	0.092
10	10.750	0.750	0.500	10.562±0.027	0.094
12	12.750	0.750	0.500	12.531±0.030	0.109

*Dimension D is a convenient reference only, dimension C governs

The grooves are normally machined or rolled in the pipe end by the manufacturer before shipment. The dimensions of the groove will be as recommended by the grooved coupling manufacturer as shown in table 59, Grooved Joint Dimensions.

The working pressure and/or test pressure in a grooved joint PVC piping system should not exceed the recommended maximum pressures shown in Table 60, Maximum Pressures for Grooved PVC Pipes, at temperatures at or below 73°F (23°C). The maximum recommended operating temperature in grooved-jointed PVC pipe systems is 100°F (38°C).

The installation of grooved-jointed PVC pipe should ensure that:

a) Thrust reaction is restrained at points of deflection or dead ends by external supports or harnesses. Thrust forces should not be transferred to the joints by design.

b) Straight alignment of pipe is maintained at the joints, using a suitable support system.

c) Thermal expansion/contraction movement does not exceed .0625" per joint.

Table 60 Maximum Pressure (psi) for cut grooved PVC pipe at 73°F.

Pipe Size (IN.)	SDR 26	SDR21	SCH 40	SCH 80
2	—	—	100	170
2½	—	—	110	175
3	—	—	100	160
4	—	75	85	140
6	60	80	70	125
8	65	85	65	115
10	70	90	—	110
12	70	90	—	110

The maximum recommended operating temperature for grooved PVC piping systems is 100°F.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

THERMOPLASTIC PIPE JOINT REPAIR & HOT GAS WELDING

The most common method for repairing faulty and leaking thermoplastic pipe joints is hot gas welding at the fillet formed by the fitting socket entrance and the pipe. Fillet welding of thermoplastics is quite similar to the acetylene welding or brazing process used with metals. The fundamental differences are: 1) that the plastic rod must always be the same basic material as the pieces to be joined, and 2) heated gas, rather than burning gas, is used to melt the rod and adjacent surfaces.

Welding with plastics involves only surface melting because plastics, unlike metals, must never be "puddled." Therefore the resulting weld is not as strong as the parent pipe and fitting material. This being the case, fillet welding as a repair technique is recommended for minor leaks only. It is not recommended as a primary joining technique for pressure-rated systems.

Welding Tools and Materials

- Plastic welding gun with pressure regulator, gauge and hose
- Filler rod
- Emery cloth
- Clean Cotton rags
- Cutting pliers
- Hand grinder (optional)
- Compressed air supply or bottled nitrogen (see Caution)
- Source of compressed air

Weld Area Preparation

Wipe all dirt, oil and moisture from the joint area. A very mild solvent may be necessary to remove oil.

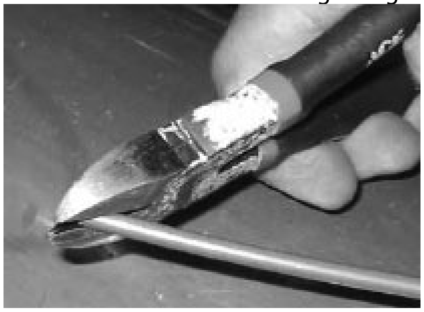
CAUTION: Make sure that all liquid has been removed from the portion of the piping system where the weld is to be made.

Remove residual solvent cement from the weld area using emery cloth. When welding threaded joints, a file can be used to remove threads in the weld area.

Wipe the weld area clean of dust, dirt and moisture.

Determine the correct filler rod size (see Table 61) and length necessary to make one complete pass around the joint by wrapping the rod around the pipe to be welded. Increase this length enough to allow for handling the rod at the end of the pass.

Make about a 60° angular cut on the lead end of the filler rod. This will make it easier to initiate melting and will insure fusion of the rod and base material at the beginning of the weld.



Welding temperatures vary for different thermoplastic materials 500°F–550°F (260°C–288°C) for PVC and CPVC. Welding temperatures can be adjusted for the various thermoplastic materials as well as any desired welding rate by adjusting the pressure regulator (which controls the gas flow rate) between 3 and 8 psi.

CAUTION: For welding guns which require compressed gas, nitrogen is preferred when the compressed plant air system does not contain adequate drying and filtrations.

Because of its economy, compressed air is normally the gas of choice for most plastic welding. A welding gun which generates its own air supply is frequently desirable for field-made pipe joints where ultimate weld strength is not required. For welding guns which require compressed gas, nitrogen is preferable when the compressed plant air system does not contain adequate drying and filtration. (Presence of moisture in the gas stream causes premature failure in the heater element of the welding gun. Impurities in the gas stream, particularly those in oil, may oxidize the plastic polymer, resulting in loss of strength. Polypropylene is known to be affected in this manner.)

With air or inert gas flowing through the welding gun, insert the electrical plug for the heating element into an appropriate electrical socket to facilitate heating of the gas and wait approximately 7 minutes for the welding gas to reach the proper temperature.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

THERMOPLASTIC PIPE JOINT REPAIR & HOT GAS WELDING

CAUTION: The metal barrel of the welding gun houses the heating element so it can attain extremely high temperatures. Avoid contact with the barrel and do not allow it to contact any combustible materials.

Filler rod size and number of weld passes required to make a good plastic weld are dependent upon the size of the pipe to be welded as presented below:

Table 61

PIPE SIZE (IN.)	ROD SIZE (IN.)	NUMBER OF PASSES
½-¾	3⁄32	3
1-2	⅛	3
2½-4	3⁄16	3
6-8	3⁄16	5
10-12	3⁄16	5

Place the leading end of the filler rod through the speed-tip opening and into the fillet formed by the junction of the pipe and fitting socket entrance. Holding the weld tip at a 45° angle to the fitting, slowly move the weld tip across the area to be welded while applying a slight pressure by pushing the rod from the inlet side. The weld tip should be approximately ¼" to ½" away from the material.

End each pass by mating the rod end to the starting point. Do not overlap on top or to the side of the start point. Each weld end should match perfectly with the starting point.

When welding large-diameter pipe, more than three weld passes may be required. The first bead should be deposited at the bottom of the fillet and subsequent beads should be deposited on each side of the first bead. When making multiple pass welds, the starting points for each bead should be staggered and ample time must be allowed for each weld to cool before proceeding with additional welds.

Properly applied plastic welds can be recognized by the presence of small flow lines or waves on both sides of the deposited bead. This indicates that sufficient heat was applied to the surfaces of the rod and base materials to affect adequate melting and that sufficient pressure was applied to the rod to force the rod melt to fuse with base-material melt. If insufficient heat is used when welding PVC or CPVC, the filler rod will appear in its original form and can easily be pulled away from the base material. Excessive heat will result in a brown or black discoloration of the weld.

Welding Principles

The procedures for making good thermoplastic welds can be summarized into four basic essentials:

Correct Temperature — Excessive heating will char or burn the material. Insufficient heating will result in incomplete melting.

Correct Pressure — Excessive pressure can result in stress cracking when the weld cools. Insufficient pressure will result in incomplete fusion of the rod material with the base material.

Correct Angle — Incorrect rod angle during welding will stretch the rod and the rod material with the base material.

Correct Speed — Excessive welding speed will stretch the weld bead and the finished weld will crack upon cooling.

The preceding instructions show the use of a high-speed welding tip, which provides better control of the filler rod and direction of the hot gases. This process is not as easy as it may sound and requires a learned skill and knack for the job. Harrington highly recommends several practice welds be attempted before trying to repair even minor leaks. Most Harrington branches can also recommend local experienced professionals that are capable of making field welds on thermoplastic pipe.

Free-Hand Thermoplastic Welding

The oldest method of welding filler rod. This process is much slower than high-speed welding, but it must be used where very small parts are being welded, or where the available space prohibits the use of high-speed welding tips. The only nozzle used in this process is a small jet pipe with an opening of ⅛" or 5⁄32" to concentrate the heat. The welder performs a waving action of the nozzle at the base material and the welding rod with an up-and-down and side-to-side motion to bring the rod and material to melting form. Hand apply pressure vertically at 90° to begin. After reaching the correct amount of pressure and heat to the rod and base material, a small wave of molten material forms in front of the welding rod. If bent backward, the welding rod will stretch and thin out; if bent forward, no wave will occur in front, resulting in insufficient pressure. Free-hand welding requires a highly skilled operator and should be avoided if a simpler method can be used.

Harrington offers a complete line of welding equipment for rent and/or sale.

FIBERGLASS REINFORCED PLASTICS (FRP)

FRP is a special segment of the corrosion-resistant plastics industry. By combining flexible strands of glass with various thermoset resins, a wide range of performance characteristics can be achieved. Unlike thermoplastic resins, thermoset resins do not return to a liquid state with heat.

The glass can be prepared in a variety of forms which determine the final properties of the glass-resin combination. As an example, the glass can be chopped strands in a mat or felt type fabric, yarns, woven fabric, continuous strands, unidirectional or bidirectional fabrics and so on. The choices are almost infinite.

The different types of glass all have different rates of resin absorption. For the most part, every mechanical attribute is enhanced by increasing the volume of glass contained in the plastic thermoset resin. Thus, the glass-versus-resin ratio becomes a key criteria in defining a product for a particular application.

Glass fiber and resin are described as a composite or laminate. When combining glass and resin, it is important to “wet the glass” and this is done by eliminating the trapped air, which increases the glass to resin interface. The glass used for FRP is treated with silane or other similar chemistry to enhance the resin’s affinity to the glass.

Selecting a specific resin will dictate the performance characteristics of the final FRP product. Chemical resistance, temperature range and mechanical properties are determined by the choice of resin and the glass.

Epoxy resins give exceptional mechanical strength and are very chemically resistant. Epoxies are used for caustics, hydrocarbons, and most organic chemicals. Several catalysts can be used in curing the epoxy resin by a crosslinking of the long polymer chain. The choice of catalyst will determine the properties of the finished FRP product. For example, an anhydride catalyst will give an epoxy product with limited chemical resistance and limited temperature capability. An aromatic amines catalyst, on the other hand, will produce a final product with broad chemical resistance and a temperature range of up to 300° F in certain services.

Primary disadvantages of epoxies are they require long curing times and are best cured using heat to promote complete reaction for all the epoxy sites. Epoxies are, therefore, stronger when the catalyzation is enhanced by heat.

Polyester resins are available in many forms. The two that are relevant to FRP are orthophalic and isophalic resins. The former is a noncorrosion-resistant resin used in boats, auto bodies, and structural forms. The latter is the chemically resistant resin that is appropriate for our use in handling corrosive fluids. Isophalic polyester is the most economical of all the resin choices for FRP.

Vinylester is a coined word describing a polyester that has been modified by the addition of epoxide reactive sites. The vinylester resin has broad chemical resistance including most acids and weak bases. It is generally the choice for high-purity deionized water storage in an FRP vessel.

FRP piping is available from a few major manufacturers as a standard catalog, off-the-shelf product in diameters up to 16 inches. Face-to-face dimensions for fittings are based on steel and the requirements of American National Standards Institute ANSI B-16.3. Not all fittings meet ANSI requirements unless specified by agreement. FRP flanges are always thicker than steel, so longer bolts are needed.

There are many fabricators who specialize in made-to-order or custom vessels, as well as special made-to-order piping. For FRP piping larger than 16 inches in diameter, it is also made to order. Large diameter FRP pipe can be custom made in sizes even larger than 12 feet.

FRP pipe products are manufactured by several techniques. Filament winding is done using continuous lengths of fiberglass yarn or tape which are wound onto a polished steel mandrel. The glass is saturated with a catalyzed resin as it is being wound onto the mandrel. This process is continued until the desired wall thickness is achieved. The resin polymerizes usually by an exothermic reaction. Depending on the angle at which the glass is applied and the tension, the mechanical properties of the finished product can be affected. Piping and vessels are produced in this manner.

Centrifugal casting involves applying glass and catalyzed resin to the inside of a rotating polished cylindrical pipe. Curing of the glass resin combination forms a finished pipe. The forces of the centrifugal rotating cylinder forces the resin to wet the glass and gives an inherent resin rich and polished outside diameter to the final product. The resin that is in excess of that required to wet the glass forms a pure resin liner. Pipe, both small and larger diameter, as well as tanks, are manufactured by this process.

Applications for FRP have grown since the introduction almost forty years ago of thermoset resins. The following is a list of some of the general advantages of FRP:

- Corrosion resistant
- Lightweight
- High strength-to-weight ratio
- Low resistance to flow
- Ease of installation
- Low cost of installation
- Very low electrical conductivity
- Excellent thermal insulation
- Long service life
- Dimensional stability

Industrial uses for FRP tanks and piping have developed in oil and gas, chemical processing, mining, nuclear, and almost every other industry you can think of.

FIBERGLASS REINFORCED PLASTICS (FRP)

FRP piping is very amenable to the addition of specific additives to achieve certain properties. Antimony trioxide or brominated compounds, for example, can be added to provide excellent fire resistant characteristics. Specifically, designed FRP piping systems are produced for internal pressures up to 3000 psi. Other FRP piping is used for down hole in the oil field, usually for salt water reinjection. FRP products are one of the most easily modified to meet specific needs, thus the broad range of industrial applications.

As with any piping material, good system design, proper fabrication, and correct installation techniques are necessary for long and reliable service life.

Selecting the proper joining method is important for controlling installation costs and being compatible with the nature of the installation.

Butt and wrap is used to join FRP pipe by simply butting two sections of pipe together and overwrapping the joint with multiple layers of fiberglass saturated with the appropriate resin.

Threaded connections are often used for rapid and easy joining. There can be an O-ring gasket used to provide the sealing mechanism.

Bell and spigot joints are used usually with a bonding adhesive or with a gasket.

Flanges are most often used to join FRP pipe to metal or other dissimilar piping materials.

Contact molding is a process of applying fiberglass and resin to the surface of a mold that may be a variety of shapes. This process can be done by hand, spraying, or with an automated system. FRP fittings, vessels, and piping are produced by this method.

Compression molding is a process normally used to manufacture FRP fittings. A mixture of glass and resin is placed inside a mold and with heat and other molding techniques a finished part is produced.

Current standards outline the composition, performance requirements, construction method, design criteria testing and quality of workmanship. The modern standards have their origin in the U.S. Dept. of Commerce Voluntary Standard PS1549. Custom Contact Molded Reinforced Polyester Chemical Resistant Equipment. The ASTMC-582-95 takes the place of PS1569.

The following is a partial listing of ASTM standards for FRP Industrial products.

FIBERGLASS PIPE AND FITTINGS
Specification for:

D 2997 - 95	Centrifugally Cast "Fiberglass" Pipe
D 5421 - 93	Contact Molded "Fiberglass" Flanges
D 5677 - 95	Fiberglass" Pipe and Pipe Fittings, Adhesive Bonded Joint Type, for Aviation Jet Turbine Fuel Lines
D 5686 - 95	Fiberglass" Pipe and Pipe Fittings, Adhesive Bonded Joint Type Epoxy Resin, for Condensate Return Lines
D 3517 - 91	"Fiberglass" Pressure Pipe
D 5685 - 95	"Fiberglass" Pressure Pipe Fittings
D 2996 - 95	Filament-Wound"Fiberglass" Pipe
D 4024 - 94	Reinforced Thermosetting Resin (RTR) Flanges

FIBERGLASS TANKS AND EQUIPMENT
Specifications for:

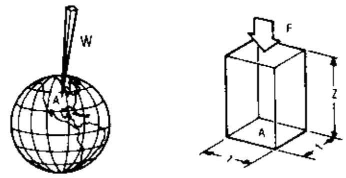
D 4097 - 95a	Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks
C 482 - 95	Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
D 3982 - 92	Custom Contact-Pressure-Molded Glass-Fiber-Reinforced Thermosetting Resin Hoods
D 3299 - 95a	Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks

There are many special tools used for making field joints. The best policy is to follow the FRP pipe manufacturer's recommendations precisely. Most manufacturers offer the services of a factory person to train or supervise fabrication and installation.

To take maximum advantage of the many advantages of FRP in your corrosive or high-purity application, contact your nearest Harrington location using the number listed on the inside back cover.

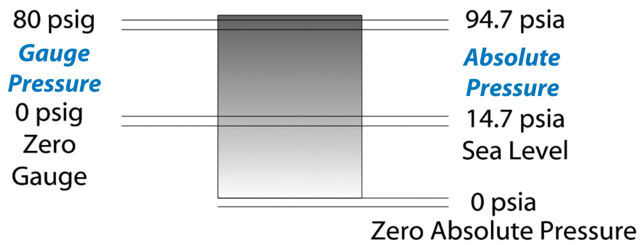
HYDRAULIC FUNDAMENTALS

PRESSURE is the force per unit area. As commonly used in hydraulics and in this publication, it is expressed in pounds per square inch (psi).



ATMOSPHERIC PRESSURE is the force exerted on a unit area by the weight of the atmosphere. At sea level, the atmospheric standard pressure is 14.7 pounds per square inch.

GAUGE PRESSURE Using atmospheric pressure as a zero reference, gauge pressure is a measure of the force per unit area exerted by a fluid. Units are in psig.



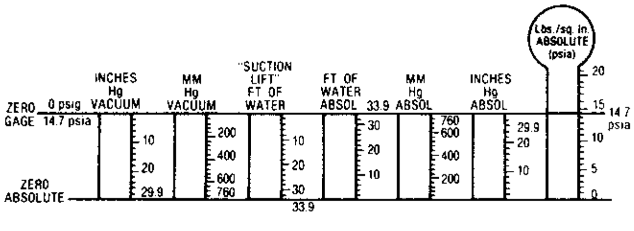
ABSOLUTE PRESSURE is the total force per unit area exerted by a fluid. It equals atmospheric pressure plus gauge pressure. Units are expressed in psia.

OUTLET PRESSURE or discharge pressure is the average pressure at the outlet of a pump during operation, usually expressed as gauge pressure (psig).

INLET PRESSURE is the average pressure measured near the inlet port of a pump during operation. It is expressed either in units of absolute pressure (psia) preferably, or gauge pressure (psig).

DIFFERENTIAL PRESSURE is the difference between the outlet pressure and the inlet pressure. Differential pressure is sometimes called Pump Total Differential pressure.

VACUUM OR SUCTION are terms in common usage to indicate pressures in a pumping system below normal atmospheric pressure and are often measured as the difference between the measured pressure and atmospheric pressure in units of inches of mercury, vacuum, etc. It is more convenient to discuss these in absolute terms (i.e., from a reference of absolute zero pressure in units of psia).



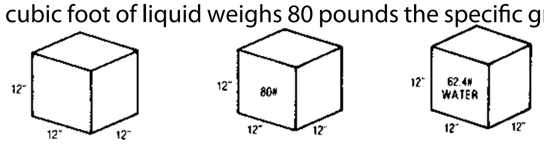
FLUID FUNDAMENTALS Fluids include liquids, gases, and mixtures of liquids, solids, and gases. For the purpose of this publication, the terms fluid and liquid are used interchangeably to mean pure liquids, or liquids mixed with gases or solids, which act essentially as a liquid in a pumping application.

DENSITY and SPECIFIC GRAVITY have very similar, but not quite identical definitions. Density, or specifically mass density is a measure of the mass of a substance per unit volume, often expressed in pounds per cubic foot or grams per cubic centimeter. **Specific gravity** is a ratio of the mass of a material to the mass of an equal volume of water at 4°C. Because specific gravity is a ratio, it is a unit-less quantity. For example, the specific gravity of water at 4°C is 1.0 while its density is 1.0 gcm^{-3}. The density of a fluid changes with temperature.

SPECIFIC GRAVITY of a fluid is the ratio of its density to the density of water. As a ratio, it has no units associated with it.

Example: When a cubic foot of water weighs 62.4 pounds, the mass density is 62.4 pounds per cubic foot at 4°C and the specific gravity is 1.0.

If the cubic foot of liquid weighs 80 pounds the specific gravity



is 1.282

$$SG = \frac{\text{weight of slution}}{\text{weight of water}} = \frac{80\text{ lbs}}{62.4\text{ lbs}} = 1.282\text{ SG}$$

TEMPERATURE is a measure of the internal energy level in a fluid. It is usually measured in units of degrees fahrenheit (°F) or degrees centigrade (°C). The temperature of a fluid at the pump inlet is usually of greatest concern. See °F-°C conversion chart on page 101.

VAPOR PRESSURE of a liquid is the absolute pressure (at a given temperature) at which a liquid will change to a vapor. Vapor pressure is best expressed in units of psi absolute (psia). Each liquid has its own vapor pressure/temperature relationship.

For example: If 100°F water is exposed to the reduced absolute pressure of .95 psia, it will boil. It will boil, even at 100°F.

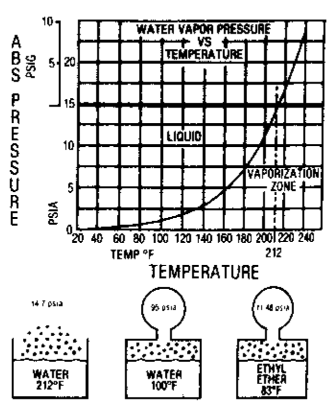
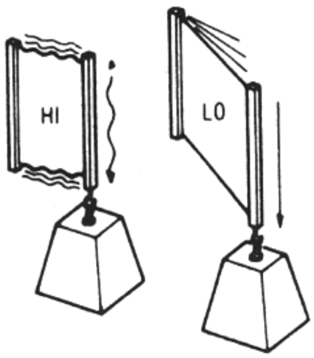


Figure 50

HYDRAULIC FUNDAMENTALS

VISCOSITY of a fluid is a measure of its tendency to resist a shearing force. High viscosity fluids require a greater force to shear at a given rate than low viscosity fluids.

The **CENTIPOISE** (cps) is the most convenient unit of absolute viscosity measurement. Other units of viscosity measurement such as the centistoke (cks) or Saybolt Second Universal (SSU) are measures of Kinematic viscosity where the specific gravity of the fluid influences the viscosity measured. Kinematic viscometers usually use the force of gravity to cause the fluid to flow down a calibrated tube while timing its flow.



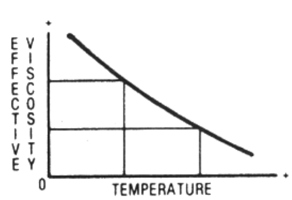
The absolute viscosity, measured in units of centipoise (1⁄100 of a poise) is used throughout this catalog because it is a convenient and consistent unit for calculation. Other units of viscosity can easily be converted to centipoise:

Kinematic Viscosity x Specific Gravity = Absolute Viscosity Centistokes x Specific Gravity = Centipoise

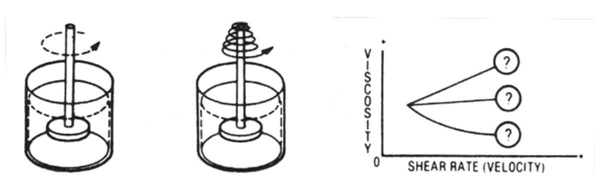
SSU x .216 x Specific Gravity = Centipoise

See page 111 for detailed conversion chart.

Viscosity unfortunately is not a constant, fixed property of a fluid, but is a property which varies with the conditions of the fluid and the system.



In a pumping system, the most important factors are the normal decrease in viscosity with temperature increase. And the viscous behavior properties of the fluid in which the viscosity can change as shear rate or flow velocity changes.



EFFECTIVE VISCOSITY is a term describing the real effect of the viscosity of the ACTUAL fluid, at the SHEAR RATES which exist in the pump and pumping system at the design conditions. Centrifugal pumps are generally not suitable for pumping viscous liquids. When pumping more viscous liquids (up to 2,000 SSU) instead of water, the capacity and head of the pump will be reduced and the horsepower required will be increased as indicated in the following table.

Table 62

VISCOSITY IN SSU	100	250	500	750	1000	1500	2000
Flow reduction in % of GPM	3	8	14	19	23	30	40
Head Reduction in % of Feet	2	5	11	14	18	23	30
Horse-power Increase %	10	20	30	50	65	85	100

Consider positive displacement or semi-positive displacement pumps (gear, piston, lobe or diaphragm) designs when pumping viscose fluids.

pH value for a fluid is used to define whether the aqueous solution is an acid or base (with values of pH usually between 0 and 14): Acids or acidic solutions have a pH value less than 7. Neutral solutions have a pH value of 7 at 25°C (i.e: pH of pure water = 7). Bases or alkaline solutions have a pH value greater than 7.

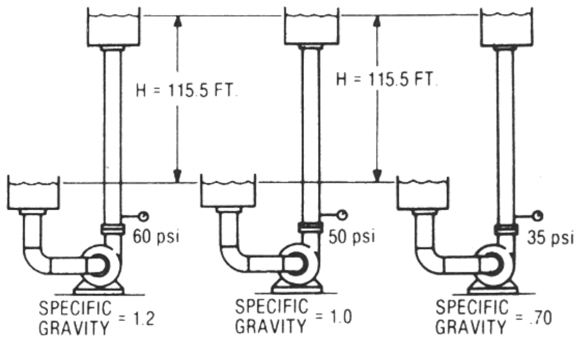
RELATION OF PRESSURE TO ELEVATION

In a static liquid (a body of liquid at rest) the pressure difference between any two points is in direct proportion only to the vertical distance between the points. This pressure difference is due to the weight of the liquid and can be calculated by multiplying the vertical distance by the specific gravity of the fluid. The resulting number is an expression of static head in feet of water.

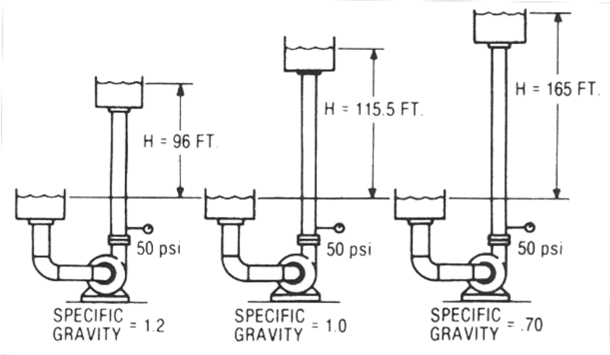
Centrifugal pumps in "Series" can effectively double the discharge pressure while providing the same flow rate.
Ask your local Harrington salesperson for more information.

HYDRAULIC FUNDAMENTALS

PUMP HEAD-PRESSURE-SPECIFIC GRAVITY in a centrifugal pump the head developed (in feet) is dependent on the velocity of the liquid as it enters the impeller eye and as it leaves the impeller periphery and therefore, is independent of the specific gravity of the liquid. The pressure head developed (in psi) will be directly proportional to the specific gravity.



Pressure-head relation of identical pumps handling liquids of differing specific gravities.



Pressure-head relation of pumps delivering same pressure handling liquids of differing specific gravity.

IMPORTANT PUMP TERMS: The term HEAD is expresses the difference in depth of a liquid at two given points. The measure of pressure at the lower point expressed in terms of this difference. Generally expressed in feet, head can best be defined by the following equation:

$$\frac{\text{Pounds per square inch} \times 2.31}{\text{Specific Gravity}} = \text{Head in feet}$$

The following expressions of HEAD terms are generally accepted as standards throughout the industry.

Static Head is the hydraulic pressure at a point in a fluid when the liquid is at rest.

Friction Head is the loss in pressure or energy due to frictional losses in flow.

Velocity Head is the energy in a fluid due to its velocity, expressed as a head unit.

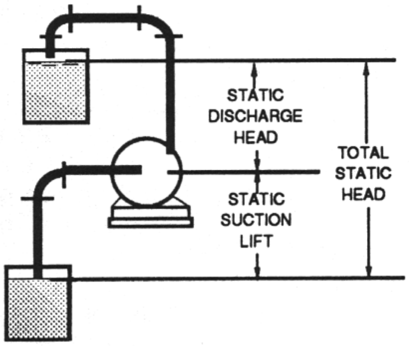
Pressure Head is a pressure measured in equivalent head units.

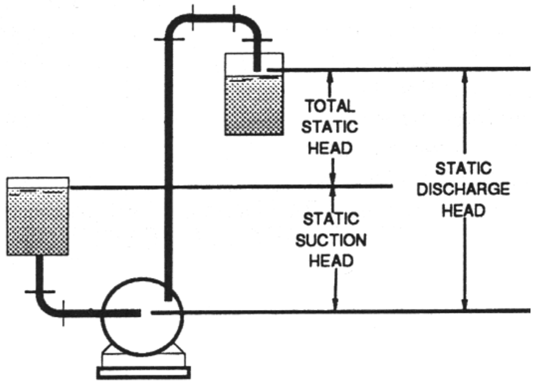
Discharge Head is the output pressure of a pump in operation.

Total Dynamic is the total pressure difference head between the inlet and outlet of a pump in operation.

Suction Head is the inlet pressure of a pump when above atmospheric.

Suction Lift is the inlet pressure of a pump when below atmospheric.





NPSH

Fluid will only flow into the pump head by atmospheric pressure or atmospheric pressure plus a positive suction head. If suction pressure at the suction pipe is below the vapor pressure of the fluid, the fluid may flash into a vapor. A centrifugal pump cannot pump vapor only. If this happens, fluid flow to the pump head will drop off and cavitation may result.

NET POSITIVE SUCTION HEAD, AVAILABLE (NPSHA) is based on the design of the system around the pump inlet. The average pressure (in psia) is measured at the port during operation, minus the vapor pressure of the fluid at operating temperature. It indicates the amount of useful pressure energy available to fill the pump head.

NET POSITIVE SUCTION HEAD, REQUIRED (NPSHR) is based on the pump design. This is determined by testing of the pump for what pressure energy (in psia) is needed to fill the pump inlet. It is a characteristic which varies primarily with the pump speed and the viscosity of the fluid.

HYDRAULIC FUNDAMENTALS

Frictional losses due to flow in pipes are directly proportional to the:

- **Length of pipe**
- **Flow rate**
- **Pipe diameter**
- **Viscosity of the fluid**

FRICTIONAL LOSSES

The nature of frictional losses in a pumping system can be very complex. Losses in the pump itself are determined by an actual test and are allowed for in the manufacturers' curves and data. Similarly, manufacturer's of processing equipment, heat exchangers, static mixers, etc., usually have data available for friction losses.

Pipe friction tables have been established by the Hydraulic Institute and many other sources which can be used to compute the friction loss in a system for given flow rates, viscosities, and pipe sizes. Friction loss charts for plastic pipe appear in this catalog on pages 28-35. Tables of equivalent lengths for fittings and valves are on page 36.

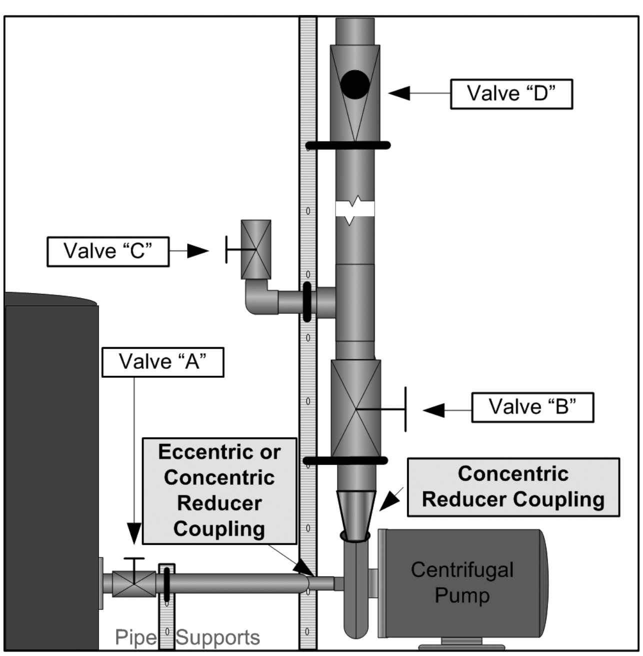
CENTRIFUGAL PUMPS INSTALLATION RECOMMENDATIONS

Most centrifugal pump failures occur within the first 90 days of operation due to improper installation. Normal pump life expectancy may be obtained by following the manufacturer's installation instructions which frequently get discarded with the pumps shipping container and packaging. Therefore, Harrington offer the following simple guidelines and "rules of thumb" applicable to most centrifugal pump installations.:

Properly support and align all piping leading to and coming out of the pump. Avoid applying any undue stresses or forces to the pump.

Provide inlet isolation valve (Valve "A" in drawing below) on suction side of the pump. Support valve in such a way as to avoid operating torque being applied to the pump or piping. Do not throttle flow on inlet to the pump.

Always increase inlet piping by at least one pipe size keeping friction losses to a minimum. Keep inlet lines as short as possible.



Allow fluids to flow freely into pump with minimum restrictions, turbulence, and/or changes in direction.

Use eccentric or concentric reducer on inlet of pump to reduce turbulence and avoid trapping air in inlet piping. Avoid using couplings with reducing bushings having square corners in the flow path.

If changes in direction are required on inlet side of pump, use two 45° elbows instead of one 90° elbow to reduce turbulence.

Mount pump to solid surface, use resilient mounting pad to reduce normal operating noise.

Allow sufficient air flow around motor.

Immediately increase discharge piping by at least one pipe size using a reducing coupling. Centrifugal pumps normally discharge at velocities several times greater than the 5 feet per second recommendation for plastic piping. See volume (gpm) and velocities (ft/sec.) shown in the carrying capacity charts on pages 28-35.

Install isolation shut-off valve (Valve "B" in drawing) on discharge side of pump. Support valve and piping properly.

Install priming tee or air-bleed valve (Valve "C" in drawing) in discharge line. This valve can be used to drain a portion of discharge line should pump need to be removed for servicing.

Consider using Unions or Flanges on both sides of pump to facilitate easy removal, if and when removal for normal maintenance is required.

Use check valve (Valve "D") in vertical discharge lines. Note: ball check valves must be installed at least 10 pipe diameters down stream from pump discharge. Beware of excessive discharge velocities when using check valves. Remember to properly support valves.

Ensure all electrical motors are grounded using true earth ground.

Check motor for proper rotation prior to filling piping system and pump. Briefly "Bump" three-phase, electrical motors prior to start-up to ensure proper rotation. Remember any two wires of three-phase installation can be switched to reverse rotation.

Fill both inlet and discharge pipelines completely with fluid prior to startup when possible or throttle discharge line to avoid fluid surges during startup. Trapped air bubbles, compressed air in lines, and rapid surges can destroy both piping and pump seals. Avoid "water hammer" on startup. See Water Hammer and Hydraulic Shock calculations on page 39.

In critical applications, consider installing two pumps in parallel (with insolation valve) with lead-lag startup and run sequencer.

When in doubt about proper pump selection or application engineering, contact your local Harrington Representative.

PIPING SYSTEM SELECTION CRITERIA

Most of the following information will be required for anyone selecting or designing a corrosion-resistant piping system.

The system will handle (*please check one*) Fluid __________ Gas _________ Note: Dry Materials (***Not recommended in Plastics)***

The system be (check all that apply) Indoors _________ Outdoors _______ Buried __________ Suspended ___________

Chemical ____ Concentration __________________ Specific Gravity_________

Solution temperature ______________ Minimum _______________ Maximum Abrasive? ________ Yes _________No

Ambient temperature at point of installation _________ Minimum _______________ Maximum

Viscosity (*at temperature provided*) __________________ in Centipoise (cP) or Seconds Saybolt Universal (SSU)

Does the Solution Crystallize ________ Yes __________ No Shear Sensitive ______ Yes _________ No

Additional Contaminants (*such as oil in Airline*) ____________________ Type ___________________ Flash Point ____________

Pipe and Fittings Requirements:

Flow Rate _____________ in gpm Working Pressure Required _________________ psi Safety Factor _______ Vacuum _______

Connection Requirements (*please check one or more*) Flange __________ NPT ________ Other ___________ Sizes ____________

Double Containment Required ______ Yes ________ No Plastic-Lined Steel Piping Required ______ Yes ________ No

Maximum Allowable Pressure Drop ______

Valve Requirements:

Type of Service (*please check one or more*) On/Off _______ Throttling _______ Automated ______ No _______ Yes

Pneumatically Operated ___________ Electric Actuated ___________ Voltage _______________ Duty Cycle_____________

Response time _______ Precision Flow Control ______ No _______ Yes ___________ Accuracy

Self-Regulating ____ Check Valves ___ Pressure Regulators ______ Pressure Relief ______ Vacuum Breakers ________

Pressure by-pass _________ Fixed Flow Control _______ Diverter _______ Air Release _________

Self-draining ______ Sanitary Configuration ______ Slurry or Abrasive Handling _______

Maximum Allowable Pressure Drop ______

Filtration Requirements: (*Please complete as much information as possible while noting not all applications require everything*)

New Installation ___________ or Replacement of ________ Cartridges _________ Bags ______ Screens or _______ Membranes

Goals of filtration: To Save Solids ________ to Save Fluid ________ Neither ______ Both _______ Flow Rate ___________ gpm

Continuous ________ or Batch _________ (*please check one*) Batch Size _____________ Gallons Processing Time ____________

Size of Particle to be Removed __________ in Microns or _____ Sieve Size or Molecular Weight ______

Percentage of Solids by Volume ________ or by Weight ____________ Particle Size Distribution ________________ if available

Efficiency Required ____________ % Nominal ______ or Absolute _________

Particle Characteristics: gelatinous or soft _____ yes _____no Do particles agglomerate after separation _____ yes _____no

Stringy __________ yes __________no Will solids settle out or sink when not in motion? _____ yes _____no

Turbidity __________ NTU Silt Density Index _________ Rejection Rate ____

Instrumentation: (*Requirements for each type of instrument will vary greatly.*))

What is to be Measured ___ or Monitored ___ or Recorded _____ Transmitted or Controlled ______ (*please check one or more*)

Desire Display: Digital or ________ Analog _________ Local __________ Remote _________ Both _____________________

Temperature ____ Pressure _____ ph ________ ORP __________ Conductivity _________ Resistivity ________ Turbidity _____

Density_________ Flow Rate ________ Flow Accumulation ___________ Continuous _________ or Batch Treatment ________

Liquid Level __________________ Dissolved Oxygen ________________

Please ask your local Harrington Representative for more detailed design assistance and application engineering guides.

HARRINGTON

PUMP SIZING GUIDELINES

The following worksheet is designed to take you step-by-step through the process of selecting the proper pump for most common applications. There are three major decisions to make when choosing the right pump. They are size, type and best buy for the particular application. Each factor must be weighed carefully and a final selection refined through the process of elimination. The following worksheet will help eliminate many common oversights in design selection. This is a combination of many manufacturers' specification requests, so it may be photocopied and used by any applications engineer.

I. Sketch the layout of the proposed installation. Trying to pick a pump without a sketch of the system is like a miner trying to work without his lamp. You are in the dark from start to finish. When drawing the system, show the piping, fittings, valves and/or other equipment that may affect the system. Mark the lengths of pipe runs. Include all elevation changes.

II. Determine and study what is to be pumped. All of the following criteria will affect the pump selection in terms of materials of construction and basic design.

What is the material to be pumped and its concentration?____

Is it Corrosive? __________ Yes ___________ No ____________pH value.

Specific Gravity __________ or Pounds Per Gallon ___________. Temperature: Min ______Max _______ Degrees C or F

Viscosity at Temperature(s) given above ______________in Centipoise or _____________Seconds Saybolt Universal

Is the Material Abrasive _____yes ______no. If so, what is the percentage of solid in solution _____________ and the size range________________ Min _______________________ Max ______________________

Capacity required (constant or variable) ___________________________U.S. Gallons per minute (gpm) __________

U.S. Gallon per hour (gph) _______ U.S. Gallons per day (gpd) _________ Cubic Centimeters per day (ccpd) _________

PUMP SIZING GUIDELINES

III. Calculating the total pressure requirements.

The Inlet Side of the Pump

1. What is the material of the inlet piping ____ and size _________________?
   (a) What is the total length of the inlet piping, in feet?______________________
   (b) Fitting Type & Quantity = Equivalent length of straight pipe (See page 36)
   ________________ x __________ = ___________
   ________________ x __________ = ___________
   ________________ x __________ = ___________
2. Total length (a+b above) for calculating friction loss ___________
3. Friction loss per 100 foot of pipe (See pages 28-35) ________________
4. Total inlet friction loss (use answer from #2 above multiplied by answer in #3 above, then divide the product by 100) ____ = friction loss on inlet
5. Static suction lift (See important terms under Hydraulic Fundamentals, page 93) _____________
6. Static suction head _____________
7. Total inlet head = (4 + 5 - 6 from above) ____________________

NPSHA (Net Positive Suction Head, available) has been calculated to be _____________________.

The Discharge Side of the Pump

8. What is the material of the discharge piping ________________________________and the size__________________?
   (c) What is the total length of the discharge piping, in feet? ____________________
   (d) Fitting Type & Quantity = Equivalent length of straight pipe (See page 36)
   ________________ x __________ = ___________
   ________________ x __________ = ___________
   ________________ x __________ = ___________
9. Total length (c+d above) for calculating friction loss ________________
10. Friction loss per 100 foot of pipe (See pages 28-35) = ______________
11. Total discharge friction loss (Use answer from #9 above multiplied by answer in #10 above then divide the product by 100) ____
12. Static discharge head (See page 93) and (See sketch on previous page) Total elevation difference between centerline of the pumps inlet and the point of discharge.____
13. Add any additional pressure requirements on the system (e.g., valves filters, nozzles or equipment) psig converted to feet of head) ______________________________________
14. Total Discharge Head = (11 + 12 + 13)____________
15. Total System Head = (7 + 12 + 13) _____________ in feet
16. Total Static Head = (5 - 6 + 12 +13) ____________ in feet
17. Total Friction Loss = (4 + 11) __________________in feet

IV. Service Cycle

How many hours per day will this pump operate? ____________ How many days per week will it be used?___________

V. Construction Features

Is a sanitary pump design required? ___________ yes ________no

Will the pump be required to work against a closed discharge? ________ yes ________no

Is it possible for this pumping system to run dry? __________ yes ________ no

Is a water-jacketed seal required to prevent crystallization on the seal faces? _______yes _______no

Can the pump be totally isolated, drained, and flushed? _______ yes _______no

Does this application and environment require a chemically resistant epoxy coating? ____________ yes ____________no

VI. Drive Requirements

AC______ or DC ______ Motor, Voltage____________________ Cycle (Hz) ____________ Phase ________________

Motor enclosure design ________ Open ________ Totally Enclosed _________ Explosion Proof ___________Sanitary

Pneumatic (Air Motor) ________ Plant air pressure available__________ psig. Volume of air available __________SCFM

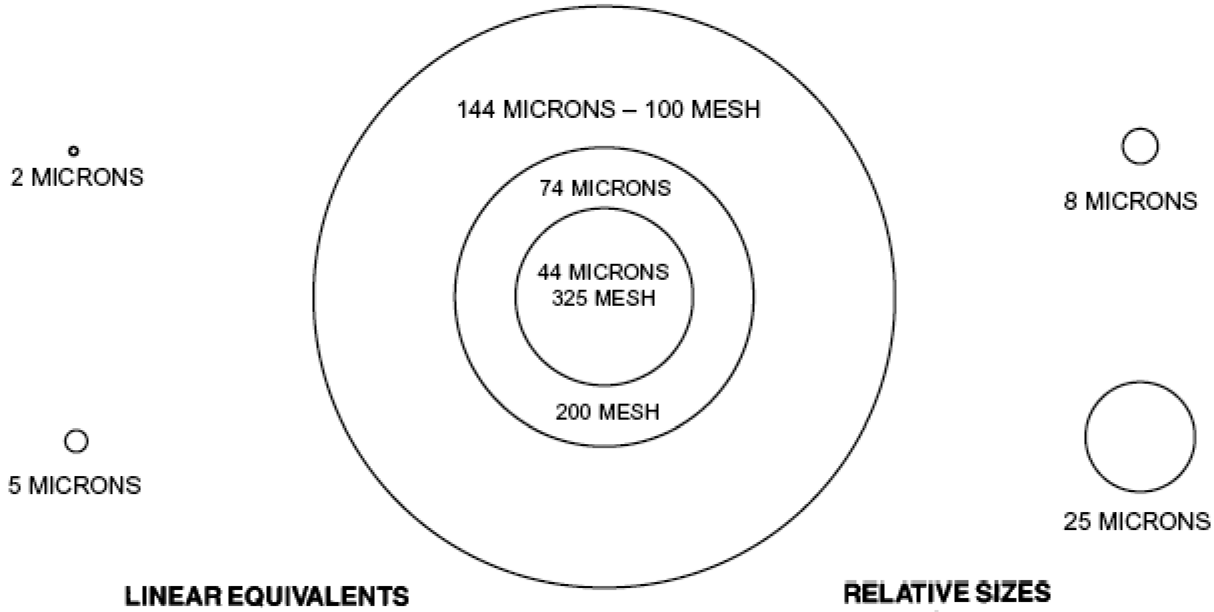
VII. What accessories will be required? Foot Valve____________________, Suction Strainer_____________________

Check Valves ________________ Isolation Valves______________ Pressure Relief Valve_______________________

Pressure Gauges___________ Flow indicators_________________ Filter/Lubricator/Regulator__________________

RELATIVE SIZE OF PARTICLES

MAGNIFICATION 500 TIMES



LINEAR EQUIVALENTS

1 INCH	25.4 MILLIMETERS	25,400 MICRONS
1 MILLIMETER	.0394 INCHES	1,000 MICRONS
1 MICRON	$\frac{1}{25,400}$ OF AN INCH	.001 MILLIMETERS
1 MICRON	3.94×10^{-5}	.000039 INCHES

RELATIVE SIZES

LOWER LIMIT OF VISIBILITY (NAKED EYE)	40 MICRONS
WHITE BLOOD CELLS	25 MICRONS
RED BLOOD CELLS	8 MICRONS
BACTERIA (COCCI)	2 MICRONS

COCOA EQUIV. TO 8-10 MICRONS
TALCUM POWDER EQUIV. TO 10 MICRONS
AVG. DIAM. HUMAN HAIR IS 50-70 MICRONS
TABLE SALT EQUIV. TO 100 MICRONS

US AND ASTM STD SIEVE NO.	ACTUAL OPENING		US AND ASTM STD SIEVE NO.	ACTUAL OPENING	
	INCHES	MICRON		INCHES	MICRON
10	.0787	2000	170	.0035	88
12	.0661	1680	200	.0029	74
14	.0555	1410	—	.0026	65
16	.0469	1190	230	.0024	62
18	.0394	1000	270	.0021	53
20	.0331	840	—	.0020	50
25	.0280	710	325	.0017	44
30	.0232	590	—	.0016	40
35	.0197	500	400	.00142	36
40	.0165	420	—	.00118	30
45	.0138	350	550	.00099	25
50	.0117	297	625	.00079	20
60	.0098	250	—	.00059	15
70	.0083	210	1,250	.000394	10
80	.0070	177	1,750	.000315	8
100	.0059	149	2,500	.000197	5
120	.0049	125	5,000	.000099	2.5
140	.0041	105	12,000	.0000394	1.0

CONVERSION DATA

CONVERSION OF THE THERMOMETER READINGS

Degrees centigrade to degrees fahrenheit

°C	°F	°C	°F	°C	°F	°C	°F
-40	-40.0	+5	+41.0	+40	+104.0	+175	+347
-38	-36.4	6	42.8	41	105.8	180	356
-36	-32.8	7	44.6	42	107.6	185	365
-34	-29.2	8	46.4	43	109.4	190	374
-32	-25.6	9	48.2	44	111.2	195	383
-30	-22.0	10	50.0	45	113.0	200	392
-28	-18.4	11	51.8	46	114.8	205	401
-26	-14.8	12	53.6	47	116.6	210	410
-24	-11.2	13	55.4	48	118.4	215	419
-22	-7.6	14	57.2	49	120.2	220	428
-20	-4.0	15	59.0	50	122.0	225	437
-19	-2.2	16	60.8	55	131.0	230	446
-18	-0.4	17	62.6	60	140.0	235	455
-17	+1.4	18	64.4	65	149.0	240	464
-16	3.2	19	66.2	70	158.0	245	473
-15	5.0	20	68.0	75	167.0	250	482
-14	6.8	21	69.8	80	176.0	255	491
-13	8.6	22	71.6	85	185.0	260	500
-12	10.4	23	73.4	90	194.0	265	509
-11	12.2	24	75.2	95	203.0	270	518
-10	14.0	25	77.0	100	212.0	275	527
-9	15.8	26	78.8	105	221.0	280	536
-8	17.6	27	80.6	110	230.0	285	545
-7	19.4	28	82.4	115	239.0	290	554
-6	21.2	29	84.2	120	248.0	295	563
-5	23.0	30	86.0	125	257.0	300	572
-4	24.8	31	87.8	130	266.0	305	581
-3	26.6	32	89.6	135	275.0	310	590
-2	28.4	33	91.4	140	284.0	315	599
-1	30.2	34	93.2	145	293.0	320	608
0	32.0	35	95.0	150	302.0	325	617
1	33.8	36	96.8	155	311.0	330	626
2	35.6	37	98.6	160	320.0	335	635
3	37.4	38	100.4	165	329.0	340	644
4	39.2	39	102.2	170	338.0	345	653

WATER PRESSURE TO FEET HEAD

Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head
1	2.31	100	230.90
2	4.62	110	253.98
3	6.93	120	277.07
4	9.24	130	300.16
5	11.54	140	323.25
6	13.85	150	346.34
7	16.16	160	369.43
8	18.47	170	392.52
9	20.78	180	415.61
10	23.09	200	461.78
15	34.63	250	577.24
20	46.18	300	692.69
25	57.72	350	808.13
30	69.27	400	922.58
40	92.36	500	1154.48
50	115.45	600	1385.39
60	138.54	700	1616.30
70	161.63	800	1847.20
80	184.72	900	2078.10
90	207.81	1000	2309.00

NOTE: One pound of pressure per square inch of water equals 2.31 feet of water at 60°F. To find the feet head of water for any pressure not given in the table above, multiply the pressure pounds per square inch by 2.31.

FEET HEAD OF WATER TO PSI

Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head
1	.43	100	43.31
2	.87	110	47.64
3	1.30	120	51.97
4	1.73	130	56.30
5	2.17	140	60.63
6	2.60	150	64.96
7	3.03	160	69.29
8	3.46	170	73.63
9	3.90	180	77.96
10	4.33	200	86.62
15	6.50	250	108.27
20	8.66	300	129.93
25	10.83	350	151.58
30	12.99	400	173.24
40	17.32	500	216.55
50	21.65	600	259.85
60	25.99	700	303.16
70	30.32	800	346.47
80	34.65	900	389.78
90	38.98	1000	433.00

NOTE: One foot of water at 60°F equals 0.433 pounds pressure per square inch. To find the pressure per square inch for any feet head not given in the table above, multiply the feet head by 0.433.

HARRINGTON

CONVERSION DATA

EQUIVALENTS OF PRESSURE AND HEAD

TO OBTAIN MULTIPLY BY	lb/in^3	lb/ft^3	Atmospheres	kg/cm^3	kg/m^3	in. Water (68°F)	ft. Water (68°F)	in. Mercury (32°F)**	mm Mercury (32°F)**	Bar ***	Mega pascal (MPa)***
lb/in2	1	144	.068046	.070307	703.070	27.7276	2.3106	2.03602	51.7150	0.06895	0.006895
lb/ft2	0.0069445	1	0.000473	0.000488	4.88241	0.1926	0.01605	0.014139	0.35913	0.000479	0.000479
Atmospheres	14.696	2116.22	1	1.0332	10332.27	407.484	33.9570	29.921	760	1.01325	0.101325
kg/cm2	14.2233	2048.155	0.96784	1	10000	394.38	32.8650	28.959	735.559	0.98067	0.098067
kg/m2	0.001422	0.204768	0.0000968	0.0001	1	0.03944	0.003287	0.002896	0.073556	0.000098	0.0000098
in. Water*	0.036092	5.1972	0.002454	0.00253	25.375	1	0.08333	0.073430	1.8651	0.00249	0.000249
ft. Water*	0.432781	62.3205	0.29449	0.03043	304.275	12	1	0.88115	22.3813	0.29839	0.0029839
in. Mercury**	0.491154	70.7262	0.033421	0.03453	345.316	13.6185	1.1349	1	25.40005	0.033864	0.0033864
mm Mercury**	0.0193368	2.78450	0.0013158	0.013595	13.59509	0.53616	0.044680	0.03937	1	0.001333	0.0001333
Bar***	14.5038	2088.55	0.98692	1.01972	10197.2	402.156	33.5130	29.5300	750.062	1	.10
MPa***	145.038	20885.5	9.8692	10.1972	101972	4021.56	335.130	295.300	7500.62	10	1

* WATER AT 68°F (20°C) **MERCURY AT 32°F (0°C) ***1 MPa (MEGAPASCAL) = 10 BAR = 1,000 N/m^2

To convert from one set of units to another, locate the given unit in the left-hand column, and multiply the numerical value by the factor shown horizontally to the right, under the set of units desired.

WEIGHT CONVERSION

Units of Weight	grain	ounce	pound	ton	gram	kilogram	metric tonne
grain	1	-	-	-	0.0648	-	-
ounce	437.5	1	0.0625	-	28.35	0.0283	-
pound	7000	16	1	0.005	453.6	0.4536	-
ton	-	32,000	2000	1	-	907.2	0.9072
gram	15.43	0.0353	-	-	1	0.001	-
kilogram	-	35.27	2.205	-	1000	1	0.001
metric tonne	-	35,274	2205	1.1023	-	1000	1

LENGTH CONVERSION

Units of Length	inch	foot	yard	mile	millimeter	centimeter	meter	kilometer
inch	1	0.0833	0.0278	-	25.4	2.54	0.0254	-
foot	12	1	0.3333	-	304.8	30.48	0.3048	-
yard	36	3	1	-	914.4	91.44	0.9144	-
mile	-	5280	1760	1	-	-	1609.3	1.609
millimeter	0.0394	0.0033	-	-	1	0.100	0.001	-
centimeter	0.3937	0.0328	0.0109	-	10	1	0.01	-
meter	39.37	3.281	1.094	-	1000	100	1	0.001
kilometer	-	3281	1094	0.6214	-	-	1000	1

(1 MICRON = 0.001 MILLIMETERS)

SQUARE/CUBIC MEASURE EQUIVALENTS

Measurement	Area	Measures
144	Square Inches	1 Square Foot
9	Square Feet	1 Square Yard
30.25	Square Yards	1 Square Rod
160	Square Rods	1 Acre
640	Acres	1 Square Mile
1728	Cubic Inches	1 Cubic Foot
27	Cubic Feet	1 Cubic Yard

CONVERSION DATA

VOLUME CONVERSION

Units of Volume	in^3	ft^3	yd^3	cm^3	m^3	liter	U.S. Gal.	Imp. Gal.	lb.	kg.
cubic inch	1	0.00058	-	16.387	-	0.0164	0.0043	0.0036	0.036	0.016
cubic foot	1728	1	0.0370	28,317.8	0.0283	28.32	7.481	6.229	62.430	28.343
cubic yard	46,656	27	1	-	0.7646	764.55	201.97	168.8	1,685.610	765.267
cubic cm	0.0610	-	-	1	-	0.001	0.0003	0.0002	0.002	0.001
cubic meter	61,023.7	35.31	1.308	-	1	1000	264.17	220.0	2,210.000	1,000.000
liter	61.02	0.0353	0.0013	1000	0.001	1	0.2642	0.22	2.210	1.003
U.S. Gallon	231	0.1337	0.0050	3785.4	0.0038	3.785	1	0.8327	8.350	3.791
Imp. Gallon	277.42	0.1605	0.0059	4546.1	0.0045	4.546	12.01	1	10.020	4.549
1 cubic ft of water @ 50°F	-	-	-	-	-	-	-	-	62.41	-
1 cubic ft of water @ 39.2°F	-	-	-	-	-	-	-	-	62.43	-

VOLUME-DRY CONVERSION

Units of Volume - Dry	barrel	bushel	liter	peck	pint (pt)	quart
barrel	1	3.281	115.627	13.125	209.998	104.999
bushel	0.305	1	35.239	4	64	32
liter	0.009	0.028	1	0.114	1.816	0.908
peck	0.076	0.25	8.81	1	16	8
pint (pt)	0.005	0.016	0.551	0.063	1	0.5
quart	0.01	0.031	1.101	0.125	2	1

AREA CONVERSION

Units of Area	in^2	ft^2	acre	sq mile	cm^2	m^2	sq hectare	km^2
sq inch	1	0.0069	-	-	6.452	-	-	-
sq foot	144	1	-	-	929.0	0.0929	-	-
acre	-	43,560	1	0.0016	-	4047	0.4047	0.004
sq mile	-	2.79 e+6	640	1	-	2.59 e+6	259.0	2.59
sq cm	0.155	0.001	-	-	1	0.0001	-	-
sq meter	1550	10.76	-	-	10,000	1	0.0001	-
hectare	-	1.076 e+5	2.471	0.004	-	10,000	1	0.01
sq kilometer	-	1.076 e+7	247	0.386	-	1.0 e+6	100	1

DENSITY CONVERSION

Units of Density	lb/in^3	lb/ft^3	lb/gal	g/cm^3	g/l
pound/cubic in.	1	1728	231.0	27.68	27,680
pound/cubic ft.	-	1	0.1337	0.0160	16.019
pound/gal.	0.00433	7.481	1	0.1198	119.83
gram/cubic cm	0.0361	62.43	8.345	1	1000.0
gram/liter	-	0.0624	0.00835	0.001	1

ENERGY CONVERSION

Units of Energy	ft lb	BTU	g cal	Joule	kw hr	hp hr
foot-pound	1	0.001285	0.3240	1.3556	-	-
British Thermal Unit	778.2	1	252.16	1054.9	-	-
gram calorie	3.0860	0.003966	1	4.1833	-	-
Int. Joule	0.7377	0.000948	0.2390	1	-	-
Int. kilowatt-hour	2,655,656	3412.8	860,563	-	1	1.3412
horsepower-hour	1,980,00	2544.5	641,617	-	0.7456	1

FLOW CONVERSION

Units of Flow Rate	US gps	US gpm	US gph	US gpd	Imp gps	Imp gpm	Imp gph	Imp gpd	liters/ sec	liters/ min	liters/ hr	liters/ day
US gal/sec (gps)	1	0.017	-	-	1.2	0.02	-	-	0.264	0.004	-	-
US gal/min (gpm)	60	1	0.017	0.001	72.06	1.2	0.02	0.001	15.85	0.264	0.004	-
US gal/hr (gph)	3,600	60	1	0.042	4,323	72.06	1.2	0.05	951.02	15.85	0.264	0.011
US gal/day (gpd)	86,400	1,440	24	1	103,762	1,729.40	28.82	1.2	22,824	380.41	6.34	0.264
Imperial gal/sec	0.833	0.014	-	-	1	0.017	-	-	0.22	0.004	-	-
Imperial gal/min	49.96	0.833	0.014	0.001	60	1	0.017	0.001	13.2	0.22	0.004	-
Imperial gal/hr	2,997.60	49.96	0.833	0.035	3,600	60	1	0.042	791.89	13.2	0.22	0.009
Imperial gal/day	71,943	1,199	19.98	0.833	86,400	1,440	24	1	19,005	316.76	5.279	0.22
Liters/sec	3.79	0.063	0.002	-	4.55	0.076	0.001	-	1	0.017	-	-
Liters/min	227.12	3.785	0.063	0.003	272.77	4.55	0.076	0.003	60	1	0.017	0.001
Liters/hr	13,627	227.12	3.785	0.158	16,366	272.77	4.55	0.189	3,600	60	1	0.042
Liters/day	327,060	5,451	90.85	3.785	392,782	6,546	109.11	4.55	86,400	1,440	24	1
Cubic ft/sec (cfs)	0.134	0.002	-	-	0.161	0.003	-	-	0.035	0.001	-	-
Cubic ft/min (cfm)	8.02	0.134	0.002	-	9.633	0.161	0.003	-	2.119	0.035	0.001	-
Cubic ft/hr (cfh)	481.25	8.02	0.134	0.006	577.96	9.63	0.161	0.007	127.13	2.119	0.035	0.001
Cubic ft/day (cfd)	11,550	192.5	3.21	0.134	13,871	231.18	3.853	0.161	3,051.20	50.85	0.848	0.001
Acre in/min	0.002	-	-	-	0.003	-	-	-	0.001	-	-	-
Acre in/hr	0.133	0.002	-	-	0.159	0.003	-	-	0.035	-	-	-
Acre in/day	3.182	0.053	0.001	-	3.821	0.064	0.001	-	0.841	0.001	-	-
Cubic m/sec	0.004	-	-	-	0.005	-	-	-	0.001	-	-	-
Cubic m/min	0.227	0.004	-	-	0.273	0.005	-	-	0.06	0.001	-	-
Cubic m/hr	13.628	0.227	0.004	-	16.366	0.273	0.005	-	3.6	0.06	0.001	-
Cubic m/day	327.06	5.451	0.091	0.004	392.78	6.546	0.109	0.005	86.4	1.44	0.024	0.001

Units of Flow Rate	ft^3/sec	ft^3/min	ft^3/hr	ft^3/day	Acre in/ min	Acre in/hr	Acre in/ day	m^3/sec	m^3/min	m^3/hr	m^3/day
US gal/sec (gps)	7.48	0.125	0.002	-	452.6	7.54	0.31	264.2	4.4	0.073	0.003
US gal/min (gpm)	448.8	7.48	0.125	0.005	27,154	452.6	18.86	15,850	264.2	4.403	0.183
US gal/hr (gph)	26,930	448.83	7.481	0.312	1.629 e+06	27,154	1,131	951,019	15,850	264.17	11.007
US gal/day (gpd)	646,317	10,772	179.53	7.481	3.910 e+07	651,703	27,154	2.282 e+07	380,408	6,340	264.17
Imperial gal/sec	6.229	0.104	0.002	-	376.8	6.28	0.26	220	3.67	0.061	0.003
Imperial gal/min	373.73	6.229	0.104	0.004	22,611	376.8	15.7	13,198	220	3.666	0.153
Imperial gal/hr	22,424	373.73	6.229	0.259	1.357 e+06	22,611	942.1	791,889	13,198	220	9.165
Imperial gal/day	538,171	8,970	149.49	6.229	3.256 e+07	542,656	22,611	1.901 e+07	316,756	5,279	220
Liters/sec	28.32	0.472	0.008	-	1,713	2.86	1.19	1,000	16.67	0.278	0.012
Liters/min	1,699	28.32	0.472	0.2	102,790	1,713	71.38	60,000	1,000	16.67	0.694
Liters/hr	101,941	1,669	28.32	1.18	6.167 e+06	102,790	4,283	3.600 e+06	60,000	1,000	42.67
Liters/day	2,446,575	40,776	679.6	28.32	1.480 e+08	2.467 e+06	102,790	8.640 e+07	1.440 e+06	24,000	1,000
Cubic ft/sec (cfs)	1	0.017	-	-	60.5	1.008	0.042	35.31	0.589	0.01	-
Cubic ft/min (cfm)	60	1	0.017	-	3,630	60.5	2.52	2,119	35.31	0.59	0.025
Cubic ft/hr (cfh)	3,600	60	1	0.042	271,800	3,630	151.25	127,133	2,119	35.31	1.471
Cubic ft/day (cfd)	86,400	14,400	24	1	5.227 e+06	87,120	3,630	3,051,187	50,853	847.55	35.31
Acre in/min	0.017	-	-	-	1	0.017	0.001	0.584	0.01	-	-
Acre in/hr	0.992	0.001	-	-	60	1	0.042	35.02	0.584	0.01	-
Acre in/day	23.8	0.033	0.006	-	1,440	24	1	840.55	14.001	0.233	0.001
Cubic m/sec	0.028	-	-	-	1.71	0.029	0.001	1	0.017	-	-
Cubic m/min	1.7	0.028	-	-	102.8	1.71	0.071	60	1	0.017	0.001
Cubic m/hr	101.94	1.7	0.028	0.001	6,167	102.8	4.283	3,600	60	1	0.042
Cubic m/day	2446.6	40.78	0.68	0.028	148,018	2,467	102.79	86,400	1,400	24	1

POWER CONVERSION

Units of Power	hp	watt	kw	BTU/sec	BTU/ min	BTU/hr	ft lb/ sec	ft lb/ min	ft lb/ hr	cal/sec	cal/min	cal/hr	j/sec	j/min	j/hr
horsepower international	1	0.001	1.34	1.41	0.24	-	0.002	-	-	0.006	-	-	0.001	-	-
watt	745.7	1	1,000	1,055	17.58	0.29	1.36	0.023	-	4.19	0.07	0.001	1	0.017	-
kilowatt	0.746	0.001	1	1.06	0.018	-	0.001	-	-	0.004	-	-	0.001	-	-
BTU per second	0.707	0.001	0.948	1	0.017	-	0.001	-	-	0.004	-	-	-	-	-
BTU per minute	42.41	0.057	56.87	60	1	0.017	0.077	0.001	-	0.238	0.004	-	0.057	-	-
BTU per hour	2,544	3.412	3,412	3,600	60	1	4.63	0.077	0.001	14.29	0.238	0.004	3.412	0.057	0.001
foot pound force per second	550	0.738	738	778	12.97	0.216	1	0.017	-	3.09	0.05	0.001	0.738	0.012	-
foot pound force per minute	33,000	44.25	44,254	46,690	778	12.97	60	1	0.017	185.3	3.09	0.05	44.25	0.738	0.012
foot pound force per hour	1.980 e+06	2,655	2.655 e+06	2.801 e+06	46.69	778	3,600	60	1	11,117	185.28	3.09	2,655	44.25	0.738
calories per second	178	0.239	238.9	252	4.2	0.07	0.324	0.005	-	1	0.017	-	0.239	0.004	-
calories per minute	10,686	14.33	14,331	15,120	252	4.2	19.43	0.324	0.005	60	1	0.017	14.33	0.239	0.004
calories per hour	641,186	859.85	859,845	907,185	15,120	252	1,166	19.43	0.324	3,600	60	1	860	14.33	0.239
joules per second	746	1	1,000	1,055	17.58	0.29	1.36	0.023	-	4.19	0.07	0.001	1	0.017	-
joules per minute	44,742	60	60,000	63,303	1,055	17.58	81.35	1.36	0.023	251.2	4.19	0.07	60	1	0.017
joules per hour	2.685 e+06	3,600	3.600 e+06	3.798 e+06	63,303	1,055	4,881	81.35	1.36	15,072	251.2	4.19	3600	60	1

PRESSURE CONVERSION

Units of Pressure	atm	bar	lb/in²	lb/ft²	kg/cm²	kg/m²	inch H_2O	inch Hg	inch air	ft H_2O	ft air	mm Hg	mm H_2O	kilopascal	N/m²
atmosphere (atm)	1	0.987	0.068	-	0.968	-	0.002	0.033	-	0.029	-	0.001	-	0.01	-
bar	1.013	1	0.069	-	0.981	-	0.002	0.034	-	0.03	-	0.001	-	0.01	-
pound per square inch (psi)	14.7	14.5	1	0.007	14.22	0.001	0.036	0.491	-	0.434	0.001	0.019	0.001	0.145	-
pound per square foot (psf)	2,116	2,089	144	1	2,048	0.205	5.2	70.73	0.006	62.43	0.076	2.784	0.205	20.89	0.021
kilogram per square centimeter	1.033	1.02	0.07	-	1	0.001	0.003	0.035	-	0.03	-	0.001	-	0.01	-
kilogram per square meter	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
inch of water (H2O) (4°C)	406.78	401.46	27.68	0.192	393.7	0.039	1	13.6	0.001	12	0.015	0.535	0.039	4.015	0.004
inch of mercury (Hg) (0°C)	29.921	29.53	2.036	0.014	28.96	0.003	0.074	1	-	0.883	0.001	0.039	0.003	0.295	-
inch of air (15°C)	332,005	327,664	22,592	148.7	321,328	32.13	816.2	11,096	1	9,794	12	436.8	32.13	3,277	3.106
foot of water (4°C)	33.9	33.46	2.307	0.016	32.81	0.003	0.083	1.133	-	1	-	0.045	0.003	0.335	-
foot of air (15°C)	27,677	27,305	1,883	13.07	26,77	2.678	0.006	924.7	0.083	816.2	1	36.4	2.678	273.1	0.273
milimeter of mercury (°C)	760	750	51.71	0.36	735.6	0.074	1.868	25.4	0.002	22.42	0.027	1	0.074	7.5	0.008
millimeter of water (4°C)	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
kilopascal (kP)	101.3	100	6.89	0.048	98.07	0.01	0.249	3.386	-	2.99	0.004	0.133	0.01	1	0.001
Newton per square meter	-	-	-	0.021	-	0.102	0.004	-	3.277	-	0.273	0.008	0.102	0.001	1

HARRINGTON

CONVERSION DATA

TO CHANGE	TO	MULTIPLY BY
Amps	Watts	Volts
Atmospheres	PSI (Lbs/Sq In.)	14.696
Atmospheres	Feet of Water	33.9
Atmospheres	Inches of Mercury	29.92
Barrels (US)	Gallons (US)	31.5
Barrels of Oil	Gallons (US)	42
B.T.U.	H.P.Lr	0.0003929
Centimeters	Feet	0.0328
Centimeters	Inches	0.3937
Centimeters/Sec.	Feet/Min	1.9684
Centimeters/Sec.	Feet/Sec	0.0328
Centipoise	Poises	0.01
Centistokes	Stokes	0.01
Cubic Centimeters	Cubic Feet	3.5314×10^{-5}
Cubic Centimeters	Cubic Inches	0.06102
Cubic Centimeters	Gallons	0.0002642
Cubic Feet	Gallons	7.4805
Cubic Feet	Cubic Inches	0.06102
Cubic Feet	Cubic Yards	0.03703
Cubic Feet/Min	GPM	7.4805
Cubic Inches	Gallons	0.004329
Cubic Inches	Cubic Centimeters	16.387
Cubic Inches	Cubic Feet	35.31
Cubic Meters	Cubic Inches	61,023.74
Cubic Meters/Hr	GPM	4,403
Cubic Yards	Cubic Feet	27
Degrees	Revolution	0.00277778
Drams	Ounces	0.0625
Drams	Grams	1.7718
Dynes	Pounds	2.248009×10^{-6}
Dynes/SqCm	PSI	1.45038×10^{-5}
Fathom	Feet	6
Feet	Centimeters	30.48006
Feet	Meters	0.3048006
Feet	Inches	12
Feet	Yards	0.3333
Feet of Water	Atmosphere	0.2949
Feet of Water	PSI	0.433
Feet of Water	Inches of Mercury	0.88265
Feet of Water	Pounds per SqFt	62.5
Feet/Hr	Miles/Hour	0.00018939
Feet/Min	Meters/Min.	0.3048
Feet/Min	Miles/Hour	0.01136
Feet/Sec	Miles/Hour	0.681818
Fluid Ounces	Millimeters	29.57
Fluid Ounces	Liters	0.2957
Gallons	Cubic Centimeters	3,785.43
Gallons	Gallons (Imp)	0.83268

TO CHANGE	TO	MULTIPLY BY
Gallons	Cubic Feet	0.13368
Gallons	Cubic inches	231
Gallons	Pound of Water	8.33
Gallons/Min.	Cubic Feet/Min	0.13368
Grams	Ounces	0.0353
Grams	Grains	15.43
Horsepower	Ft Lbs/Min	33,000
Horsepower	Ft Lbs/Sec	550
Horsepower	Kilowatts	0.7457
Inches	Feet	0.083333
Inches	Meters	0.0254
Inches	Millimeters	25.40005
Inches	Mils	1000
Inches of Mercury	Atmosphere	0.033327
Inches of Mercury	Feet of Water	1.1309
Inches of Mercury	PSI	0.489
Inches of Water	Inches of Mercury	0.735
Inches of Water	Pounds per Sq In	0.361
Kilograms	Pounds (avdp)	2.2046
Kilograms/Sq cm	PSI	14.2233
Kilograms/Sq mm	PSI	1422.33
Liters	Gallons	0.264178
Long Tons	Pounds	2240
Meters	Feet	3.2808
Meters	Inches	39.37
Milliliters	Fluid Ounces	0.03382
Ounces	Pounds	0.625
Ounces per Sq In	Inches of Mercury	0.127
Ounces per Sq In	Inches of Water	1.733
Ounces	Grams	15.43
Poise	Centipoise	100
Pounds	Ounces	16
Pounds	Kilograms	0.45359
Pounds per Sq In	Inches of Water	27.72
Pounds per Sq In	Feet of Water	2.31
Pounds per Sq In	Inches of Mercury	2.04179
Pounds per Sq In	Atmospheres	0.06804
Pounds of Water	Gallon	0.12004
Square Feet	Square Inches	144
Square Feet	Square Yards	0.11111
Square Inches	Square Centimeters	6.4516
Square Inches	Square Feet	0.006944
Square Inches	Square Millimeters	645.163
Square Meters	Square Feet	10.76
Square Millimeters	Square Inches	0.0015499
Square Yards	Square Feet	9
Tons Molasses/Hr	GPM	2.78
Watts	Horsepower	0.001341

HARRINGTON

CONVERSION DATA

EQUIVALENT OF COMMON FRACTIONS OF AN INCH

Inches		Millimeters
Fractions	Decimals	
1/64	0.015625	0.397
1/32	0.03125	0.794
3/64	0.046875	1.191
1/16	0.0625	1.588
5/64	0.078125	1.984
3/32	0.09375	2.381
7/64	0.019375	2.778
1/8	0.1250	3.175
9/64	0.140625	3.572
5/32	0.15625	3.969
11/64	0.171875	4.366
3/16	0.1875	4.762
13/64	0.203125	5.159
7/32	0.21875	5.556
15/64	0.234375	5.953
1/4	0.25	6.350
17/64	0.265625	6.747
9/32	0.28125	7.144
19/64	0.296875	7.541
5/16	0.3125	7.938
21/64	0.328125	8.334
11/32	0.34375	8.731
23/64	0.359375	9.128
3/8	0.3750	9.525
25/64	0.390625	9.922
13/32	0.40625	10.319
27/64	0.421875	10.716
7/16	0.4375	11.112
29/64	0.453125	11.509
15/32	0.46875	11.906
31/64	0.484375	12.303
1/2	0.50	12.700

Inches		Millimeters
Fractions	Decimals	
33/64	0.515625	13.097
17/32	0.53125	13.494
35/64	0.546875	13.891
9/16	0.5625	14.288
37/64	0.578125	14.684
19/32	0.59375	15.081
39/64	0.609375	15.478
5/8	0.625	15.875
41/64	0.640625	16.272
21/32	0.65625	16.669
43/64	0.671875	17.066
11/16	0.6875	17.462
45/64	0.703125	17.859
23/32	0.71875	18.256
47/64	0.734375	18.653
3/4	0.7500	19.050
49/64	0.765625	19.447
25/32	0.78125	19.844
51/64	0.796875	20.241
13/16	0.8125	20.638
53/64	0.828125	21.034
27/32	0.84375	21.431
55/64	0.859375	21.828
7/8	0.8750	22.225
57/64	0.890625	22.622
29/32	0.90625	23.019
59/64	0.921875	23.416
15/16	0.9375	23.812
61/64	0.953125	24.209
31/32	0.96875	24.606
63/63	0.984375	25.003
1	1.0	25.400

Inches	Millimeters
0	0.0000
1/128	0.1984
1/64	0.3969
3/128	0.5953
1/32	0.7937
5/128	0.9921
3/64	1.1906
7/128	1.3890

EXAMPLE:

Convert 3.7643 meters to feet, inches and fractions

3.7643 meters
3.6556 = 12'

108.70 mm
107.95 = 4 ¼"

.75 = 1/32"

3.7643 meters = 12' - 4 9/32"

EXAMPLE:

Convert 15' - 6 7/16" to meters

15' = 4.5720 meters

6 7/16" = .163513 meters

15'- 6 7/16" = 4.735513 meters

HARRINGTON
CONVERSION DATA

CONCENTRATION CONVERSION

Units of Concentration	kmol/m^3	µmol/cm^3	µmol/dm^3	µmol/L	mmol/cm^3	mmol/dm^3	mmol/L	mmol/m^3	mmol/mL	mol/dm^3	mol/L	mol/m^3	one elem entity meter^3
kilomole/meter^3	1	1,000	1,000,000	1,000,000	1	1000	1000	1000000	1	1	1	1000	6.022137 e+26
micromole/centimeter^3	0.001	1	1000	1000	0.001	1	1	1000	0.001	0.001	0.001	1	6.022137 e+23
micromole/decimeter^3	1.000 e-6	0.001	1	1	1.000 e-6	0.001	0.001	1	1.000 e-6	1.000 e-6	1.000 e-6	0.001	6.022137 e+20
micromole/liter	1.000 e-6	0.001	1	1	1.000 e-6	0.001	0.001	1	1.000 e-6	1.000 e-6	1.000 e-6	0.001	6.022137 e+20
millimole/centimeter^3	1	1000	1000000	1000000	1	1000	1000	1000000	1	1	1	1000	6.022137 e+26
millimole/decimeter^3	0.001	1	1000	1000	0.001	1	1	1000	0.001	0.001	0.001	1	6.022137 e+23
millimole/liter	0.001	1	1000	1000	0.001	1	1	1000	0.001	0.001	0.001	1	6.022137 e+23
millimole/meter^3	1.000 e-6	0.001	1	1	1.000 e-6	0.001	0.001	1	1.000 e-6	1.000 e-6	1.000 e-6	0.001	6.022137 e+20
millimole/milliter	1	1000	1000000	1000000	1	1000	1000	1000000	1	1	1	1000	6.022137 e+26
mole/decimeter^3	1	1000	1000000	1000000	1	1000	1000	1000000	1	1	1	1000	6.022137 e+26
mole/liter	1	1000	1000000	1000000	1	1000	1000	1000000	1	1	1	1000	6.022137 e+26
mole/meter^3	0.001	1	1000	1000	0.001	1	1	1000	0.001	0.001	0.001	1	6.022137 e+23
one elementary entity/meter^3	1.661 e-27	1.661 e-24	1.661 e-21	1.661 e-21	1.661 e-27	1.661 e-24	1.661 e-24	1.661 e-21	1.661 e-27	1.661 e-27	1.661 e-27	1.661 e-24	1

TIME CONVERSION

Units of Time	century	day	decade	hour	millennium	millisecond	minute	month (30 day)	nanosecond	second	week	year
century	1	36500	10	876000	.01	3153600000000	52560000	1216.667	3.1536 e+18	3153600000	5214.286	100
day	2.740 e-5	1	2.740 e-4	24	2.740 e-6	86400000	1440	0.033	86400000000000	86400	0.143	0.003
decade	.01	3650	1	87600	0.01	31536000000	5256000	121.667	3.1536 e+17	315360000	521.429	10
fortnight	3.836 e-4	14	0.004	336	3.836 e-5	1209600000	20160	0.467	1.2096 e+15	1209600	2	0.038
hour	1.142 e-6	0.042	1.142 e-5	1	1.142 e-7	3600000	60	0.001	3600000000000	3600	0.006	1.142 e-4
leap-year	0.01	366	0.1	8784	0.001	31622400000	527040	12.2	3.16224 e+16	31622400	52.286	1.003
millennium	10	365000	100	8760000	1	31536000000000	525600000	12166.667	3.1536 e+19	31536000000	52142.857	1000
millisecond	3.171 e-13	1.157 e-8	3.171 e-12	2.778 e-7	3.171 e-14	1	1.667 e-5	3.858 e-10	1000000	0.001	1.653 e-9	3.171 e-11
minute	1.903 e-8	0.001	1.903 e-7	0.017	1.903 e-9	60000	1	2.315 e-5	60000000000	60	9.921 e-50	1.903 e-6
month (30 day)	0.001	30	0.008	720	8.219 e-5	2592000000	43200	1	2.592 e+15	2592000	4.286	0.082
nanosecond	3.171 e-19	1.157 e-14	3.171 e-18	2.778 e-13	3.171 e-20	1.000 e-6	1.667 e-11	3.858 e-16	1	10.000 e-10	1.653 e-15	3.171 e-17
second	3.171 e-10	1.157 e-5	3.171 e-9	2.778 e-4	3.171 e-11	1000	0.017	3.858 e-7	1000000000	1	1.653 e-6	3.171 e-8
week	1.918 e-4	7	0.002	168	1.918 e-5	604800000	10080	0.233	604800000000000	604800	1	0.019
year	0.01	365	0.1	8760	0.001	31536000000	525600	12.167	3.1536 e+16	31536000	52.143	1

FORCE CONVERSION

Units of Force	dyne	gram force	kilogram force	kilonewton	millinewton	newton	ounce-force (ozf)	pound-force (lbf)
dyne	1	0.001	1.020 e-6	1.000 e-8	0.01	1.000 e-5	3.597 e-5	2.248 e-6
gram force	980.665	1	0.001	9.807 e-6	9.807	0.01	0.035	0.002
kilogram force	980665	1000	1	0.01	9806.65	98.07	35.274	2.205
kilonewton	100000000	101971.621	101.972	1	1000000	1000	3596.942	224.809
millinewton	100	0.102	1.020 e-4	1.000 e-6	1	0.001	0.004	2.248 e-4
newton	100000	101.972	0.102	0.001	1000	1	3.597	0.225
ounce-force (ozf)	27801.39	28.35	0.028	2.780 e-4	278.014	0.278	1	0.063
pound-force (lbf)	444822.2	453.592	0.454	0.004	4448.222	4.448	16	1

TORQUE CONVERSION

Units of Torque	dyn-cm	gf-cm	kgf-m	kN-m	kP-m	MN-m	μN-m
dyne centimeter	1	1.02 e-3	1.02 e-8	1.00 e-10	1.02 e-8	10.00 e-14	0.1
gram-force centimeter	980.67	1	1.00 e-5	9.81 e-8	1.00 e-5	9.81 e-11	98.07
kilogram-force meter	98066500	100000	1	0.01	1	9.81 e-6	9806650
kilopond meter	10000000000	10197162.13	101.97	1	101.97	1.00 e-3	1000000000
meganewton meter	10000000000000	1019762129.78	101971.62	1000	101971.62	1	1000000000000
micronewton meter	10	.01	1.02 e-7	1.00 e-9	1.02 e-7	10.00 e-13	1
millinewton meter	10000	10.2	1.02 e-4	1.00 e-6	1.02 e-4	1.00 e-9	1000
newton meter	10000000	10197.16	0.1	1.00 e-3	0.1	1.00 e-6	1000000
ounce-force foot	847387.9	864.1	0.01	8.47 e-5	0.01	8.47 e-8	84738.79
ounce- force inch	70615.5	72.01	7.20 e-4	7.06 e-6	7.20 e-4	7.06 e-9	7061.55
pound-force foot	13558200	13825.52	0.14	1.36 e-3	0.14	1.36 e-6	1355820
pound-force inch	1129848	1152.12	0.01	1.13 e-4	0.01	1.13 e-7	112984.8

Units of Torque	mN-m	N-m	ozf-ft	ozf-in	lbf-ft	lbf-in
dyne centimeter	1.00 e-4	1.00 e-7	1.18 e-6	1.42 e-5	7.38 e-8	8.85 e-7
gram-force centimeter	0.1	9.81 e-5	1.16 e-3	0.01	7.23 e-5	8.68 e-4
kilogram-force meter	9806.665	9.81	115.73	1388.74	7.23	86.8
kilopond meter	1000000	1000	11800.97	141611.97	737.56	8850.75
meganewton meter	1000000000	1000000	11800970.96	141611969.04	737561.03	8850748.07
micronewton meter	1.00 e-3	1.00 e-6	1.18 e-5	1.42 e-4	7.38 e-7	8.85 e-6
millinewton meter	1	1.00 e-3	0.01	0.14	7.38 e-4	0.01
newton meter	1000	1	11.8	141.61	0.74	8.85
ounce-force foot	84.74	0.08	1	12	0.06	0.75
ounce- force inch	7.06	0.01	0.08	1	0.01	0.06
pound-force foot	1355.82	1.36	16	192	1	12
pound-force inch	112.98	0.11	1.33	16	0.08	1

MASS CONVERSION

Units of Mass	carat	grain (gr)	gram (g)	kilogram (kg)	megagram (Mg)	microgram (µg)	milligram (mg)	ounce (avdp)
carat	1	3.09	0.2	2.00 e-4	2.00 e-7	200000	200	0.01
grain (gr)	0.32	1	0.06	6.48 e-5	6.48 e-8	64798.91	64.8	2.29 e-3
gram (g)	5	15.43	1	1.00 e-3	1.00 e-6	1000000	1000	0.04
kilogram (kg)	5000	15432.36	1000	1	1.00 e-3	1000000000	1000000	35.27
megagram (Mg)	5000000	15432358.35	1000000	1000	1	1000000000000	1000000000	35273.97
microgram (µg)	5.00 e-6	1.54 e-5	1.00 e-6	1.00 e-9	10.00 e-13	1	1.00 e-3	3.53 e-8
milligram (mg)	0.01	0.02	1.00 e-3	1.00 e-6	1.00 e-9	1000	1	3.53 e-5
ounce (avdp)	141.75	437.5	28.35	0.03	2.83 e-5	28349520	28349.52	1
ounce (troy)	155.52	480	31.1	.03	3.11 e-5	3103470	31103.47	1.1
pennyweight	7.78	24	1.56	1.56 e-3	1.56 e-6	1555174	15555.17	0.05
pound (avdp)	2267.96	7000	453.59	0.45	4.54 e-4	453592400	453592.4	16
pound (troy)	1866.21	5760	373.24	0.37	3.73 e-4	373241700	373241.7	13.17
stone	31751.47	98000	6350.29	6.35	0.01	6350293000	6350293	224
ton (long)	5080235	15680001.41	1016047	1016.05	1.02	1016047000000	1016047000	35840.01
ton (short)	4535923.5	13999999.38	907184.7	907.18	0.91	907184700000	907184700	32000
tonne(metric)	5000000	15432358.35	1000000	1000	1	1000000000000	1000000000	35273.97

Units of Mass	ounce (troy)	pennyweight	pound (avdp)	pound (troy)	stone	ton (long)	ton (short)	tonne (metric)
carat	0.01	0.13	4.41 e-4	5.36 e-4	3.15 e-5	1.97 e-7	2.20 e-7	2.00 e-7
grain (gr)	2.08 e-3	0.04	1.43 e-4	1.74 e-4	1.02 e-5	6.38 e-8	7.14 e-8	6.48 e-8
gram (g)	0.03	0.64	2.20 e-3	2.68 e-3	1.57 e-4	9.84 e-7	1.10 e-6	1.00 e-6
kilogram (kg)	32.15	643.01	2.2	2.68	0.16	9.84 e-4	1.10 e-3	1.00 e-3
megagram (Mg)	32150.75	643014.87	2204.62	2679.23	157.47	0.98	1.1	1
microgram (µg)	3.22 e-8	6.43 e-7	2.20 e-9	2.68 e-9	1.57 e-10	9.84 e-13	1.10 e-12	10.00 e-13
milligram (mg)	3.22 e-5	6.43 e-4	2.20 e-6	2.68 e-6	15.7 e-7	9.84 e-10	1.10 e-9	1.00 e-9
ounce (avdp)	0.91	18.23	0.06	0.08	4.46 e-3	2.79 e-5	3.12 e-5	2.83 e-5
ounce (troy)	1	20	0.07	0.08	4.90 e-3	3.06 e-5	3.43 e-5	3.11 e-5
pennyweight	0.05	1	3.43 e-3	4.17 e-3	2.45 e-4	1.53 e-6	1.71 e-6	1.56 e-6
pound (avdp)	14.58	291.67	1	1.22	0.07	4.46 e-4	5.00 e-4	4.54 e-4
pound (troy)	12	240	0.82	1	0.06	3.67 e-4	4.11 e-4	3.73 e-4
stone	204.17	4083.33	14	17.01	1	0.01	0.01	0.01
ton (long)	32666.68	653333.32	2240	2722.22	160	1	1.02	1.02
ton (short)	29166.67	583333.25	2000	2430.56	142.86	0.89	1	0.91
tonne (metric)	32150.75	643014.87	2204.62	2679.23	157.47	0.98	1.1	1

HARRINGTON

CONVERSION DATA

VISCOSITY CONVERSION

SAYBOLT UNIVERSAL SSU	STOKES	CENTISTOKES	POISES*	CENTIPOISES*	ENGLER SECONDS	REDWOOD NO.1 SECONDS	TYPICAL LIQUIDS AT 70°F
31	0.010	1.00	0.008	0.8	54	29	WATER
35	0.025	2.56	0.020	2.05	59	32.1	KEROSENE
50	0.074	7.40	0.059	5.92	80	44.3	NO.2 FUEL OIL
80	0.157	15.7	0.126	12.6	125	69.2	NO.4 FUEL OIL
100	0.202	20.2	0.162	16.2	150	85.6	TRANSFORMER OIL
200	0.432	43.2	0.346	34.6	295	170	HYDRAULIC OIL
300	0.654	65.4	0.522	52.2	470	254	SAE 10W OIL
500	1.10	110	0.88	88.8	760	423	SAE 10 OIL
1,000	2.16	220	1.73	173	1,500	896	SAE 20 OIL
2,000	4.40	440	3.52	352	3,000	1,690	SAE 30 OIL
5,000	10.8	1,080	8.80	880	7,500	4,230	SAE 50 OIL
10,000	21.6	2,160	17.0	1,760	15,000	8,460	SAE 60-70 OIL
50,000	108	10,800	88	8,800	75,000	43,660	MOLASSES B
100,000	216	21,600	173	17,300	150,000	88,160	MOLASSES C

$$\text{Kinematic Viscosity (in centistokes)} = \frac{\text{Absolute Viscosity (in centipoise)}}{\text{Density}}$$

REYNOLDS NUMBER, R

Reynolds Number R is a dimensionless number or ration of velocity in ft/sec. times the internal diameter of the pipe in feet times the density in slugs per cu ft. divided by the absolute viscosity in lb sec. per sq ft.

This is equivalent to R = VD/v (VD divided by the kinematic viscosity). Reynolds Number is of great significance because it determines the type of flow, either laminar or turbulent, which will occur in any pipeline, the only exception being a critical zone roughly between an R of 2,000 to 3,500. Within this zone it is recommended that problems be solved by assuming that turbulent flow is likely to occur. Computation using this assumption gives the greatest value of friction loss and hence the result is on the safe side.

For those who prefer the greater precision of an algebraic equation, Reynolds Number for a pipeline may also be computed from the following formula:

R = Q/29.4dv, where Q is in GPM, d is inside diameter of pipe in inches, and V is kinematic viscosity in ft^2/sec.

POISE = C.G.S. UNIT OF ABSOLUTE VISCOSITY
STOKE = C.G.S UNIT OF KINEMATIC VISCOSITY
CENTIPOISE = 0.01 POISE
CENTISTOKE = 0.01 STOKE
CENTIPOSES = CENTISTOKES X DENSITY (AT TEMPERATURE UNDER CONSIDERATION REYN (1LB SEC/SQ IN.) = 69 x 105 CENTIPOISES

PUMPING VISCOUS LIQUIDS WITH CENTRIFUGAL PUMPS

Centrifugal pumps are generally not suitable for pumping viscous liquids; however, liquids with viscosities up to 2,000 SSU can be handled with Centrifugal Pumps. The volume and pressure of the pump will be reduced according to the following table.

Percent reduction in flow and head and percentage increase in power when pumping viscous liquid instead of water are shown in the table below.

VISCOSITY SSU	30	100	250	500	750	1,000	1,500	2,000
Flow Reduction GPM %	-	3	8	14	19	23	30	40
Head Reduction Feet %	-	2	5	11	14	18	23	30
Horsepower Increase %	-	10	20	30	50	65	85	100

CONVERSION DATA BAUME

UNITED STATES STANDARD BAUME SCALES
RELATION BETWEEN BAUME DEGREES AND SPECIFIC GRAVITY

LIQUIDS HEAVIER THAN WATER

FORMULA: $SP\ GR = \frac{145}{145 - °\ BAUME}$

BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°
0	1.00000	**20**	1.16000	**40**	1.38095	**60**	1.70588
1	1.00694	**21**	1.16935	**41**	1.39423	**61**	1.72619
2	1.01399	**22**	1.17886	**42**	1.40777	**62**	1.74699
3	1.02113	**23**	1.18852	**43**	1.42157	**63**	1.76829
4	1.02837	**24**	1.19835	**44**	1.43564	**64**	1.79012
5	1.03571	**25**	1.20833	**45**	1.34500	**65**	1.81250
6	1.04317	**26**	1.21849	**46**	1.46465	**66**	1.83544
7	1.05072	**27**	1.22881	**47**	1.47959	**67**	1.85897
8	1.05839	**28**	1.23932	**48**	1.49485	**68**	1.88312
9	1.06618	**29**	1.25000	**49**	1.51042	**69**	1.90789
10	1.07407	**30**	1.26087	**50**	1.52632	**70**	1.93333
11	1.08209	**31**	1.27193	**51**	1.54255	**71**	1.95946
12	1.09023	**32**	1.28319	**52**	1.55914	**72**	1.98630
13	1.09848	**33**	1.29464	**53**	1.57609	**73**	2.01389
14	1.10687	**34**	1.30631	**54**	1.59341	**74**	2.04225
15	1.11538	**35**	1.31818	**55**	1.61111	**75**	2.07143
16	1.12403	**36**	1.33028	**56**	1.62921	**76**	2.10145
17	1.13281	**37**	1.34259	**57**	1.64773	**77**	2.13235
18	1.14173	**38**	1.35514	**58**	1.66667	**78**	2.16418
19	1.15079	**39**	1.36792	**59**	1.68605	**79**	2.19697

LIQUIDS LIGHTER THAN WATER

FORMULA: $SP\ GR = \frac{140}{130 + °\ BAUME}$

BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°	BAUME DEGREES	SP GR 60°- 60°
10	1.00000	**30**	0.87500	**50**	0.77778	**70**	0.70000
11	0.99291	**31**	0.86957	**51**	0.77348	**71**	0.69652
12	0.98592	**32**	0.86420	**52**	0.76923	**72**	0.69307
13	0.97902	**33**	0.85890	**53**	0.76503	**73**	0.68966
14	0.97222	**34**	0.85366	**54**	0.76087	**74**	0.68627
15	0.96552	**35**	0.84848	**55**	0.75676	**75**	0.68293
16	0.95890	**36**	0.84337	**56**	0.75269	**76**	0.67961
17	0.95238	**37**	0.83832	**57**	0.74866	**77**	0.67633
18	0.94595	**38**	0.83333	**58**	0.74468	**78**	0.67308
19	0.93960	**39**	0.82840	**59**	0.74074	**79**	0.66986
20	0.93333	**40**	0.82353	**60**	0.73684	**80**	0.66667
21	0.92715	**41**	0.81871	**61**	0.73298	**81**	0.66351
22	0.92105	**42**	0.81395	**62**	0.72917	**82**	0.66038
23	0.91503	**43**	0.80925	**63**	0.72539	**83**	0.65728
24	0.90909	**44**	0.80460	**64**	0.72165	**84**	0.65421
25	0.90323	**45**	0.80000	**65**	0.71795	**85**	0.65117
26	0.89744	**46**	0.79545	**66**	0.71428	**86**	0.64815
27	0.89172	**47**	0.79096	**67**	0.71066	**87**	0.64516
28	0.88608	**48**	0.78652	**68**	0.70707	**88**	0.64220
29	0.88050	**49**	0.78212	**69**	0.70352	**89**	0.63927

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Notes

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