Engineering Guide

Index

MATERIAL DESCRIPTION

POLYVINYLS

PVC (POLYVINYL CHLORIDE) is, by far, the most common plastic material used for plastic pipe. Its basic properties are chemical inertness, corrosion and weather resistance, high strength to weight ratio, electrical and thermal insulators. The service temperature is 140°F. PVC has been used successfully for 40 years in such areas as chemical processing, industrial plating, chilled water distribution, deionized water, and chemical drainage. Care should be taken to avoid using with Ketones, Chlorinated Hydrocarbons, and Aromatic Solvents. 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 line, 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 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 have excellent chemical resistance to a wide range of common chemicals. Avoid strong oxidizing agents and solvents.

FLUOROPLASTICS

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.

HALAR® (ECTFE) ETHYLENE CHLOROTRIFLUORO ETHYLENE) 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.

PTFE (POLYTETRAFLUORETHYLENE)

There are three members of the PTFE family of resins. 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.

MATERIAL DESCRIPTION

FEP (FLUORINATED ETHYLENE PROPYLENE) 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 PTFE, 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 is the mostly transparent and is widely used for its high ultraviolet light transmitting ability.

PFA (PERFLUOROALKOXY) is similar to PTFE and FEP. It has excellent melt-processability and properties rivaling or exceeding those of PTFE. 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 offers superior stress and crack resistance with good flex-life in tubing. It is generally not as permeable as PTFE.

ETFE (TEFZEL®, ETHYLENE TETRAFLUORO-ETHYLENE) Tefzel® combines the mechanical toughness with outstanding chemical resistance that approaches PTFE. Effective from -20°F to 300°F, Tefzel is known for its processability and high energy radiation resistance.

ABS (ACRYLONITRILE-BUTADIENE-STYRENE)
Identifies a broad family of engineering thermoplastics with a range of performance characteristics. The copolymeric system can be blended to yield the optimum balance of properties suited to a selected end use. Acrylonitrile imparts chemical resistance and rigidity. Butadiene endows the product with impact strength and toughness, while Styrene contributes to ease of processing.

RYTON® (PPS) POLYPHENYLENE SULFIDE PPS exhibits outstanding high temperature stability, inherent flame resistance and good chemical resistance. Because of its high crystallinity and dimensional stability, PPS is used extensively for molded pump and valve components. Relatively few chemicals react with PPS, even at temperatures up to 200°F. PPS is compatible with such hostile environments as esters, ketones, alcohols, bases and hydrocarbons.

SULFONE POLYMERS

Polysulfone is a tough, clear thermoplastic used in corrosive environments. It has a temperature range to 300°F. Polysulfone has high resistance to acids, alkali, and salt solution but is attacked by ketones, chlorinated hydrocarbons and aromatic hydrocarbons. Polysulfone has found wide usage as flowmeters and sight gauges.

ELASTOMERIC MATERIALS

VITON® (FLUOROELASTOMER) 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. Its maximum temperature limit is 250°F.

EPDM (ETHYLENE PROPYLENE TERPOLYMER) is a terpolymer elastomer made from ethylene-propylene 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. Its maximum temperature limit is 212°F

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.

NITRILE (BUNA-N) Nitrile rubber is a copolymer of butadiene and acrylonitrile. In addition to its excellent elastomeric properties, it is resistant to aliphatic hydrocarbons and aromatic solvents. Its maximum temperature is 212°F.

HYPALON® This is the DuPont name for its elastomer of chlorosulfonated polyethylene used for valve seats and seals. Its maximum temperature limit is 212°F.

NEOPRENE A chlorinated synthetic rubber used primarily as a seating and sealing material in valves, its maximum temperature limit is 212°F.

NATURAL RUBBER This is a high molecular weight polymer isoprene derived from the Hevea tree. It is used as diaphragm and sealing material because of its elastomeric properties and resistance to abrasion. Its maximum temperature limit is 212°F.

THERMOSETS

FRP (FIBERGLASS REINFORCED PLASTICS) OR RTRP (REINFORCED THERMOSETTING RESIN PIPE)
FRP piping is a highly valuable engineering material for process piping and vessels. It has been accepted by many industries because it offers the following significant advantages, (1) moderate initial cost and low maintenance (2) broad range of chemical resistance (3) high strength-to-weight ratio (4) ease of fabrication and flexibility of design and (5) good electrical insulation properties.

MATERIAL DESCRIPTION

Epoxy glass fiber pipe exhibits all the above mentioned characteristics as well as performance temperatures to 300°F. Epoxy piping is commonly used in the oil, mining and chemical industries. New application in the geothermal and steam condensate systems have also proven successful.

Vinylester resins are epoxy-based thermosetting resins that are cured by free radical polymerization similar to the curing mechanism of conventional polyester resins. Physical properties are tensile strength, elongation and fatigue resistance very close to those of the premiums aromatic amine cured epoxies. Chemical resistance represents the best of two worlds; the excellent alkali resistance of the epoxy and the acid and oxidation chemical resistance of the polyester.

INDUSTRY STANDARDS

Because plastic piping and plastic lined metallic piping are used for so many applications and because the requirements for each application are somewhat different, numerous standards and a variety of joining systems have been developed. Additional standards are being prepared and will be added to this list in future revisions as they become available.

The standards referenced herein, like all other standards, are of necessity minimum requirements. It should be recognized that two different plastic resin materials even though 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 for the aforementioned tests from the resin supplier to assure optimum pipe from a particular material. In case of a material not covered by industry specifications, this suggestion assumes paramount importance.

ANSI

American National Standards Institute, Inc.
655 15th St. N.W.
300 Metropolitan Square
Washington, DC 20005
Phone (202) 639-4090

ANSI PRESSURE CLASSES

ANSI Class 125 means 175 PSIG at 100°F
ANSI Class 150 means 285 PSIG at 100°F
ANSI Class 300 means 740 PSIG at 100°F
ANSI A119.2 - 1963
ANSI B72.2 - 1967
ANSI B31.8 - 1968
ANSI Z21.30 - 1969

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

Table 1

ANSI Designation	ASTM Designation	ANSI Designation	ASTM Designation
B72.1	D 2239	B 72.11	D 2412
B72.2	D 2241	B 72.12	D 2446
B72.3	D 2282	B 72.13	D 2447
B72.4	D 1503	B 72.16	D 2564
B72.5	D 1527	B 72.17	D 2657
B72.6	D 1598	B 72.18	D 2661
B72.7	D 1785	B 72.19	D 2662
B72.8	D 2104	B 72.20	D 2672
B72.9	D 2152	B 72.22	D 2740
B72.10	D 2153	B 72.23	D 2235

ASTM

American Society of Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

Plastic Pipe Specifications:

D	1785	Polyvinyl chloride (PVC) plastic pipe, schedules 40, 80, and 120
F	441	Chlorinated poly (vinyl chloride) (CPVC) plastic pipe, schedules 40 and 80
D	2241	Polyvinyl chloride (PVC) plastic pipe (SD - PR)
D	2513	Thermoplastic gas pressure pipe, tubing and fittings
D	2665	PVC plastic drain, waste, and vent pipe and fittings
D	2672	Bell-ended PVC pipe
D	2729	PVC sewer pipe and fittings
D	2846	Chlorinated (CPVC) plastic hot water distribution system
D	2949	3" thin wall PVC plastic drain, waste, and vent pipe and fittings
D	3034	Type PSM PVC sewer pipe and fittings

Plastic Pipe Fittings Specifications:

D	2464	Threaded PVC plastic pipe fittings, Schedule 80
F	437	Threaded chlorinated polyvinyl chloride (CPVC) plastic pipe fittings, Schedule 80
D	2466	Socket-type PVC plastic type fittings, Schedule 40
D	2467	Socket-type PVC plastic type fittings, Schedule 80
F	439	Socket-type chlorinated polyvinyl chloride (CPVC) plastic pipe fittings Schedule 80
D	3036	PVC plastic pipe lined couplings, socket type

Plastic Pipe Solvent Cement/Primer Specifications

D	2564	Solvent cements for PVC plastic pipe and fittings
F	493	CPVC solvent cement
F	656	Primers for PVC/CPVC pipe and fitting joints

Plastic Lined Steel Piping Specifications:

ASTM A-587	Standard specification for electric-welded low carbon steel pipe for the chemical industry
ASTM A-53	Standard specification for pipe, steel, black and hot-dipped, zinc-coated, welded and seamless
ASTM A-105	Standard specification for forgings, carbon steel, for piping components
ASTM A-125	Standard specification for steel springs, helical, heat-treated
ASTM A-126	Standard specifications for gray iron castings for valves, flanges, and pipe fittings

INDUSTRY STANDARDS

ASTM A-395	Standard specification for ferritic ductile iron pressure retaining castings for use at elevated temperatures
ASTM A-216	Standard specification for carbon steel castings suitable for fusion welding for high temperature service
ASTM A-234	Standard specification for piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures
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 Class 150 and 300
ANSI B-16.5	Steel pipe flanges and flanged fittings Class 150, 300, 400, 600, 900, 1500 and 2500
A-587	Standard specification for electric-welded low carbon steel pipe for the chemical industry
A-53	Standard specification for pipe, steel black and hot-dipped, zinc-coated, welded and seamless
A-105	Standard specification for forgings, carbon steel, for piping components
A-125	Standard specification for steel springs, helical, heat-treated
A-126-73	Standard specification for gray iron castings for valves, flanges, and pipe fittings
A-395-77	Standard specification for ferritic ductile iron pressure retaining castings for use at elevated temperatures
A-216-77	Standard specification for carbon steel castings suitable for fusion welding for high temperature service

Methods of Test Specifications:

D	256	Test for impact resistance of plastics and electrical insulating materials
D	543	Test for resistance of plastics to chemical reagents
D	570	Test for water absorption of plastics
D	618	Conditioning plastics and electrical insulating materials for testing
D	621	Tests for deformation of plastics under load
D	635	Test for flammability of self-supporting plastics
D	638	Test for tensile properties of plastics
D	648	Test for deflection temperature of plastics under load
D	671	Tests for repeated flexural stress of plastics
D	757	Test for flammability of plastics, self-extinguishing type
D	790	Test for flexural properties of plastics
D	883	Nomenclature relating to plastics
D	1180	Test for bursting strength of round, rigid plastic tubing
D	1598	Test for time to failure of plastic pipe under long-term hydrostatic pressure
D	1599	Test for short-time rupture strength of plastic pipe, tubing and fittings
D	2122	Determining dimensions of thermoplastic pipe and fittings
D	2152	Test for quality of extruded PVC pipe by acetone immersion
D	2412	Test for external loading properties of plastic pipe by parallel-plate loading
D	2444	Test for impact resistance of thermoplastic pipe and fittings by means of a tup (falling weight)
D	2837	Obtaining hydrostatic design basis thermoplastic pipe materials
D	2924	Test for external pressure resistance of plastic pipe

RECOMMENDED PRACTICES

D	2153	Calculating stress in plastic pipe under internal pressure
D	2321	Underground installation of flexible thermoplastic sewer pipe
D	2657	Heat joining of thermoplastic pipe and fittings
D	2749	Standard definitions of terms relating to plastic pipe fittings
D	2774	Underground installation of thermoplastic pressure pipe
D	2855	Making solvent cemented joints with PVC pipe and fittings

ASTM STANDARDS FOR PLASTIC MATERIALS REFERENCED IN PLASTIC PIPE, FITTINGS, AND CEMENT STANDARDS

D	1784	PVC compounds and CPVC compounds

INDUSTRY STANDARDS

BOCA

Building Officials Conference of America
1313 East 60th Street
Chicago, Illinois 60637

BOCA Basic Plumbing Code

Table 2

Group	Commercial Standard or Product Standard	ASTM Standard or Tentative Specification
A	PS10	D2104
B	PS11	D2238
C	PS12	D2447
D	PS18	D1527
E	PS19	D2282
F	PS21	D1785
G	PS22	D2241
H	CS228	D2852
I	CS270	D2661
J	CS272	D2665

COMMERCIAL AND PRODUCT STANDARDS

Supt. of Documents
U.S. Government Printing Office
Washington, DC 20402

CS 272 — PVC-DWV pipe and fittings

PS 21 — PVC plastic pipe (Schedules 40, 80, 120) supersedes CS 207-60

PS 22 — PVC plastic pipe (SDR) supersedes CS 256

CSA

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario, Canada

B 137.0 — Defines general requirements and methods of testing for thermoplastic pressure pipe

B 137.3 — Rigid polyvinyl chloride (PVC) pipe for pressure applications

B 137.4 — Thermoplastic piping systems for gas service

B 137.14 — Recommended practice for the installation of thermoplastic piping for gas service

B 181.2 — Polyvinyl chloride drain, waste, and vent pipe and pipe fittings

B 181.12 — Recommended practice for the installation of PVC drain, waste, and vent pipe fittings

B 182.1 — Plastic drain and sewer pipe and pipe fittings for use underground

B 182.11 — Recommended practice for the installation of plastic drain and sewer pipe and pipe fittings

DEPARTMENT OF AGRICULTURE

U.S. Department of Agriculture
Soil Conservation Service
Washington, DC 20250

SCS National Engineering Handbook, Section 2, Part 1, Engineering Practice Standards

SCS432-D — High pressure underground plastic irrigation pipelines

SCS432-E — Low head underground plastic irrigation pipelines

DEPARTMENT OF DEFENSE MILITARY STANDARDS

Commanding Officer
Naval Publications and Forms Center
5108 Tabor Avenue
Philadelphia, Pennsylvania 19120

MIL-A-22010A(1) — Adhesive solvent-type, polyvinyl chloride amendment

MIL-C-23571A(YD) — Conduit and conduit fittings, plastic, rigid

MIL-P-14529B — Pipe, extruded, thermoplastic

MIL-P-19119B(1) — Pipe, plastic, rigid, unplasticized, high impact, polyvinyl chloride

MIL-P-22011A — Pipe fittings, plastic, rigid, high impact, polyvinyl chloride, (PVC) and poly 1, 2 dichlorethylene

MIL-P-28584A — Pipe and pipe fittings, glass fiber reinforced plastic for condensate return lines

MIL-P-29206 — Pipe and pipe fittings glass fiber reinforced plastic for liquid petroleum lines

DOT - OTS

Department of Transportation, Hazardous Materials Regulation Board, Office of Pipeline Safety, Title 49, Docket OPS-3 and amendments, Part 192. Transportation of Natural Gas and Other Gas by Pipeline: Minimum Federal Safety Standards, Federal Register, Vol, 35, No. 161, Wednesday, August 19, 1980. Amendments to date are 192-1, Vol. 35, No. 205, Wednesday, October 21, 1970; 19-2, Vol.35, No. 220, Wednesday, November 11, 1970; and 192-3, Vol. 35, No. 223, Tuesday, November 17, 1970.

FEDERAL SPECIFICATIONS

Specifications Activity
Printed Materials Supply Division
Building 197, Naval Weapons Plant
Washington, DC 20407

L-P-320a — Pipe and fittings, plastic (PVC, drain, waste, and vent)

L-P-1036(1) — Plastic rod, solid, plastic tubes and tubing, heavy walled; polyvinyl chloride

INDUSTRY STANDARDS

FHA
Architectural Standards Division
Federal Housing Administration
Washington, DC 20412

FHA UM-41	PVC plastic pipe and fittings for domestic water service
FHA UM-49	ABS and PVC plastic drainage and vent pipe and fittings, FHA 4550.49
FHA UM-53a	Polyvinyl chloride plastic drainage, waste and vent pipe and fittings
FHA MR-562	Rigid chlorinated polyvinyl chloride (CPVC) hi/temp water pipe and fittings
FHA MR-563	PVC plastic drainage and vent pipe and fittings
FHA Minimum	Property standards interim revision No. 31

IAPMO
International Association of Plumbing and Mechanical Officials
5032 Alhambra Avenue
Los Angeles, California 90032

Uniform Plumbing Code

IAPMO IS8	Solvent cemented PVC pipe for water service and yard piping
IAPMO IS9	PVC drain, waste, and vent pipe and fittings
IAPMO IS10	Polyvinyl chloride (PVC) natural gas yard piping
IAPMO PS27	Supplemental standard to ASTM D2665; polyvinyl chloride (PVC) plastic drain, waste, and vent pipe and fittings

(NOTE: IS = installation standard; PS = property standard)

NSF
National Sanitation Foundation
School of Public Health
University of Michigan
Ann Arbor, Michigan 48106

NSF
Standard No. 14: Thermoplastic Materials, Pipe, Fittings, Valves, Traps, and Joining Materials

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

NSPI
National Swimming Pool Institute
2000 K Street, N.W.
Washington, DC 20006

T.R.-19 The Role of Corrosion-Resistant Materials in Swimming Pools, Part D, The Role of Plastics in Swimming Pools.

PHCC
National Association of Plumbing-Heating-Cooling Contractors
1016 20th Street, N.W.
Washington, DC 20036
National Standard Plumbing Code

SBCC
Southern Building Code Congress
1166 Brown-Marx Building
Birmingham, Alabama 35203
SBCC Southern Standard Plumbing Code

SIA
Sprinkler Irrigation Association
1028 Connecticut Avenue, N.W.
Washington, DC 20036
Minimum Standards for Irrigation Equipment

WUC
Western Underground Committee, W.H. Foote
Los Angeles Department of Water and Power
P.O. Box 111
Los Angeles, California 90054
Interim Specification 3.1: Plastic Conduit and Fittings

UL
Underwriters Laboratories, Inc.
207 East Ohio Street
Chicago, Illinois 60611
UL 651 Rigid Nonmetallic Conduit (September 1968)
UL 514 Outlet Boxes and Fittings (March 1951 with Amendments of 22-228-67)

Table 3 - PIPE O.D.s

U.S. (ANSI)		EUROPE (ISO)			
NOMINAL BORE INCHES	ACTUAL OD INCHES	DN (NOMINAL BORE) MM	DN (NOMINAL BORE) IN.	d (ACTUAL OD) MM	d (ACTUAL OD) IN.
1/8	.405	6	(.236)	10	(.394)
1/4	.540	8	(.315)	12	(.472)
3/8	.675	10	(.394)	15	(.630)
1/2	.840	15	(.591)	20	(.787)
3/4	1.050	20	(.787)	25	(.984)
1	1.315	25	(.984)	32	(1.260)
1 1/4	1.660	32	(1.260)	40	(1.575)
1 1/2	1.900	40	(1.575)	50	(1.969)
2	2.375	50	(1.969)	63	(2.480)
2 1/2	2.875	65	(2.559)	75	(2.953)
3	3.500	80	(3.150)	90	(3.543)
4	4.500	100	(3.937)	110	(4.331)
5	5.563	125	(4.921)	140	(5.512)
6	6.625	150	(5.906)	160	(6.299)
8	8.625	200	(7.874)	225	(8.858)
10	10.750	250	(9.843)	280	(11.024)
12	12.750	300	(11.811)	315	(12.402)

INDUSTRY STANDARDS

NEMA
National Electrical Manufacturers' Association
2101 "L" St. N.W.
Washington, DC 20037

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 — Dripproof - Indoor: Type 2 dripproof 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 — Dusttight, Raintight, 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 — Dusttight, Raintight, 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 Dusttight - 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, Dusttight 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.

Type 6 — Submersible, Watertight, Dusttight, 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.

INDUSTRY STANDARDS

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.

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, nondeteriorating, verminproof 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 Dripproof-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 - Dusttight and Driptight - 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 — Oiltight and Dusttight - Indoor: Type 13 enclosures are intended for use indoors primarily to house pilot devices such as limit switches, foot switches, pushbuttons, 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.

HAZARDOUS (CLASSIFIED) LOCATIONS IN ACCORDANCE WITH FACTORY MUTUAL ENGINEERING CORP.

The National Electrical Code and the Canadian Electrical Code divide hazardous locations into three "classes" according to the nature of the hazard: Class I, Class II, and Class III. The locations in each of these classes are further divided by "divisions" according to the degree of the hazard.

Class I, Division 1 locations are those in which flammable gases or vapors are or may be present in sufficient quantities to produce an ignitable mixture (continuously, intermittently, or periodically).

Class I, Division 2 locations are those in which hazardous mixtures may frequently exist due to leakage or maintenance repair.

Class I, Division 3 are those in which the breakdown of equipment may release concentration of flammable gases or vapors which could cause simultaneous failure of electrical equipment.

For purposes of testing, classification and approval of electrical equipment atmospheric mixtures are classified in seven groups (A through G) depending on the kind of material involved.

Class II locations are classified as hazardous because of the presence of combustible dusts.

Class III locations are hazardous because of the presence of combustible fibers or flyings in textile processes.

There are similar divisions and groups for Class II and Class III as those described for Class I. For specifics or further details contact your Corr Tech representative.

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.

Table 4 - ARRANGEMENT AND ORDER OF SIGNALS - OPTIONAL FORM OF APPLICATION

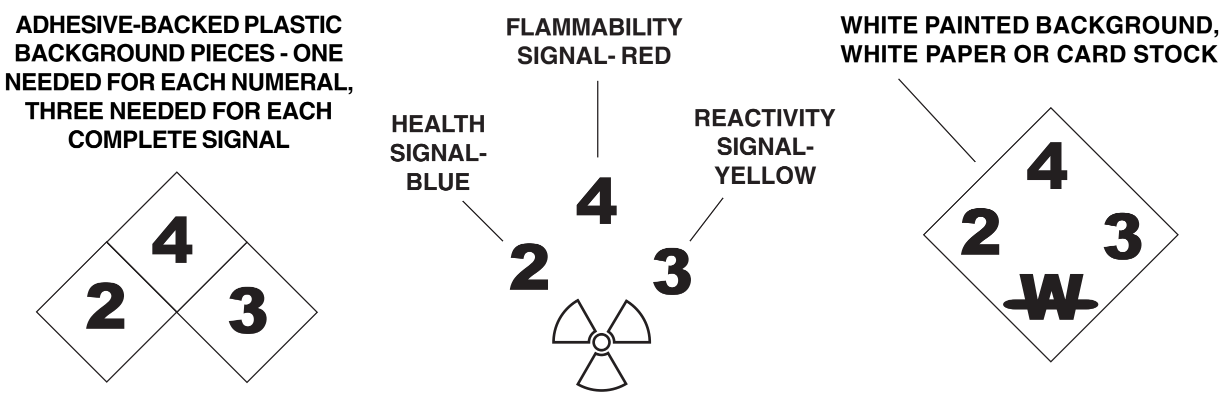


Figure 1. For use where specified color background is used with numerals of contrasting colors.

Figure 2. For use where a white background is necessary.

Figure 3. For use where a white background is used with painted numerals, or for use when the signal is in the form of sign or placard.

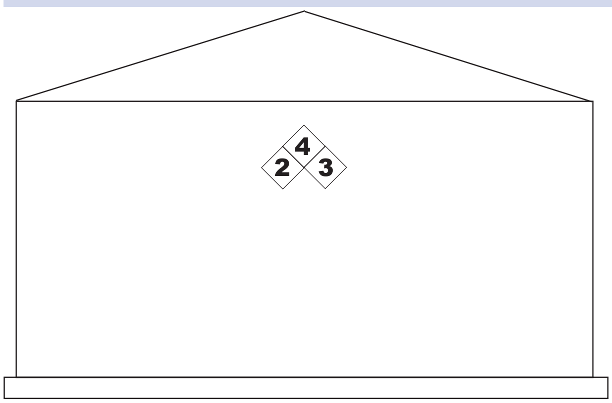


Figure 4. Storage Tank

Table 4 - Arrangement and Order of Signals - Optional Form of Application

DISTANCE AT WHICH SIGNALS MUST BE LEGIBLE	MINIMUM SIZE OF SIGNALS REQUIRED
50 FEET	1"
75 FEET	2"
100 FEET	3"
200 FEET	4"
300 FEET	6"

IDENTIFICATION OF MATERIALS BY HAZARD SIGNAL ARRANGEMENT

This is a system for the identification of hazards to life and health of people in the prevention and control of fires and explosions in the manufacture and storage of materials.

The basis for identification are the physical properties and characteristics of materials that are known or can be determined by standard methods. Technical terms, expressions, trade names, etc., are purposely avoided as this system is concerned only with the identification of the involved hazard from the standpoint of safety.

The explanatory material on this page is to assist users of these standards, particularly the person who assigns the degree of hazard in each category.

NOTE:
This shows the correct spatial arrangement and order of signals used for identification of materials by hazard.

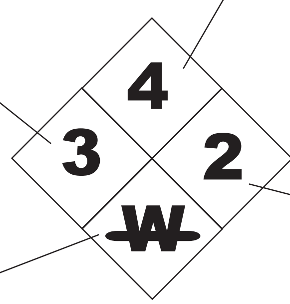
INDUSTRY STANDARDS

Table 5 **IDENTIFICATION OF THE FIRE AND HEALTH HAZARDS OF MATERIALS**

IDENTIFICATION OF HEALTH HAZARDS COLOR CODE: BLUE		IDENTIFICATION OF FLAMMABILITY COLOR CODE: RED		IDENTIFICATION OF REACTIVITY COLOR CODE: YELLOW	
SIGNAL	**TYPE OF POSSIBLE INJURY**	**SIGNAL**	**SUSCEPTIBILITY OF MATERIALS TO BURNING**	**SIGNAL**	**SUSCEPTIBILITY TO 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 before 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.

HEALTH HAZARD
4 - DEADLY
3 - EXTREME DANGER
2 - HAZARDOUS
1 - SLIGHTLY HAZARDOUS
0 - NORMAL MATERIAL

FIRE HAZARD
FLASH POINTS
4 - BELOW 73°F
3 - BELOW 100°F
2 - BELOW 200°F
1 - ABOVE 200°F
0 - WILL NOT BURN



SPECIFIC HAZARD

Oxidizer	OXY
Acid	ACID
Alkali	ALK
Corrosive	COR
Use NO WATER	~~W~~
Radiation Hazard	

REACTIVITY
4 - MAY DETONATE
3 - SHOCK AND HEAT MAY DETONATE
2 - VIOLENT CHEMICAL CHANGE
1 - UNSTABLE IF HEATED
0 - STABLE

RELATIVE PROPERTIES

TABLE 1

Table 1

MATERIAL	SPECIFIC GRAVITY ASTM-D792	WATER ABSORPTION %/24 hrs at 73°F ASTM - D570	TENSILE STRENGTH psi at 73°F ASTM - D638	MODULUS OF ELASTICITY IN TENSION psi @ 73°F x 10 ASTM - D638 "E"	FLEXURAL STRENGTH psi ASTM - D790	IZOD IMPACT 73° ft. lbs/in. notched ASTM - D256	COMPRESSIVE STRENGTH psi ASTM - D695 "σ"	POISSON'S RATIO "V"
STEEL Gr. B	7.86	—	60,000	290	—	32	—	.33
ALUMINUM 3003	2.73	—	16,000	100	—	20	—	.33
COPPER	8.94	—	30,000	170	—	43	—	—
(PVC) POLYVINYL CHLORIDE TYPE 1	1.38	.05	7,940	4.2	14,500	.65	9,600	.35-.38
(CPVC) CHLORINATED POLYVINYL CHLORIDE	1.55	.05	8,400	4.2	15,600	3.0	9,000-22,000	.35-.38
(PP) POLYPROPYLENE NON PPFR (PPFR) POLYPROPYLENE FLAME RETARDANT	.905	.02	5,000	1.7-2.5	7,000	1.3	5,500-8,000	.38-.40
(PROLINE) POLYPROPYLENE/ POLYBUTYLENE COPOLYMER	.905	.02	5,800	1.1	2,900	4.7	7,000	.34-4.0
(RYTON) POLYPHYLENE SULFIDE 40% GLASS FIBER REINFORCED	1.6	.05	19,500	1.6	29,000	1.4	21,000	—
(PVDF) POLYVINYLIDENE FLUORIDE	1.75-1.78	.04	5,000 - 7,000	2.13	12,180	2.8	10,500	.38
POLYETHYLENE LD PE - LOW DENSITY	.925	.01	2,300	.14-.38	—	9.0	—	—
HALAR	1.69	.04	4,500	2.40	---	No Break	---	0.3-0.4
DURAPLUS (ABS)	1.06	---	5,500	2.40	---	8.5	6,150	---
HD PE - HIGH DENSITY	.965	.01	4,500	.6-1.8	7,000	4.0	3,600	—
XL PE - CROSS LINK PE	1.28	.02	3,000	—	5,000	2.0	4,000	—
(PTFE) POLYTETRAFLUORETHYLENE	2.14	.02	2,600	1.0	81,000	No Break	3,500	—
(PFA) POLYFLUOROALKOXY	2.2	0.0	2,000-5,000	.58	—	3.0	1,700	—
(FEP) FLUORINATED ETHYLENE PROPYLENE	2.1	0.0	2,700-3,100	.50	—	No Break	2,200	—
EPOXY FIBERGLASS	1.6	.05-.20	10,000	1.35	10,000	1.0	25,000	—
VINYLESTER FIBERGLASS	1.6	.02	10,500	1.4	15,600	2.5	18,000	—
POLYSULFONE	1.24	0.3	10,200	3.6	15,400	1.3	—	—

RELATIVE PROPERTIES

TABLE 2

Table 2

MATERIAL	WORKING STRESS @ 73° FM, psi "S"	COEFFICIENT OF LINEAR EXPANSION in/(in °F) x 10^5 ASTM - D696 "e"	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 at 264 psi ASTM - D648	THERMAL CONDUCTIVITY BTU/hr/sq. ft/°F/in. ASTM - C177 "K"	BURNING RATE ASTM - D635	LIMITED OXYGEN index (%) ASTM - D2863-70	BURNING CLASS UL 94	SURFACE BURNING OF BLDG. MATERIALS E-84	
STEEL Gr. B	20,000	.06	1/16"	750°	—	—	290	—	—	—	FLAME	SMOKE
ALUMINUM 3003	—	—	5/32"	400°	—	—	1450	—	—	—		
COPPER	—	—	1/8"	400°	—	—	2610	—	—	—		
(PVC) POLYVINYL CHLORIDE TYPE 1	2,000	3.0	1/3"	140°	173	160	1.2	*	43	V-0	15	850
(CPVC) CHLORINATED POLYVINYL CHLORIDE	2,000	3.8	1/2"	210°	238	221	.95	*	60	V-0	10	286
(PP) POLYPROPYLENE NON PPFR	725-800	5.0	5/8"	180°	220	125-140	1.2	Slow	17	V-2	119	791
(PPFR) POLYPROPYLENE FLAME RETARDANT											115	412
(PROLINE) POLYPROPYLENE/ POLYBUTYLENE COPOLYMER	800	8.33	1"	200°	—	—	1.2	Slow	—	V-2	110	515
(RYTON) POLYPHYLENE SULFIDE 40% GLASS FIBER REINFORCED	—	—	1/2"	200°	—	485	1.5 -0.91	*	—	V-0	—	—
(PVDF) POLYVINYLIDENE FLU-ORIDE	2,300	6.6-8.7	1"	280°	284	195	1.32	*	44	V-0	—	—
POLYETHYLENE LD PE - LOW DENSITY	—	10.0-22.0	1-1/4"	140°	100-121	90-105	2.3	Very Slow	—	V-1	—	—
HD PE - HIGH DENSITY	—	7.2	7/8"	160°	175-196	110-130	3.5	VerySlow	226	V-1	—	—
XL PE - CROSS LINK PE	—	—	—	180°	180	120	—	Slow	—	V-1	—	—
(PTFE) POLYTETRAFLUORETHYLENE	—	10.0	2/3"	500°	250	—	6.0	*	95	V-0	—	—
(PFA) PERFLUOROALKOXY	—	7.6	0.9"	500°	—	—	1.3	*	95	V-0	—	—
(FEP) FLUORINATED ETHYLENE PROPYLENE	—	8.3-10.5	1/3"	300°	158	—	6.0	*	95	V-0	—	—
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	—	—
HALAR	—	4.4-9.2	1"	300°	195	151	1.07	*	60	V-O	—	—
DURAPLUS (ABS)	—	5.6	5/8"	176°	194	223	1.7	*	—			

* Self-Extinguishing

SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

INTRODUCTION

In the engineering of thermoplastic piping systems, it is necessary to have not only a working knowledge of piping design but also an awareness of a number of the unique properties of thermoplastics.

In addition to chemical resistance, important factors to be considered in designing piping systems employing thermoplastics are:

1. Pressure ratings.
2. Water hammer.
3. Temperature-Pressure relationships.
4. Friction-loss characteristics.
5. Dimensional and Weight data.

These factors are considered in detail in this section.

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 relation-ship of stress, pressure and pipe dimensions is described by the ISO (for International Standardization Organization) Equation. In various forms this equation is:

$$P = \frac{2S}{R-1} = \frac{2St}{D_0 - t} \qquad \frac{2S}{P} = \left(\frac{D_0}{t}\right) - 1$$

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

Where:

- P = Internal Pressure, psi
- S = Circumferential Stress, psi
- t = Wall thickness, in.
- D_0 = Outside Pipe diameter, in.
- R = D_0/t

LONG-TERM STRENGTH

To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends (see Figure 1) and subjected to various internal pressures, to produce circumferential stresses that will produce failure in from 10 to 10,000 hours. The test is run according to ASTMD 1598 — Standard Test for Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure.

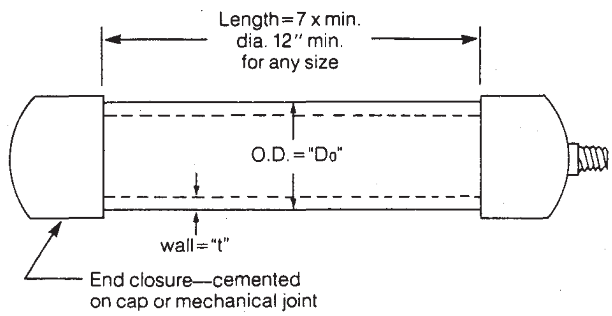
The resulting failure points are used in a statistical analysis (outlined in ASTM D-2837; see page 6 to determine the characteristic regression curve that represents the stress/ time-to-failure relationship for the particular thermoplastic pipe compound under test. This curve is represented by the equation: 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.

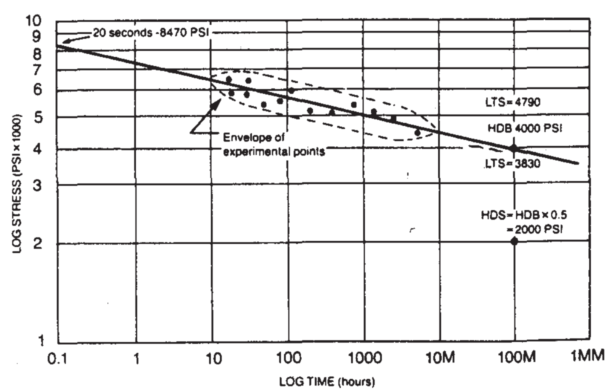
The regression curve may be plotted on a log-log paper, as shown in Figure 2, and extrapolated from 10,000 to 100,000 hours (11.4 years). The stress at 100,000 hours is known as the Long Term Hydrostatic Strength (LTHS) for that particular thermoplastic compound. From this (LTHS) the Hydrostatic Design Stress (HDS) is determined by applying the service factor multiplier, as described below.

FIGURE 1
LONG-TERM STRENGTH TEST PER ASTM D1 598



Pipe test specimen per ASTM D 1598 for "Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure"

FIGURE 2
REGRESSION CURVE—STRESS/TIME-TO-FAILURE FOR PVC TYPE I



SERVICE FACTOR

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 minimum of 50 years.

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Accordingly, the standards for plastic pipe, using the 0.5 service factor, required 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 in Table I-A below.

SERVICE FACTORS AND HYDROSTATIC DESIGN STRESS (HDS)*

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

*Material: PVC Type 1 & CPVC

TEMPERATURE-PRESSURE AND MODULUS RELATIONSHIPS

Temperature Derating.

Pressure ratings for thermoplastic pipe are generally deter-mined 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 in Table 1by the temperature correction factor for that material shown in Table 2. Attention must also be given to the pressure rating of the joining technique i.e. Threaded system normally reduces pressure capabilities, substantially.

TABLE 1

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

NOMINAL SIZE	PVC & CPVC SCHEDULE 40 SOLVENT WELD	PVC & CPVC SCHEDULE 80		POLYPROPYLENE*(PP)			POLYVINYLIDENE FLUORIDE (PVDF)			
		SOLVENT WELD	THREADED	PPRO-SEAL	PROLINE SDR 11	PROLINE SDR 32	SUPER PROLINE SDR 11	SUPER PROLINE SDR 32	SCHEDULE 80 SOCKET FUSION	SCHEDULE 80 THREADED
1/4	780	1130	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3/8	620	920	—	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1/2	600	850	420	150	160	45	230	N/A	975	290
3/4	480	690	340	150	160	45	230	N/A	790	235
1	450	630	320	150	160	45	230	N/A	725	215
1-1/4	370	520	260	N/A	160	45	230	N/A	600	180
1-1/2	330	471	240	150	160	45	230	N/A	540	160
2	280	400	200	150	160	45	230	N/A	465	135
2-1/2	300	425	210**	N/A	160	45	N/A	160	N/A	N/R
3	260	375	190**	N/A	160	45	N/A	160	430	N/R
4	220	324	160**	N/A	160	45	N/A	160	370	N/R
6	180	280	N/R	N/A	160	45	N/A	160	N/A	N/R
8	160	250	N/R	N/A	160	45	N/A	160	N/A	N/A
10	140	230	N/R	N/A	160	45	N/A	160	N/A	N/A
12	130	230	N/R	N/A	160	45	N/A	160	N/A	N/A

— = Data not available at printing; N/R = Not Recommended; N/A = Not Available (not manufactured)
* Threaded Polypropylene is not recommended for pressure applications and Fuseal drainage systems are not pressure rated.
**For threaded joints properly backwelded.
NOTE: The pressure ratings in this chart are based on water and are for pipe and fittings only. Systems that include valves, flanges, or other weaker items will require derating the entire system.

SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

Table 2

TEMPERATURE CORRECTION FACTORS

OPERATING TEMPERATURES °F	FACTORS					
			POLYPROPYLENE		POLYVINYLIDENE FLUORIDE	
	PVC	CPVC	PPRO-SEAL NATURAL	PROLINE	SUPER PROLINE	SCHEDULE 80
73	1.00	1.00	1.00	1.00	1.00	1.00
80	.88	.94	.93		.95	.93
90	.75	.86	.83		.87	.87
100	.62	.78	.74	.64	.80	.82
110	.50	.71	.66			.76
120	.40	.64	.58		.68	.71
130	.30	.57	.51			.65
140	.22	.50	.40	.40	.58	.61
150	N/R	.43	.38			.57
160	N/R	.37	.35		.49	.54
180	N/R	.25	.23	.28	.42	.47
200	N/R	.18	.14	.10	.36	.41
210	N/R	.16	.10	N/R		.38
220	N/R	N/R	N/R	N/R		.35
240	N/R	N/R	N/R	N/R	.25	
250	N/R	N/R	N/R	N/R		.28
280	N/R	N/R	N/R	N/R	.18	.22

FLANGED SYSTEMS

FLANGED SYSTEMS
Maximum pressure for any flanged system is 150 psi. At elevated temperatures the pressure capability of a flanged system must be derated as shown in Table 12.

Design Pressure - Pressure rating at 73°F x temperature correction factor.

Table 3 - MAXIMUM OPERATING PRESSURE (PSI) FOR FLANGED SYSTEMS

OPERATING TEMPERATURE °F	PVC*	CPVC*	PP**	PVDF
100	150	150	150	150
110	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 2-1/2 through 3-/and 4-inch threaded must be backwelded for the above pressure capability to be applicable.

** Threaded PP flanges size 1/2 through 4 inch as well as the 6" back welded socket flange are not recommended for pressure applications (drainage only).

CORR TECH INCORPORATED

PRESSURE RATINGS

PVC LARGE DIAMETER FABRICATED FITTINGS AT 73°F 10" THROUGH 24"

The following tables indicate the working pressure recommended by the manufacturer for large diameter PVC fabricated fittings. These fittings are not generally recommended for high pressure applications. Pressure capabilities are not necessarily the same as the rating of the pipe from which they are fabricated. Be sure pressure to temperature correction factors are considered when system design calls for temperatures above 73°F.

Water hammer and surge pressure are the two most critical elements in large-diameter design. Keeping velocities below 5 feet per second and working pressures to these guidelines will give years of trouble-free service.

Table 4

90° ELBOW

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	22	140	34	230
12	30	130	50	230
14	40	130	70	220
16	56	130	100	220
18	90	100	93	125
20	121	50	125	75
24	202	50	208	75

Table 5

COUPLING

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	9	140	15	230
12	15	130	23	230
14	19	130	33	220
16	29	130	54	220
18	33	100	53	160
20	45	50	74	75
24	77	50	110	75

Table 6

TEE

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	28	140	44	230
12	41	130	69	230
14	54	130	95	220
16	78	130	139	220
18	115	100	156	160
20	153	50	204	75
24	231	50	338	75

Table 7

45° ELBOW

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	15	140	24	230
12	21	130	36	230
14	30	130	52	220
16	42	130	75	220
18	47	100	71	160
20	62	50	95	75
24	103	50	159	75

Table 8

REDUCING TEE

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10 x 8	23	140	32	230
10 x 6	21	140	30	230
10 x 4	18	140	28	230
12 x 10	32	130	55	220
12 x 8	30	130	49	220
12 x 6	26	130	47	220
12 x 4	24	130	45	220
14 x 12	46	100	70	160
14 x 10	39	100	66	160
14 x 8	36	100	59	160
16 x 14	68	100	118	160
16 x 12	61	100	105	160
16 x 10	54	100	90	160
16 x 8	49	100	82	160
18 x 16	82	100	132	160
18 x 14	73	100	116	160
20 x 18	104	75	160	100
20 x 16	98	75	156	100
24 x 20	162	50	251	75

PRESSURE RATINGS

PVC LARGE DIAMETER FABRICATED FITTINGS AT 73°F 10" THROUGH 24"

Table 9

CONCENTRIC REDUCER

NOMINAL SIZE (IN.)	SCHEDULE 40	
	WT. (LBS.)	PSI RTG
10 x 8	9	140
10 x 6	22	140
10 x 4	23	140
12 x 10	15	130
12 x 8	31	130
12 x 6	34	130
14 x1 2	23	130
14 x 10	36	130
16 x 14	32	130
16 x 12	54	130
18 x 16	46	100
20 x 18	45	100
24 x 20	87	100

Table 10

BUSHING (SPIG x SOC)

NOMINAL SIZE (IN.)	SCHEDULE 40	
	WT. (LBS.)	PSI RTG
10 x 8	11	140
10 x 6	16	140
10 x 4	20	140
12 x 10	15	130
12 x 8	26	130
12 x 6	31	130
14 x 12	24	100
16 x 14	22	100
16 x 12	46	100
16 x 10	61	100
16 x 8	72	100
18 x 16	30	100
20 x 18	33	100
24 x 20	55	100

Table 11

EXTENDED BUSHING

NOMINAL SIZE (IN.)	SCHEDULE 40	
	WT. (LBS.)	PSI RTG
10 x 8	11	140
12 x 10	19	130
14 x 12	28	130
16 x 14	38	130

Table 12

MALE ADAPTOR

NOMINAL SIZE (IN.)	SCHEDULE 40	
	WT. (LBS.)	PSI RTG
6	6	25
8	7	25
10	8	25
12	14	25

Table 13

FEMALE ADAPTOR

NOMINAL SIZE (IN.)	SCHEDULE 40	
	WT. (LBS.)	PSI RTG
6	6	25
8	7	25
10	8	25
12	14	25

PRESSURE RATINGS

PVC LARGE DIAMETER FABRICATED FITTINGS AT 73°F

Table 14

CROSS

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
3	2	240	5	260
4	3	220	7	240
6	13	160	22	240
8	22	160	30	240
10	38	140	62	230
12	58	130	95	230
14	74	130	129	220
16	107	130	190	220
18	117	100	185	160
20	158	50	247	75
24	267	50	413	75

Table 15

FLANGE (BLIND)

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	16	25	32	75
12	21	25	42	75
14	26	25	52	75
16	33	25	66	75
18	36	25	72	75
20	44	25	88	75
24	57	25	114	75

Table 16

CAP

NOMINAL SIZE (IN.)	SCHEDULE 40		SCHEDULE 80	
	WT. (LBS.)	PSI RTG	WT. (LBS.)	PSI RTG
10	5	140	14	230
12	7	130	17	230
14	23	130	35	220
16	32	130	49	220
18	38	100	54	160
20	49	50	69	75
24	74	50	108	75

Table 17

IPS PIPE DIMENSION TABLE

NOMINAL PIPE SIZE (IN.)	O.D.	SCHEDULE 40		SCHEDULE 80	
		AVERAGE I.D.	MINIMUM WALL	AVERAGE I.D.	MINIMUM WALL
1	1.315	1.033	.133	.935	.179
1-1/4	1.660	1.364	.140	1.256	.191
1-1/2	1.900	1.592	.145	1.476	.200
2	2.375	2.049	.154	1.913	.218
3	3.500	3.042	.216	2.864	.300
4	4.500	3.998	.237	3.786	.337
5	5.563	5.047	.258	4.813	.375
6	6.625	6.013	.280	5.709	.432
8	8.625	7.943	.322	7.565	.500
10	10.750	9.976	.365	9.492	.593
12	12.750	11.890	.406	11.294	.687
14	14.000	13.126	.437	12.440	.780
16	16.000	15.000	.500	14.200	.900
CLASS 100				CLASS 160	
18	18.000	17.120	.440	16.614	.693
20	20.000	19.022	.489	18.460	.770
24	24.000	22.870	.585	22.152	.924

SYSTEMS ENGINEERING DATA

FOR THERMOPLASTIC PIPING

Table 18

MODULUS OF ELASTICITY (x10-) PSI VS. TEMPERATURE

MATERIAL	TEMPERATURE, °F								
	73	90	110	140	170	200	210	250	280
PVC	4.20	3.85	3.40	3.00	—	—	—	—	—
CPVC	4.23	4.10	3.70	3.27	2.93	2.40	2.26	—	—
PP Fuseal	2.00	1.30	.097	.074	0.61	0.55	0.53	—	—
PP Pressure	1.50	1.34	1.18	0.96	0.77	0.59	0.53	—	—
PVDF	2.13	1.66	1.37	1.04	0.80	0.61	0.55	0.37	0.29

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:

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

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 40-41 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 in Table 19.

Collapse pressures must be adjusted for temperatures other than for room temperature. The pressure temperature correction chart (Table 19) used to adjust pipe pressure ratings may be used for this purpose. (See note below table).

Table 19

SHORT-TERM COLLAPSE PRESSURE IN PSI AT 73°F

1/2	3/4	1	1-1/4	1-1/2	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
SUPER PROLINE											
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 1/3 to 1/2 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.

CORR TECH INCORPORATED

SYSTEMS ENGINEERING DATA

FOR THERMOPLASTIC PIPING

WATER HAMMER

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. The five factors that determine the severity of water hammer are:

1. Velocity (The primary factor in excessive water hammer: see discussion of "Velocity " and "Safety Factor" on page 62).
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 ft. per sec.
Di = Inside Diameter of Pipe, in.
E = Modulus of Elasticity of Pipe Material, psi
t = Wall Thickness of Pipe, in.

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 13-14. Here are the most commonly used surge pressure tables for IPS pipe sizes.

Table 20 - SURGE PRESSURE, Ps IN PSI AT 73°F

WATER VELOCITY (FT/SEC)	NOMINAL PIPE SIZE											
	1/2	3/4	1	1-1/4	1-1/2	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	65.8	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	78.8	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 POYLPROPYLENE												
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	28.2	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	85.5	82.5	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
SUPER PROLINE												
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	44.6	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	92.1	84.6	77.6	75.8	76.8	76.8	76.5	76.3	76.5	76.4	76.5	76.4
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

NOTE: For sizes larger than 12", call your Corr Tech representative.

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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.

$$T_c > \frac{2L}{C}$$

Where: T c = Valve Closure time, sec.
L = Length of Pipe run, ft.
C = Sonic Velocity of the Pressure Wave = 4720 ft. sec.

Another formula which closely predicts water hammer effects is:

$$p = a \frac{w}{144g}$$

Which is based on the elastic wave theory. In this text, we have further simplified the equation to:

$$p = Cv$$

Where: p = 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.

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 or Liquid

For example, for a liquid with a specific gravity of 1.2 in 2" Schedule 80 PVC pipe, from Table 43 = 24.2

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

$$C^1 = 2.42 + 24.2$$

$$C^1 = 26.6$$

Table 21 - Surge Wave Correction for Specific Gravity

PIPE SIZE (IN.)	PVC SCH 40	PVC SCH 80	CPVC SCH 40	CPVC SCH 80	POLY-PROPYLENE SCH 80	KYNAR (PVDF) SCH 80
1/4	31.3	34.7	33.2	37.3	—	—
3/8	29.3	32.7	31.0	34.7	—	—
1/2	28.7	31.7	30.3	33.7	25.9	28.3
3/4	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
1-1/4	23.2	27.0	24.5	28.6	19.8	—
1-1/2	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
2-1/2	21.1	24.7	22.2	26.0	—	
3	19.5	23.2	20.6	24.5	16.6	
4	17.8	21.8	18.8	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	13.7	18.0	14.7	19.2		
14	13.4	17.9	14.4	19.2		

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 which 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) A check valve installed near a pump in the discharge line will keep the line full and help prevent excessive water hammer during pump start-up.

VELOCITY

Thermoplastic piping systems have been installed that have successfully handled water velocities in excess of 10 ft/sec. 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.

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 2, shown on page15, 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 2, shown on page 15 - 8470 psi for PVC Type 1.

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

Pipe = 1-1/4" Schedule 80 PVC
O.D. = 1.660: Wall = 0.191
HDS = 2000 psi

The calculated surge pressure for 1-1/4" Schedule 80 PVC pipe at a velocity of 1 ft/sec is 26.2 psi/ft/sec.

CARRYING CAPACITY & FRICTION LOSS

TABLE 22

CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 80 THERMOPLASTIC PIPE

(Independent variables: Gallons per minute and nominal pipe size O.D.

Dependent variables: Velocity, friction head and pressure drop per 100 feet of pipe, interior smooth .)

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
	1/2 IN.			3/4 IN.			1 IN.			1-1/4 IN.		
1	1.48	4.02	1.74	0.74	0.86	0.37						
2	2.96	8.03	3.48	1.57	1.72	0.74	0.94	0.88	0.38	0.52	0.21	0.09
5	7.39	45.23	19.59	3.92	9.67	4.19	2.34	2.75	1.19	1.30	0.66	0.29
7	10.34	83.07	35.97	5.49	17.76	7.69	3.28	5.04	2.19	1.82	1.21	0.53
10				7.84	33.84	14.65	4.68	9.61	4.16	2.60	2.30	1.00
15	4 IN.			11.76	71.70	31.05	7.01	20.36	8.82	3.90	4.87	2.11
20	0.57	0.04	0.017				9.35	34.68	15.02	5.20	8.30	3.59
25	0.72	0.06	0.026	5 IN.			11.69	52.43	22.70	6.50	12.55	5.43
30	0.86	0.08	0.035	0.54	0.03	0.013	14.03	73.48	31.82	7.80	17.59	7.62
35	1.00	0.11	0.048	0.63	0.04	0.017				9.10	23.40	10.13
40	1.15	0.14	0.061	0.72	0.04	0.017				10.40	29.97	12.98
45	1.29	0.17	0.074	0.81	0.06	0.026	6 IN.			11.70	37.27	16.14
50	1.43	0.21	0.091	0.90	0.07	0.030	0.63	0.03	0.013	13.00	45.30	19.61
60	1.72	0.30	0.13	1.08	0.10	0.043	0.75	0.04	0.017			
70	2.01	0.39	0.17	1.26	0.13	0.056	0.88	0.05	0.022			
75	2.15	0.46	0.19	1.35	0.14	0.061	0.94	0.06	0.026			
80	2.29	0.50	0.22	1.44	0.16	0.069	1.00	0.07	0.030			
90	2.58	0.63	0.27	1.62	0.20	0.087	1.13	0.08	0.035			
100	2.87	0.76	0.33	1.80	0.24	0.10	1.25	0.10	0.043	8 IN.		
125	3.59	1.16	0.50	2.25	0.37	0.16	1.57	0.16	0.068	0.90	0.045	0.019
150	4.30	1.61	0.70	2.70	0.52	0.23	1.88	0.22	0.095	1.07	0.05	0.022
175	5.02	2.15	0.93	3.15	0.69	0.30	2.20	0.29	0.12	1.25	0.075	0.033
200	5.73	2.75	1.19	3.60	0.88	0.38	2.51	0.37	0.16	1.43	0.09	0.039
250	7.16	4.16	1.81	4.50	1.34	0.58	3.14	0.56	0.24	1.79	0.14	0.61
300	8.60	5.83	2.52	5.40	1.87	0.81	3.76	0.78	0.34	2.14	0.20	0.087
350	10.03	7.76	3.36	6.30	2.49	1.08	4.39	1.04	0.45	2.50	0.27	0.12
400	11.47	9.93	4.30	7.19	3.19	1.38	5.02	1.33	0.58	2.86	0.34	0.15
450				8.09	3.97	1.72	5.64	1.65	0.71	3.21	0.42	0.18
500				8.99	4.82	2.09	6.27	2.00	0.87	3.57	0.51	0.22
750							9.40	4.25	1.84	5.36	1.08	0.47
1000							12.54	7.23	3.13	7.14	1.84	0.80
1250										8.93	2.78	1.20
1500										10.71	3.89	1.68
2000												
2500												
3000												
3500												
4000												

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
	1-1/2 IN.			2 IN.			2-1/2 IN.			3 IN.		
1												
2	0.38	0.10	0.041									
5	0.94	0.30	0.126	0.56	0.10	0.040	0.39	0.05	0.022	0.25	0.02	0.009
7	1.32	0.55	0.24	0.78	0.15	0.065	0.54	0.07	0.032	0.35	0.028	0.012
10	1.88	1.04	0.45	1.12	0.29	0.13	0.78	0.12	0.052	0.50	0.04	0.017
15	2.81	2.20	0.95	1.68	0.62	0.27	1.17	0.26	0.11	0.75	0.09	0.039
20	3.75	3.75	1.62	2.23	1.06	0.46	1.56	0.44	0.19	1.00	0.15	0.065
25	4.69	5.67	2.46	2.79	1.60	0.69	1.95	0.67	0.29	1.25	0.22	0.095
30	5.63	7.95	3.44	3.35	2.25	0.97	2.34	0.94	0.41	1.49	0.31	0.13
35	6.57	10.58	4.58	3.91	2.99	1.29	2.73	1.25	0.54	1.74	0.42	0.18
40	7.50	13.55	5.87	4.47	3.83	1.66	3.12	1.60	0.69	1.99	0.54	0.23
45	8.44	16.85	7.30	5.03	4.76	2.07	3.51	1.99	0.86	2.24	0.67	0.29
50	9.38	20.48	8.87	5.58	5.79	2.51	3.90	2.42	1.05	2.49	0.81	0.35
60	11.26	28.70	12.43	6.70	8.12	3.52	4.68	3.39	1.47	2.99	1.14	0.49
70				7.82	10.80	4.68	5.46	4.51	1.95	3.49	1.51	0.65
75				8.38	12.27	5.31	5.85	5.12	2.22	3.74	1.72	0.74
80				8.93	13.83	5.99	6.24	5.77	2.50	3.99	1.94	0.84
90				10.06	17.20	7.45	7.02	7.18	3.11	4.48	2.41	1.04
100				11.17	20.90	9.05	7.80	8.72	3.78	4.98	2.93	1.27
125							9.75	13.21	5.72	6.23	4.43	1.92
150							11.70	18.48	8.00	7.47	6.20	2.68
175	10 IN.									8.72	8.26	3.58
200	0.90	0.036	0.015							9.97	10.57	4.58
250	1.14	0.045	0.02	12 IN.						12.46	16.00	6.93
300	1.36	0.07	0.03									
350	1.59	0.085	0.037	1.12	0.037	0.016						
400	1.81	0.11	0.048	1.28	0.05	0.022						
450	2.04	0.14	0.061	1.44	0.06	0.026						
500	2.27	0.17	0.074	1.60	0.07	0.030						
750	3.40	0.36	0.16	2.40	0.15	0.065						
1000	4.54	0.61	0.26	3.20	0.26	0.11						
1250	5.67	0.92	0.40	4.01	0.40	0.17						
1500	6.80	1.29	0.56	4.81	0.55	0.24						
2000	9.07	2.19	0.95	6.41	0.94	0.41						
2500	11.34	3.33	1.44	8.01	1.42	0.62						
3000				9.61	1.99	0.86						
3500				11.21	2.65	1.15						
4000				12.82	3.41	1.48						

CARRYING CAPACITY & FRICTION LOSS

TABLE 23

CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 40 THERMOPLASTIC PIPE

(Independent variables: Gallons per minute and nominal pipe size O. D.
Dependent variables: Velocity, friction head and pressure drop per 100 feet of pipe, interior smooth .)

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
	1/2 IN.			3/4 IN.			1 IN.			1-1/4 IN.			1-1/2 IN.			2 IN.			2-1/2 IN.			3 IN.		
1	1.13	2.06	0.90	0.63	0.51	0.22																		
2	2.26	4.16	1.80	1.26	1.02	0.44	0.77	0.55	0.24	0.44	0.14	0.06	0.33	0.07	0.03									
5	5.64	23.44	10.45	3.16	5.73	2.48	1.93	1.72	0.75	1.11	0.44	0.19	0.81	0.22	0.09	0.49	0.066	0.029	0.30	0.038	0.016	0.22	0.015	0.007
7	7.90	43.06	13.64	4.43	10.52	4.56	2.72	3.17	1.37	1.55	0.81	0.35	1.13	0.38	0.17	0.69	0.11	0.048	0.49	0.051	0.023	0.31	0.021	0.009
10	11.28	82.02	35.51	6.32	20.04	8.68	3.86	6.02	2.61	2.21	1.55	0.67	1.62	0.72	0.31	0.98	0.21	0.091	0.68	0.09	0.039	0.44	0.03	0.013
15		4 IN.		9.48	42.46	18.39	5.79	12.77	5.53	3.31	3.28	1.42	2.42	1.53	0.66	1.46	0.45	0.19	1.03	0.19	0.082	0.66	0.07	0.030
20	0.51	0.03	0.013	12.65	72.34	31.32	7.72	21.75	9.42	4.42	5.59	2.42	3.23	2.61	1.13	1.95	0.76	0.33	1.37	0.32	0.14	0.88	0.11	0.048
25	0.64	0.04	0.017		5 IN.		9.65	32.88	14.22	5.52	8.45	3.66	4.04	3.95	1.71	2.44	1.15	0.50	1.71	0.49	0.21	1.10	0.17	0.074
30	0.77	0.06	0.026	0.49	0.02	0.009	11.58	46.08	19.95	6.63	11.85	5.13	4.85	5.53	2.39	2.93	1.62	0.70	2.05	0.68	0.29	1.33	0.23	0.10
35	0.89	0.08	0.035	0.57	0.03	0.013				7.73	15.76	6.82	5.66	7.36	3.19	3.41	2.15	0.93	2.39	0.91	0.39	1.55	0.31	0.13
40	1.02	0.11	0.046	0.65	0.03	0.013				8.84	20.16	8.74	6.47	9.43	4.08	3.90	2.75	1.19	2.73	1.16	0.50	1.77	0.40	0.17
45	1.15	0.13	0.056	0.73	0.04	0.017		6 IN.		9.94	25.10	10.87	7.27	11.73	5.08	4.39	3.43	1.49	3.08	1.44	0.62	1.99	0.50	0.22
50	1.28	0.16	0.069	0.81	0.05	0.022	0.56	0.02	0.009	11.05	30.51	13.21	8.08	14.25	6.17	4.88	4.16	1.80	3.42	1.75	0.76	2.21	0.60	0.26
60	1.53	0.22	0.095	0.97	0.07	0.030	0.67	0.03	0.013				9.70	19.98	8.65	5.85	5.84	2.53	4.10	2.46	1.07	2.65	0.85	0.37
70	1.79	0.30	0.13	1.14	0.10	0.043	0.79	0.04	0.017							6.83	7.76	3.36	4.79	3.27	1.42	3.09	1.13	0.49
75	1.92	0.34	0.15	1.22	0.11	0.048	0.84	0.05	0.022							7.32	8.82	3.82	5.13	3.71	1.61	3.31	1.28	0.55
80	2.05	0.38	0.16	1.30	0.13	0.056	0.90	0.05	0.022		8 IN.					7.80	9.94	4.30	5.47	4.19	1.81	3.53	1.44	0.62
90	2.30	0.47	0.20	1.46	0.16	0.069	1.01	0.06	0.026							8.78	12.37	5.36	6.15	5.21	2.26	3.98	1.80	0.78
100	2.56	0.58	0.25	1.62	0.19	0.082	1.12	0.08	0.035	0.65	0.03	0.012				9.75	15.03	6.51	6.84	6.33	2.74	4.42	2.18	0.94
125	3.20	0.88	0.38	2.03	0.29	0.125	1.41	0.12	0.052	0.81	0.035	0.015							8.55	9.58	4.15	5.52	3.31	1.43
150	3.84	1.22	0.53	2.44	0.40	0.17	1.69	0.16	0.069	0.97	0.04	0.017		10 IN.					10.26	13.41	5.81	6.63	4.63	2.00
175	4.48	1.63	0.71	2.84	0.54	0.235	1.97	0.22	0.096	1.14	0.055	0.024										7.73	6.16	2.67
200	5.11	2.08	0.90	3.25	0.69	0.30	2.25	0.28	0.12	1.30	0.07	0.030	0.82	0.027	0.012							8.83	7.88	3.41
250	6.40	3.15	1.36	4.06	1.05	0.45	2.81	0.43	0.19	1.63	0.11	0.048	1.03	0.035	0.015		12 IN.					11.04	11.93	5.17
300	7.67	4.41	1.91	4.87	1.46	0.63	3.37	0.60	0.26	1.94	0.16	0.069	1.23	0.05	0.022									
350	8.95	5.87	2.55	5.69	1.95	0.85	3.94	0.79	0.34	2.27	0.21	0.091	1.44	0.065	0.028	1.01	0.027	0.012						
400	10.23	7.52	3.26	6.50	2.49	1.08	4.49	1.01	0.44	2.59	0.27	0.12	1.64	0.09	0.039	1.16	0.04	0.017						
450				7.31	3.09	1.34	5.06	1.26	0.55	2.92	0.33	0.14	1.85	0.11	0.048	1.30	0.05	0.022						
500				8.12	3.76	1.63	5.62	1.53	0.66	3.24	0.40	0.17	2.05	0.13	0.056	1.45	0.06	0.026						
750							8.43	3.25	1.41	4.86	0.85	0.37	3.08	0.28	0.12	2.17	0.12	0.052						
1000							11.24	5.54	2.40	6.48	1.45	0.63	4.11	0.48	0.21	2.89	0.20	0.087						
1250										8.11	2.20	0.95	5.14	0.73	0.32	3.62	0.31	0.13						
1500										9.72	3.07	1.33	6.16	1.01	0.44	4.34	0.43	0.19						
2000													8.21	1.72	0.74	5.78	0.73	0.32						
2500													10.27	2.61	1.13	7.23	1.11	0.49						
3000																8.68	1.55	0.67						
3500																10.12	2.07	0.90						
4000																11.07	2.86	1.15						

PROLINE-POLYPROPYLENE 150 FLOW RATES

TABLE 24

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
	1/2 IN.			3/4 IN.			1 IN.			1-1/4 IN.			1-1/2 IN.			2 IN.			2-1/2 IN.			3 IN.			4 IN.		
1	1.17	1.27	.55	.68	.35	.15	.39	.09	.04	.24	.02	.01															
2	2.34	4.60	1.99	1.37	1.25	.54	.78	.32	.14	.49	.09	.04	.32	.05	.02												
5	5.84	25.04	10.84	3.42	6.81	2.95	1.95	1.73	.75	1.22	.55	.24	.79	.18	.08	.50	.07	.03	.35	.02	.01	.24	.02	.01			
7	8.18	46.69	20.21	4.79	12.73	5.51	2.72	3.21	1.39	1.71	1.04	.45	1.11	.37	.16	.70	.12	.05	.49	.05	.02	.34	.05	.02			
10	11.70	90.37	39.12	6.85	24.62	10.66	3.89	6.24	2.70	2.45	2.01	.87	1.58	.69	.30	1.00	.23	.10	.70	.09	.04	.49	.07	.03			
	6 IN.																										
15				10.30	52.18	22.59	5.84	13.21	5.72	3.67	4.27	1.85	2.37	1.48	.64	1.49	.49	.21	1.05	.21	.09	.73	.14	.06	.49	.02	.01
20							7.78	22.50	9.74	4.90	7.28	3.15	3.16	2.52	1.09	1.99	.83	.36	1.41	.35	.15	.97	.23	.10	.65	.05	.02
25							9.73	34.00	14.72	6.12	11.02	4.77	3.95	3.79	1.64	2.49	1.25	.54	1.76	.53	.23	1.22	.30	.13	.81	.07	.03
30							11.70	47.66	20.63	7.34	15.43	6.68	4.74	5.31	2.30	2.99	1.73	.75	2.11	.74	.32	1.46	.38	.17	.98	.12	.05
35	.54	.02	.01							8.57	20.54	8.89	5.53	7.09	3.07	3.49	2.31	1.00	2.46	.99	.43	1.70	.53	.23	1.14	.14	.06
				8 IN.																							
40	.62	.05	.02							9.79	26.29	11.38	6.32	9.06	3.92	3.98	2.93	1.27	2.81	1.27	.55	1.94	.65	.28	1.30	.18	.08
45	.69	.06	.02							11.00	32.71	14.16	7.11	11.27	4.88	4.48	3.67	1.59	3.16	1.57	.68	2.19	.79	.34	1.46	.23	.10
50	.77	.07	.03										7.90	13.70	5.93	4.98	4.46	1.93	3.52	1.92	.83	2.43	1.09	.47	1.63	.30	.13
60	.92	.07	.03	.59	.02	.01							9.48	19.20	8.31	5.98	6.26	2.71	4.22	2.68	1.16	2.92	1.46	.63	1.95	.42	.18
70	1.08	.09	.04	.69	.05	.02							11.10	25.64	11.10	6.97	8.32	3.60	4.92	3.56	1.54	3.40	1.87	.81	2.28	.55	.24
							10 IN.																				
80	1.23	.12	.05	.79	.05	.02										7.97	10.65	4.61	5.62	4.55	1.97	3.89	2.31	1.00	2.60	.69	.30
90	1.39	.14	.06	.89	.07	.03										8.96	13.24	5.73	6.33	5.68	2.46	4.38	2.82	1.22	2.93	.88	.38
100	1.54	.16	.07	.98	.07	.03										9.96	16.10	6.97	7.03	6.91	2.99	4.86	4.25	1.84	3.25	1.06	.46
125	1.92	.25	.11	1.23	.09	.04	.79	.02	.01							12.50	24.26	10.50	8.79	10.44	4.52	6.08	5.91	2.56	4.06	1.59	.69
										12 IN.			14 IN.														
150	2.31	.37	.16	1.48	.12	.05	.96	.05	.02										10.60	14.62	6.33	7.29	7.92	3.43	4.88	2.24	.97
175	2.69	.49	.21	1.72	.16	.07	1.10	.05	.02													8.51	10.14	4.39	5.69	2.98	1.29
200	3.08	.62	.27	1.97	.21	.09	1.26	.07	.03													9.72	15.34	6.64	6.50	3.81	1.65
250	3.85	.92	.40	2.46	.30	.13	1.58	.12	.06	.99	.02	.01										12.20	21.51	9.31	8.13	5.75	2.49
300	4.62	1.32	.57	2.95	.44	.19	1.89	.14	.06	1.19	.05	.02	.94	.03	.01										9.75	8.09	3.50
																16 IN.			18 IN.								
350	5.39	1.73	.75	3.44	.60	.26	2.21	.21	.09	1.39	.07	.03	1.09	.06	.02										11.40	10.72	4.64
400	6.16	2.24	.97	3.94	.74	.32	2.52	.25	.11	1.59	.07	.03	1.25	.05	.02												
450	6.93	2.27	1.20	4.43	.92	.40	2.84	.32	.14	1.78	.09	.04	1.40	.07	.03	1.11	.02	.01									
500	7.69	3.37	1.46	4.92	1.13	.49	3.15	.37	.16	1.98	.12	.06	1.56	.07	.03	1.23	.05	.02									
600	9.23	4.71	2.04	5.90	1.59	.69	3.78	.53	.23	2.38	.16	.07	1.87	.09	.04	1.48	.06	.02	1.17	.02	.01						
700	10.80	6.28	2.72	6.89	2.13	.92	4.41	.72	.31	2.78	.23	.10	2.19	.14	.06	1.72	.07	.03	1.36	.05	.02						
800				7.87	2.70	1.17	5.04	.92	.40	3.17	.30	.13	2.50	.16	.07	1.97	.09	.04	1.55	.05	.02						
900				8.85	3.37	1.46	5.67	1.13	.49	3.57	.37	.16	2.81	.21	.09	2.21	.12	.05	1.75	.07	.03						
1000				9.84	4.11	1.78	6.30	1.39	.60	3.97	.44	.19	3.12	.25	.11	2.46	.14	.06	1.94	.07	.03						
2000							12.60	5.01	2.17	7.93	1.62	.70	6.24	.90	.39	4.92	.51	.22	3.89	.30	.13						
2500										9.92	2.47	1.07	7.80	1.38	.59	6.15	.76	.33	4.86	.44	.19						
500																12.30	2.77	1.20	9.72	1.57	.68						
7500																			14.60	3.30	1.43						

PROLINE-POLYPROPYLENE 45 FLOW RATES

TABLE 25

GALLONS PER MINUTE	2 IN.			2-1/2 IN.			3 IN.			4 IN.			6 IN.			8 IN.			10 IN.			12 IN.			14 IN.		
	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	...SQUARE INCH
5	.38	.02	.01																								
7	.53	.07	.03	.37	.02	.01																					
10	.76	.12	.05	.53	.05	.02	.37	.02	.01																		
15	1.13	.23	.10	.80	.12	.05	.55	.05	.02																		
20	1.51	.42	.18	1.07	.18	.08	.74	.07	.03	.50	.02	.01															
25	1.89	.62	.27	1.34	.28	.12	.92	.12	.05	.62	.05	.02															
30	2.27	.88	.38	1.60	.37	.16	1.11	.14	.06	.74	.07	.03															
35	2.64	1.18	.51	1.87	.51	.22	1.29	.21	.09	.87	.07	.03															
40	3.02	1.50	.65	2.14	.65	.28	1.48	.25	.11	.99	.09	.04															
45	3.40	1.87	.81	2.40	.81	.35	1.66	.32	.14	1.12	.12	.05															
50	3.78	2.29	.99	2.67	.97	.42	1.84	.39	.17	1.24	.14	.06															
60	4.53	3.19	1.38	3.20	1.36	.59	2.22	.55	.24	1.49	.21	.09	.70	.02	.01												
70	5.29	4.25	1.84	3.74	1.82	.79	2.59	.74	.32	1.74	.28	.12	.82	.05	.02												
80	6.04	5.43	2.35	4.27	2.38	1.03	2.96	.95	.41	1.99	.37	.16	.94	.07	.03												
90	6.80	6.77	2.93	4.80	2.91	1.26	3.33	1.20	.52	2.23	.44	.19	1.05	.07	.03												
100	7.55	8.22	3.56	5.34	3.53	1.53	3.69	1.43	.62	2.48	.55	.24	1.17	.09	.04												
125	9.44	12.43	5.38	6.68	5.41	2.34	4.62	2.17	.94	3.10	.83	.36	1.46	.14	.06	.93	.02	.01									
150	11.30			8.01	7.48	3.24	5.54	3.07	1.33	3.72	1.16	.50	1.76	.18	.08	1.12	.07	.03									
175				9.35	9.96	4.31	6.47	4.07	1.76	4.34	1.55	.67	2.05	.25	.11	1.31	.07	.03	.84	.02	.01						
200				10.68	12.77	5.53	7.39	5.22	2.26	4.96	1.99	.86	2.34	.32	.14	1.50	.07	.03	.96	.05	.02						
250							9.24	7.88	3.41	6.20	2.88	1.29	2.93	.49	.21	1.87	.12	.05	1.20	.05	.02						
300							11.08	11.04	4.78	7.44	4.18	1.81	3.51	.67	.29	2.24	.16	.07	1.44	.07	.03						
350										8.68	5.59	2.42	4.10	.90	.39	2.62	.23	.10	1.68	.09	.04	1.06	.02	.01			
400										9.93	7.14	3.09	4.68	1.16	.50	2.99	.30	.13	1.92	.14	.06	1.21	.05	.02			
450										11.17	8.87	3.84	5.27	1.43	.62	3.37	.37	.16	2.16	.16	.07	1.38	.05	.02	1.07	.02	

GALLONS PER MINUTE	16 IN.			18 IN.			20 IN.			24 IN.			6 IN.			8 IN.			10 IN.			12 IN.			14 IN.		
	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	...SQUARE INCH
500													5.85	1.73	.75	3.74	.44	.19	2.40	.21	.09	1.51	.07	.03	1.19	.05	
600	1.12	.02	.01										7.02	2.43	1.05	4.49	.60	.26	2.87	.28	.12	1.81	.09	.04	1.43	.05	
700	1.31	.05	.02										8.19	3.23	1.40	5.24	.83	.36	3.35	.35	.15	2.11	.12	.05	1.66	.07	
800	1.50	.05	.02										9.36	4.13	1.79	5.98	1.04	.45	3.83	.46	.20	2.41	.14	.06	1.90	.09	
900	1.68	.07	.03	1.30	.02	.01							10.53	5.15	2.23	6.73	1.29	.56	4.31	.60	.26	2.71	.18	.08	2.14	.12	
1000	1.87	.07	.03	1.48	.05	.02	1.20	.02	.01				11.70	6.26	2.71	7.48	1.67	.68	4.79	.72	.31	3.02	.23	.10	2.38	.14	
2000	3.74	.25	.11	2.96	.14	.06	2.39	.09	.04	1.51	.02	.01				14.96	5.71	2.47	9.58	2.56	1.11	6.03	.83	.36	4.75	.46	
2500	4.67	.39	.17	3.69	.23	.10	2.98	.14	.06	1.89	.05	.02							11.96	3.88	1.68	7.54	1.27	.55	5.94	.72	
5000	9.35	1.41	.61	7.39	.81	.35	5.98	.49	.21	3.77	.16	.07													11.88	2.54	
7500	14.00	.69	.30	11.00	1.71	.74	8.97	1.02	.44	5.66	.32	.14															
10000				14.80	2.91	1.26	12.00	1.73	.76	7.55	.53	.24															

SUPER/PROLINE - PVDF FLOW RATES

TABLE 26

V = Velocity, Feet per Second; FH = Friction Head, Feet; FL = Friction Loss, Pounds per Square Inch

Gallons per Minute	1/2 IN. Velocity Feet per Second	1/2 IN. Friction Head Feet	1/2 IN. Friction Loss Pounds per Square Inch	3/4 IN. Velocity Feet per Second	3/4 IN. Friction Head Feet	3/4 IN. Friction Loss Pounds per Square Inch	1 IN. Velocity Feet per Second	1 IN. Friction Head Feet	1 IN. Friction Loss Pounds per Square Inch	1-1/4 IN. Velocity Feet per Second	1-1/4 IN. Friction Head Feet	1-1/4 IN. Friction Loss Pounds per Square Inch
1	1.00	.88	.38	.58	.23	.10	.36	.07	.03	.21	.02	.01
2	2.00	3.14	1.36	1.17	.85	.37	.71	.25	.11	.42	.07	.03
5	5.00	17.14	7.42	2.92	4.64	2.01	1.78	1.39	.60	1.06	.39	.17
7	7.00	31.68	13.80	4.09	8.64	3.74	2.49	2.58	1.11	1.49	.74	.32
10	10.00	61.91	26.80	5.84	16.72	7.24	3.55	4.99	2.16	2.12	1.43	.62
15				8.76	35.34	15.30	5.33	10.56	4.57	3.19	3.03	1.31
20				11.70	60.29	26.10	7.10	17.99	7.79	4.25	5.17	2.24
25							8.88	27.28	11.80	5.31	7.78	3.37
30							10.70	38.12	16.50	6.37	10.93	4.73
35										7.43	14.65	6.30
	16 IN.											
40										8.50	18.62	8.06
45										9.56	23.10	10.00
50	.59	.02	.01							10.62	28.18	12.20
60	.70	.05	.02									
70	.82	.05	.02									
				18 IN.								
80	.94	.07	.03									
90	1.05	.07	.03									
100	1.17	.09	.04	.75	.02	.01						
							10 IN.					
125	1.46	.14	.06	.93	.05	.02						
150	1.76	.18	.08	1.12	.07	.03						
175	2.05	.23	.10	1.31	.07	.03	.96	.02	.01			
200	2.34	.32	.14	1.50	.09	.04	1.20	.05	.02			
										12 IN.		
250	2.93	.49	.21	1.87	.16	.07	1.44	.07	.03			
300	3.51	.67	.29	2.24	.23	.10	1.68	.09	.04			
350	4.10	.90	.39	2.62	.30	.13	1.92	.14	.06	1.06	.02	.01
400	4.68	1.13	.49	2.99	.37	.16	2.16	.16	.07	1.21	.05	.02
450	5.27	1.41	.61	3.37	.46	.20	2.40	.18	.08	1.36	.05	.02
500	5.85	1.73	.75	3.74	.58	.25	2.67	.28	.12	1.51	.07	.03
600	7.02	2.43	1.05	4.49	.81	.35	3.35	.37	.16	1.81	.07	.03
700	8.19	3.23	1.40	5.24	1.09	.47	3.83	.46	.20	2.11	.12	.05
800	9.36	4.13	1.79	5.98	1.39	.60	4.31	.60	.26	2.41	.14	.06
900	10.50	5.15	2.23	6.73	1.73	.75	4.79	.72	.31	2.71	.18	.08
1000				7.48	2.10	.91	9.58	2.56	1.11	3.02	.23	.10
2000				15.00	7.60	3.29	12.00	3.88	1.68	6.03	.83	.36
2500										7.54	1.27	.55
5000										15.10	4.55	1.97

Gallons per Minute	1-1/2 IN. Velocity Feet per Second	1-1/2 IN. Friction Head Feet	1-1/2 IN. Friction Loss Pounds per Square Inch	2 IN. Velocity Feet per Second	2 IN. Friction Head Feet	2 IN. Friction Loss Pounds per Square Inch	2-1/2 IN. Velocity Feet per Second	2-1/2 IN. Friction Head Feet	2-1/2 IN. Friction Loss Pounds per Square Inch	3 IN. Velocity Feet per Second	3 IN. Friction Head Feet	3 IN. Friction Loss Pounds per Square Inch	4 IN. Velocity Feet per Second	4 IN. Friction Head Feet	4 IN. Friction Loss Pounds per Square Inch
1															
2	.27	.02	.01												
5	.67	.14	.06	.41	.06	.02									
7	.94	.23	.10	.57	.07	.03	.38	.02	.01						
10	1.35	.46	.20	.81	.14	.06	.54	.05	.02	.40	.02	.01			
15	2.02	.99	.43	1.22	.30	.13	.81	.12	.05	.60	.05	.02			
20	2.69	1.71	.74	1.62	.49	.21	1.07	.18	.08	.79	.09	.04	.50	.02	.01
25	3.37	2.56	1.11	2.03	.74	.32	1.34	.28	.12	.99	.14	.06	.62	.05	.02
30	4.04	3.60	1.56	2.43	1.04	.45	1.61	.39	.17	1.19	.18	.08	.74	.07	.03
35	4.71	4.80	2.08	2.84	1.39	.60	1.88	.51	.22	1.39	.25	.11	.87	.07	.03
40	5.38	6.14	2.66	3.24	1.80	.78	2.15	.67	.29	1.59	.32	.14	.99	.09	.04
45	6.06	7.65	3.31	3.65	2.22	.96	2.42	.83	.36	1.79	.39	.17	1.12	.12	.05
50	6.73	9.29	4.02	4.05	2.70	1.17	2.69	.99	.43	1.99	.49	.21	1.24	.14	.06
60	8.08	13.01	5.63	4.86	3.79	1.64	3.22	1.39	.60	2.38	.67	.29	1.49	.21	.09
70	9.42	17.30	7.49	5.67	5.04	2.18	3.76	1.85	.80	2.78	.90	.39	1.74	.28	.12
80	10.80	22.18	9.60	6.48	6.44	2.79	4.30	2.38	1.03	3.18	1.13	.49	1.99	.37	.16
90				7.29	8.02	3.47	4.83	2.96	1.28	3.57	1.41	.61	2.23	.44	.19
100				8.10	9.75	4.22	5.37	3.58	1.55	4.96	1.71	.74	2.48	.55	.24
125				10.13	14.74	6.38	6.71	5.43	2.35	5.96	2.61	1.13	3.10	.83	.36
150							8.05	7.60	3.29	6.95	3.65	1.58	3.72	1.16	.50
175							9.40	10.09	4.37	7.94	4.85	2.10	4.34	1.96	.85
200							10.70	12.94	5.60	9.93	6.19	2.68	4.96	2.98	1.29
250										11.90	20.93	9.06	6.20	4.18	1.81
300													7.44	5.57	2.41
350													8.68	7.14	3.09
400													9.93	8.87	3.84
450													11.20	10.79	4.67

CARRYING CAPACITY & FRICTION LOSS

TABLE 27

EQUIVALENT LENGTH OF THERMOPLASTIC PIPE IN FEET

				¼"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	6"	8"	10"	12"
GLOBE VALVES	Conventional	With no obstruction in flat, bevel, or plug type seat	Fully Open	10.3	17.6	23.3	29.7	39.1	45.6	58.6	69.95	86.9	114.1	171.8	226.1	283.9	338.2
		With wing or pin guided disc	Fully Open	13.7	23.3	30.9	39.3	51.8	60.4	77.5	92.6	115.1	151.0	227.4	298.3	375.8	447.7
	Y-Pattern	(No obstruction in flat, bevel or plug type seat) —With stem 60 degrees from run of pipe line	Fully Open	5.3	9.1	12.0	15.3	20.1	23.5	30.1	36.0	44.7	58.7	88.4	116.4	146.1	174.1
		—With stem 45 degrees from run of pipe line	Fully Open	4.4	7.5	10.0	12.7	16.7	19.5	25.0	29.8	37.1	48.6	73.3	96.4	121.1	144.3
ANGLE VALVES	Conventional	With no obstruction in flat, bevel, plug type seat	Fully Open	4.4	7.5	10.0	12.7	16.7	19.5	25.0	29.8	37.1	48.6	73.3	96.4	121.1	144.3
		With wing or pin guided disc	Fully Open	6.1	10.4	13.7	17.5	23.0	26.8	34.5	41.2	51.1	67.1	101.1	133.0	167.0	199.0
GATE VALVES	Conventional Wedge Disc, Dbl Disc, or Plug Disc		Fully Open	0.4	0.7	0.9	1.1	1.5	1.7	2.2	2.7	3.3	4.4	6.6	8.6	10.9	12.9
			Three-Quarters Open	1.1	1.8	2.4	3.1	4.0	4.7	6.0	7.2	8.9	11.7	17.7	23.3	29.2	34.8
			One-Half Open	4.9	8.3	11.0	14.0	18.4	21.5	27.6	32.9	40.9	53.7	80.9	106.4	133.6	159.2
			One-Quarter Open	27.3	45.7	61.8	78.7	103.5	120.8	155.0	185.2	230.1	302.0	454.9	598.6	751.5	895.4
BALL VALVES	Full Port Design		Fully Open	Same as an equivalent of Sch. 80 Pipe													
FITTINGS	90° Standard Elbow			0.9	1.6	2.1	2.6	3.5	4.0	5.5	6.2	7.7	10.1	15.2	20.0	25.1	29.8
	45° Standard Elbow			0.5	0.8	1.1	1.4	1.8	2.1	2.8	3.3	4.1	5.4	8.1	10.6	13.4	15.9
	90° Long Radius Elbow			0.6	1.0	1.4	1.7	2.3	2.7	4.3	5.1	6.3	8.3	12.5	16.5	20.7	24.7
	90° Street Elbow			1.5	2.6	3.4	4.4	5.8	6.7	8.6	10.3	12.8	16.8	25.3	33.3	41.8	49.78
	45° Street Elbow			0.8	1.3	1.8	2.3	3.0	3.5	4.5	5.4	6.6	8.7	13.1	17.3	21.7	25.9
	Square Corner Elbow			1.7	3.0	3.9	5.0	6.5	7.6	9.8	11.7	14.6	19.1	28.8	37.9	47.6	56.7
	Standard Tee	With Flow through run		0.6	1.0	1.4	1.7	2.3	2.7	4.3	5.1	6.3	8.3	12.5	16.5	20.7	24.7
		With Flow through branch		1.8	4.0	5.1	6.0	6.9	8.1	12	14.3	16.3	22.1	32.2	39.9	50.1	59.7

SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

Water Velocity = 5 feet per second
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:

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

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

Table 28 gives the results of safety factor calculations based upon service factors of 0.5 and 0.4 for the 1-1/4" 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 basis = 4000 psi, and the water velocity = 5 feet per second.

Comparing safety factor for this 1-1/4" 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%.

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

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.

Table 28
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
1-1/4" Sch. 80	0.5	2000	520	131.0	651.0	2503.5	3.38
1-1/4" Sch. 80	0.4	1600	416	131.0	547.0	2103.5	4.03

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.

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:

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

$$= .0983 \frac{q^{1.852}}{Di^{4.8655}} \quad \text{for } C = 150$$

$$P = .4335f$$

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)

SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

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 29 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:

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

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 7 below shows the relationship between the friction factor, 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:

$$h = \frac{143\ ULV}{Wd^2}$$

Flow in the critical zone, Reynolds numbers 2000 to 4000, is unstable and a surging type of flow exists. Pipe lines should be designed to avoid operation in the critical zone since 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 turbu-lence rarely exists. Most pipe systems are designed to operate in the transition zone.

TABLE 29

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:

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

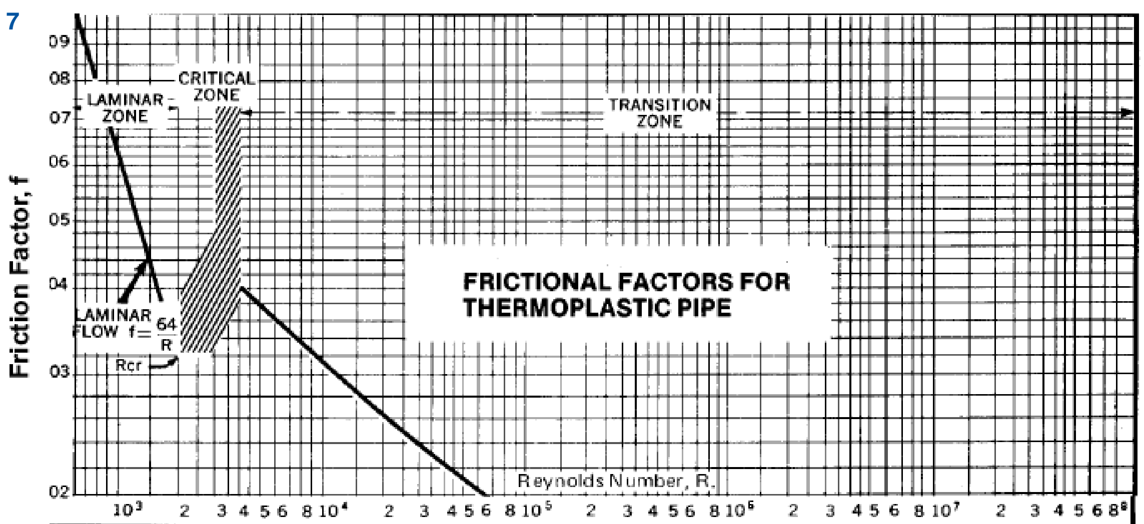
$$h = .0311 \frac{fLG^2}{d^5}$$

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

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

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

Fig. 7



MANNING EQUATION

The Manning roughness factor is another equation used to determine friction loss in hydraulic flow. Like the Hazen-Williams C factor, the Manning "n" factor is an empirical number that defines the interior wall smoothness of a pipe. PVC pipe has an "n" value that ranges from 0.008 to 0.012 from laboratory testing. Comparing with cast iron with a range of 0.011 to 0.015, PVC is at least 37.5 percent more efficient, or another way to express this would be to have equal flow with the PVC pipe size being one-third smaller than the cast iron. The following table gives the range of "n" value for various piping materials.

TABLE 30

PIPE MATERIAL	"n" RANGE
CAST IRON	0.011-0.015
WROUGHT IRON (BLACK)	0.012-0.015
WROUGHT IRON (GALVANIZED)	0.013-0.017
SMOOTH BRASS	0.009-0.013
GLASS	0.009-0.013
RIVETED AND SPIRAL STEEL	0.013-0.017
CLAY DRAINAGE TILE	0.011-0.017
CONCRETE	0.012-0.016
CONCRETE LINED	0.012-0.018
CONCRETE-RUBBLE SURFACE	0.017-0.030
PVC	0.008-0.012
WOOD	0.010-0.013

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SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

COMPENSATING FOR THERMAL EXPANSION

Thermoplastics exhibit a relatively high coefficient of thermal expansion (see Relative Properties Chart page 13 and 14)—as much as ten times that of steel. When designing plastic piping systems, expansion of long runs must be considered. Installation temperature versus working temperature or summer to winter extremes must be considered.

One area where extreme temperature variations can occur is in a polypropylene drain application. Temperature in waste systems depends on quantity and temperature of the waste liquids discharged into the system. In general, the quantities of wastes discharged through waste systems from laboratories in educational institutions will be relatively small (a few gallons at a time), while industrial laboratories and processing systems may discharge large quantities of very hot or very cold water.

There are several methods of controlling or compensating for thermal expansion of piping systems: taking advantage of off-sets and change of direction in the piping and expansion joints.

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

2. Expansion Joints—Expansion joints for pressure applications are generally expensive.

The expansion loops and offset tables as shown on following pages have been generated for elevated temperatures as noted beneath the table. If the change in temperature and working temperatures are lower than those used to derive expansion loop and offset tables, the figures will be conservative. These tables can be generated for any temperature and expansion by using the following equations and the modulus of elasticity and working stress at the given temperature.

Assume the pipe to be a cantilevered beam. Deflection of a cantilevered beam is ΔL.

$$\Delta L = \frac{Pl^3}{3EI}$$

Where:

- P = Force Causing the Pipe to Deflect
- l = Length of Pipe that is Deflected, in.
- E = Modulus of Elasticity at System Temperature, psi
- I = Moment of Inertia
- e = Coefficient of Thermal Expansion, in./in. °F
- ΔT = Change of Temperature, °F
- ΔL = Change in Length = $12e(\Delta T)$, in.
- L = Length of Straight Pipe Run, ft.

Maximum stress equation:

$$S = \frac{Mc}{I}$$

Where:

- S = Working Stress at the System Temperature, psi
- M = Bending Moment, lb. ft. = Pl
- c = Pipe O.D./2, in.
- I = Moment of Inertia

By substituting in maximum stress equation:

$$S = \frac{PlD}{2I}$$

Rearranging:

$$P = \frac{2SI}{lD}$$

Rearranging deflection equation:

$$P = \frac{3EI(\Delta L)}{l^3}$$

Equating both equations:

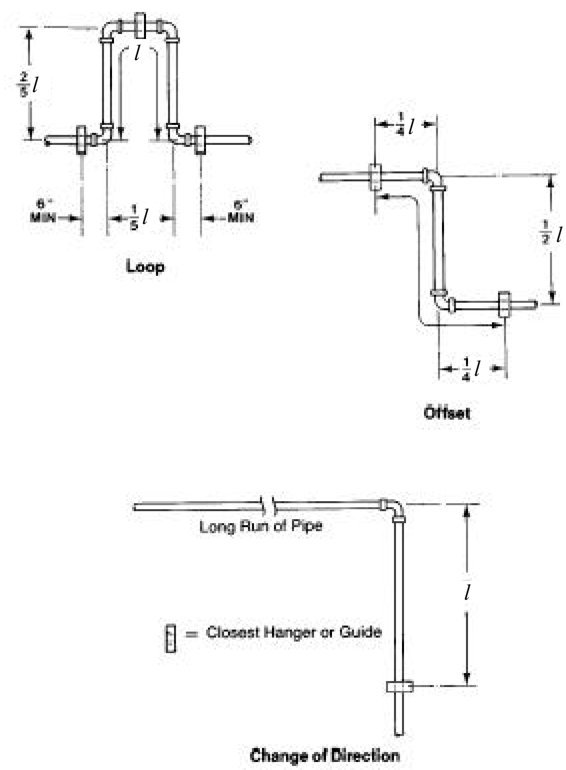
$$\frac{2SI}{lD} = \frac{3EI(\Delta L)}{l^3}$$

Solving for loop length l:

$$l = \left(\frac{3ED(\Delta L)}{2S}\right)^{1/2}$$

FIGURE 4

Expansion Loop and Offset Configurations for Thermoplastics.



SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

THERMAL EXPANSION COMPENSATION
The change in length of Thermoplastic pipe with temperature variation should always be considered when installing pipe lines and provisions made to compensate for this change in length. The following tables have been prepared to assist you in determining this expansion.

TABLE 31 - 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	.11	.22	.32	.43	.54	.65	.76	.86	.97	1.08
40	.14	.29	.43	.58	.72	.86	1.01	1.15	1.30	1.44
50	.18	.36	.54	.72	.90	1.08	1.26	1.40	1.62	1.80
60	.22	.43	.65	.86	1.08	1.30	1.51	1.73	1.94	2.16
70	.25	.50	.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
80	.29	.58	.86	1.15	1.44	1.73	2.02	2.30	2.59	2.88
90	.32	.65	.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100	.36	.72	1.03	1.44	1.80	2.16	2.52	2.88	3.24	3.60

Example: Highest temperature expected— 120°F
Lowest temperature expected— 50°F
Total Change (ΔT) 70°F
Length of run—40 feet
From 70°F row on PVC chart read 1.01 in. length change (ΔL)
NOTE: Table is based on: $\Delta L = 12eL(\Delta T)$

Where: e = Coefficient of Thermal Expansion
= 3.0×10^{-5} in./in.°F
L = Length of Run
ΔT = Temperature Change

TABLE 32 - THERMAL EXPANSION ΔL(in.) — CPVC Schd. 80

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
20	.09	.18	.27	.36	.46	.55	.64	.73	.82	.91
30	.14	.27	.41	.55	.68	.82	.96	1.09	1.23	1.37
40	.18	.36	.55	.73	.91	1.09	1.28	1.46	1.64	1.82
50	.23	.46	.68	.91	1.14	1.37	1.60	1.82	2.05	2.28
60	.27	.55	.82	1.09	1.37	1.64	1.92	2.19	2.46	2.74
70	.32	.64	.96	1.28	1.60	1.92	2.23	2.55	2.87	3.19
80	.36	.73	1.09	1.46	1.82	2.19	2.55	2.92	3.28	3.65
90	.41	.82	1.23	1.64	2.05	2.46	2.87	3.28	3.69	4.10
100	.46	.91	1.37	1.82	2.28	2.74	3.19	3.65	4.10	4.56

TABLE 33 - THERMAL EXPANSION ΔL(in.) — Copoly. Poly.

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
20	.15	.29	.44	.59	.73	.88	1.02	1.17	1.32	1.46
30	.22	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.20
40	.29	.59	.88	1.17	1.46	1.76	2.05	2.34	2.64	2.93
50	.37	.73	1.10	1.46	1.83	2.20	2.56	2.93	3.29	3.66
60	.44	.88	1.32	1.76	2.20	2.64	3.07	3.51	3.95	4.39
70	.51	1.02	1.54	2.05	2.56	3.07	3.59	4.10	4.61	5.12
80	.59	1.17	1.76	2.34	2.93	3.51	4.10	4.68	5.27	5.86
90	.66	1.32	1.98	2.69	3.29	3.95	4.61	5.27	5.93	6.59
100	.73	1.46	2.20	2.93	3.66	4.39	5.12	5.86	6.59	7.32

TABLE 34 - THERMAL EXPANSION ΔL(in.) — PVDF Schedule 80 and Pur-Flo

TEMP. CHANGE ΔT°F	LENGTH OF RUN IN FEET									
	10	20	30	40	50	60	70	80	90	100
20	.19	.38	.58	.77	.96	1.15	1.34	1.54	1.73	1.92
40	.38	.77	1.15	1.54	1.92	2.30	2.69	3.07	3.46	3.84
50	.48	.96	1.44	1.92	2.40	2.88	3.36	3.84	4.32	4.80
60	.58	1.15	1.73	2.30	2.88	3.46	4.03	4.61	5.18	5.76
70	.67	1.34	2.02	2.69	3.36	4.03	4.70	5.38	6.05	6.72
80	.77	1.54	2.30	3.07	3.84	4.61	5.38	6.14	6.91	7.68
90	.86	1.73	2.59	3.46	4.32	5.18	6.05	6.91	7.78	8.64
100	.96	1.92	2.88	3.84	4.80	5.76	6.72	7.68	8.64	9.60

The following expansion loop and offset lengths have been calculated based on stress and modulus of elasticities at the temperature shown below each chart. To calculate the proper length of loop at other temperatures the following formula may be used:

$$l \sqrt{\frac{3E\,(O.D.)\,\Delta L}{2S}}$$

Where:
ΔT = Temperature Change in °F
S = Thermal Stress, psi = e(ΔT)E
E = Modulus of Elasticity (found in relative properties chart on pages 482 and 483)
ΔL = Length Change in inches at ΔT (see tables above)
l = Total Length of Loop or Offset

TABLE 35 - EXPANSION LOOPS AND OFFSET LENGTHS, PVC Type 1, Schedule 40 and 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									
1/2	.840	11	15	19	22	24	27	29	31	32	34
3/4	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 = 3.1×10^5 psi

SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

TABLE 36

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									
1/2	.840	15	21	26	30	33	37	39	42	45	47
3/4	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 180°F.
$\Delta T = 100°F$
$S = 750$ psi
$E = 2.91 \times 10^5$ psi

TABLE 37

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									
1/2	.840	18	25	31	36	40	44	47	50	54	57
3/4	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 180°F.
$\Delta T = 100°F$
$S = 240$ psi
$E = .83 \times 10^5$ lb./in.^{2}

TABLE 38

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									
1/2	.840	10	15	18	20	23	25	27	29	31	32
3/4	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	43	45
1½	1.900	15	22	27	31	34	38	41	44	46	49
2	2.375	17	24	30	34	38	42	46	49	52	54

NOTE: Table based on stress and modulus of elasticity at 180°F.
$\Delta T = 100°F$
$S = 1080$ psi
$E = 1.04 \times 10^5$ psi

SYSTEMS ENGINEERING DATA
FOR THERMOPLASTIC PIPING

These tables are based on:

$F = As$ = restraining force, lbs.
A = Cross sectional wall area, in.²
$S = e(\Delta T)E$*
e = Coefficient of liner expansion*
E = Modulus of elasticity*
ΔT = Temperature change, °F

*All values are available from relative properties chart on pages 482 and 483

TABLE 39

RESTRAINT FORCE "F" (LB.)—PVC Type 1 Schedule 40 and 80.

PIPE SIZE	SCHEDULE 40 PVC			SCHEDULE 80 PVC		
	CROSS SECTIONAL WALL AREA (IN²)	ΔT = 50°F S = 630 PSI	ΔT = 100°F S = 1260 PSI	CROSS SECTIONAL WALL AREA (IN²)	ΔT = 50°F S = 630 PSI	ΔT = 100°F S = 1260 PSI
1/2	.250	155	310	.320	200	400
3/4	.333	210	420	.434	275	550
1	.494	310	620	.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	3,800
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 40

RESTRAINT FORCE "F" (LB.), CPVC Schedule 80

PIPE SIZE	CROSS SECTIONAL WALL AREA (IN.²)	ΔT = 50°F S = 805 PSI	ΔT = 100°F S = 1610 PSI
1/2	.320	260	520
3/4	.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 41

RESTRAINT FORCE "F" (LB.), Copolymer Polypropylene Schedule 80

PIPE SIZE	CROSS SECTIONAL WALL AREA (IN.²)	ΔT = 50°F S = 550 PSI	ΔT = 100°F S = 1110 PSI
1/2	.320	147	294
3/4	.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	2,762
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 42

RESTRAINT FORCE "F" (LB.), PVDF Schedule 80

PIPE SIZE	CROSS SECTIONAL WALL AREA (IN.²)	ΔT = 50°F S = 850 PSI	ΔT = 100°F S = 1700 PSI
1/2	.320	270	540
3/4	.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

TABLE 43

RESTRAINT FORCE "F" (LB.), PVDF

PIPE SIZE	CROSS SECTIONAL WALL AREA (IN.²)	ΔT = 50°F S = 850 PSI	ΔT = 100°F S = 1700 PSI
½	0.167	142	284
¾	0.213	180	360
1	0.346	294	588
1½	0.681	579	1158
2	0.876	745	1490
3	1.791	1522	3044
4	2.706	2300	4600

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 tables for individual material shown below. Note that additional support is required as temperatures increase. Continuous support can be accomplished by the use 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 in. 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, in.
Di = Inside diameter of the pipe, in.

Then:

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

Table 1

SUPPORT SPACING "L" (FT.) - PVC

TEMP °F	NOMINAL PIPE SIZE											
	1/2	3/4	1	1-1/4	1-1/2	2	3	4	6	8	10	12
SCHEDULE 40 PVC												
60	4-1/4	4-1/2	5	5-1/2	5-3/4	6-1/4	7-1/2	8-1/4	9-1/2	10-1/2	11-1/2	12-1/2
100	4	4-1/4	4-3/4	5-1/4	5-1/2	6	7	7-3/4	9	10	11	11-3/4
140	3-3/4	4	4-1/2	5	5-1/4	5-3/4	6-3/4	7-1/2	8-1/2	9-3/4	10-1/2	11-1/4
SCHEDULE 80 PVC												
60	4-1/2	4-3/4	5-1/4	5-3/4	6	6-1/2	8	8-3/4	10-1/2	11-1/2	12-3/4	14
100	4	4-1/2	5	5-1/2	5-3/4	6-1/4	7-1/2	8-1/4	10	11	12-1/4	13-1/4
140	3-3/4	4-1/4	4-3/4	5-1/4	5-1/4	6	7	8	9-1/2	10-1/2	11-1/2	12-1/2

Table 2

SUPPORT SPACING "L" (FT.) - CPVC Schedule 80

TEMP °F	NOMINAL PIPE SIZE											
	1/2	3/4	1	1-1/4	1-1/2	2	3	4	6	8	10	12
73	4	4-1/2	5	5-1/2	5-3/4	6-1/2	7-3/4	8-1/2	10-1/4	11-1/4	12-1/2	13-3/4
100	4	4-1/2	5	5-1/2	5-3/4	6-1/4	7-1/2	8-1/4	10	11	12-1/2	13-1/4
120	4	4-1/4	4-3/4	5-1/4	5-1/2	6-1/4	7-1/2	8-1/4	9-3/4	10-1/2	12	13
140	4	4-1/4	4-3/4	5-1/4	5-1/2	6	7-1/4	8	9-1/2	10-1/2	11-3/4	12-3/4
160	3-3/4	4-1/4	4-1/2	5	5-1/4	5-3/4	7	7-3/4	9-1/4	10-1/4	11-1/2	12-1/2
180	3-3/4	4	4-1/2	5	5-1/4	5-3/4	7	7-1/2	9	10-1/4	11-1/4	12-1/4
210	3-1/2	4	4-1/4	4-3/4	5	5-1/2	6-1/2	7-1/4	8-3/4	9-3/4	10-3/4	11-3/4

ABOVE-GROUND INSTALLATION

OF THERMOPLASTIC PIPING

Table 3

SUPPORT SPACING "L" (FT.) - Polypro Schedule 80

TEMP °F	NOMINAL PIPE SIZE											
	1/2	3/4	1	1-1/4	1-1/2	2	3	4	6	8	10	12
73	3-3/4	4	4-1/2	4-3/4	5	5-1/2	6-1/2	7-1/4	8-1/2	9-1/2	10-1/2	11-1/4
120	3-1/2	3-3/4	4	4-1/2	4-3/4	5	6	6-3/4	8	8-3/4	9-3/4	10-1/2
140	3	3-1/2	3-3/4	4	4-1/4	4-1/2	5-1/2	6	7-1/4	8	8-3/4	9-1/2
160	3	3	3-1/2	3-3/4	4	4-1/4	5-1/4	5-3/4	6-3/4	7-1/2	8-1/4	9
180	2-3/4	3	3-1/4	3-1/2	3-3/4	4	5	5-1/2	6-1/2	7	7-3/4	8-1/2
200	2-1/2	2-3/4	3	3-1/2	3-1/2	4	4-3/4	5-1/4	6	6-3/4	7-1/2	8
212	2-1/2	2-3/4	3	3-1/4	3-1/4	3-3/4	4-1/2	5	5-3/4	6-1/2	7-1/4	7-3/4

Support spacing subject to change with SDR piping systems and different manufacturers' resins. See manufacturers support spacing guide prior to installation.

Table 5

SUPPORT SPACING "L" (FT.) - PVDF Schedule 80

TEMP °F	NOMINAL PIPE SIZE											
	1/2	3/4	1	1-1/4	1-1/2	2	3	4	6	8	10	12
68	3-1/2	3-3/4	4-1/4	4-1/2	4-3/4	5-1/4	6-1/2	7	8-1/2	9-1/2	10-1/2	11-1/4
120	3	3-1/4	3-3/4	4	4-1/4	4-3/4	5-3/4	6-1/4	7-1/2	8-1/4	9-1/4	10
160	2-3/4	3	3-1/2	3-3/4	4	4-1/4	5-1/4	5-3/4	6-3/4	7-1/2	8-1/2	9
200	2-1/2	2-3/4	3	3-1/2	3-1/2	4	4-3/4	5-1/4	6-1/4	7	7-3/4	8-1/4
240	2-1/4	2-1/2	2-3/4	3	3-1/4	3-1/2	4-1/4	4-3/4	5-1/2	6-1/4	7	7-1/2
260	2-1/4	2-1/2	2-3/4	3	3-1/4	3-1/2	4	4-1/2	5-1/2	6	6-3/4	7-1/4
280	2	2-1/4	2-1/2	2-3/4	3	3-1/4	4	4-1/4	5-1/4	5-3/4	6-1/2	7

Support spacing subject to change with SDR piping systems and different manufacturers' resins. See manufacturers support spacing guide prior to installation.

Table 4

SUPPORT SPACING "L"(FT.) - Proline & Super Proline

PIPE SIZE (IN.)	TEMPERATURE						
	68°F/ 20°C	86°F/ 30°C	104°F/ 40°C	122°F/ 50°C	140°F/ 60°C	158°F/ 70°C	176°F/ 80°C
1/2	3.0	2.5	2.5	2.0	2.0	2.0	2.0
3/4	3.0	3.0	2.5	2.5	2.5	2.5	2.0
1	3.5	3.0	3.0	3.0	3.0	2.5	2.5
1-1/2	4.0	3.5	3.0	3.0	3.0	3.0	3.0
2	4.5	4.0	4.0	3.5	3.0	3.0	3.0
2-1/2	5.0	4.5	4.0	4.0	3.5	3.0	3.0
3	5.5	5.0	4.0	4.0	4.0	3.5	3.5
4	6.0	5.0	5.0	4.0	4.0	4.0	4.0
6	7.0	6.0	6.0	5.0	5.0	4.5	4.5
8	7.5	7.0	6.0	6.0	5.5	5.0	5.0
10	8.5	7.5	7.0	6.5	6.0	6.0	5.5
12	9.5	8.5	8.0	7.0	7.0	6.5	6.0
14	10.0	8.5	8.0	7.5	7.0	6.5	6.5
16	10.5	9.5	8.5	8.0	7.5	7.0	6.5
18	11.5	10.0	9.0	8.5	8.0	7.5	7.0
20	12.0	10.5	9.5	8.5	8.5	8.0	7.5
24	13.5	11.5	10.0	9.5	8.5	8.0	7.5

This support spacing chart shows spans for polypropylene (PP) SDR 11, PP SDR 17.6, and PVDF pipes. For PP SDR 32, multiply span times .55 for the reduced value.

The support spacing chart shown above is based on liquids with a specific gravity of 1.0. Spacing should be reduced by 10% for liquids having 1.5 specific gravity, 15% for 2.0 s.g., and 20% for 2.5 s.g.

NOTE: All tables shown are based in .100 inch SAG between supports.

BELOW-GROUND INSTALLATION
OF THERMOPLASTIC PIPING

WIDTH

The width of the trench should be sufficient to provide adequate room for "snaking" the pipe from side to side along the 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 sur-face 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 bounders are present, it is recommended that the trench bottom be cushioned with at least four (4) inches of sand or compacted fine-grained soils.

SNAKING

To compensate for thermal expansion and contraction, the snaking technique of offsetting the pipe with relation to the trench center line is recommended.

Example:

Snaking is particularly Important when laying small diameter pipe in hot weather. For example, a 100-foot length of PVC Type I pipe will expand or contract about ¾" 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". This degree of contraction would put such a strain on newly cemented pipe joints that a poorly made joint might pull apart.

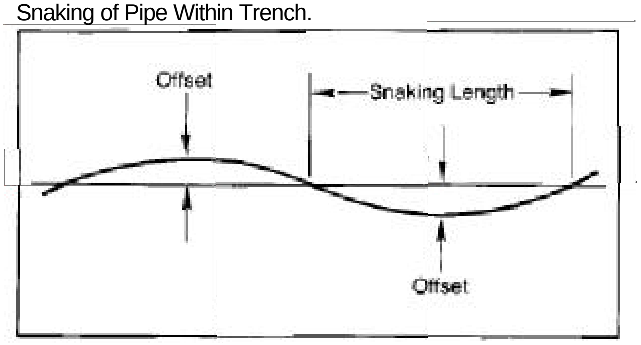
Installation:

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 joints have 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 con-traction after the trench is backfilled. See Figure 1.

Figure 1

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

Snaking of Pipe Within Trench.



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

Table 1

SNAKING LENGTH VS. OFFSET (IN.) TO COMPENSATE FOR THERMAL CONTRACTION

SNAKING LENGTH (FT.)	MAXIMUM TEMPERATURE VARIATION (°F) BETWEEN TIME OF CEMENTING AND FINAL BACKFILLING									
	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

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.

$$Wc' = \frac{\Delta x(EI + .06I\,E'r^3)80}{r^3}$$

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, in.
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 2

LIVE LOAD FOR BURIED FLEXIBLE PIPE (LB/LIN.FT)

PIPE SIZE	H20 WHEEL LOADS FOR VARIOUS DEPTHS OF PIPE (LB./LIN.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	66
12	1601	440	210	120	78

NOTE: H20 wheel load is 16,000 lb./wheel

BELOW-GROUND INSTALLATION
OF THERMOPLASTIC PIPING

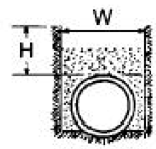
Table 3

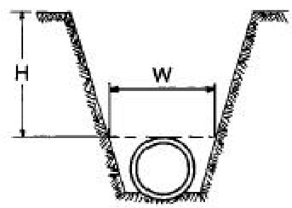
SOIL LOAD AND PIPE RESISTANCE FOR FLEXIBLE THERMOPLASTIC PIPE
PVC Schedule 40 and 80 Pipe

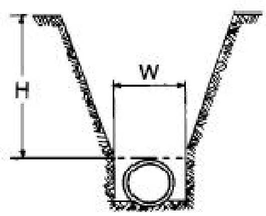
NOM. SIZE (IN.)	Wc' = LOAD RESISTANCE OF PIPE (LB./FT.) SCHEDULE 40 PIPE E'=200	SCHEDULE 40 PIPE E'=700	SCHEDULE 80 PIPE E'=200	SCHEDULE 80 PIPE E'=700	H (FT)	Wc = SOIL LOADS AT VARIOUS TRENCH WIDTHS AT TOP OF PIPE (LB./FT.) 2 FT	3 FT	4 FT	5 FT
1-1/2	1084	1282	2809	2993	10	106	125	136	152
					20	138	182	212	233
					30	144	207	264	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
2-1/2	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	266	394	469
					40	—	394	497	596
3-1/2	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	—	606	639	754
5	896	1511	2272	2861	10	310	370	407	445
					20	396	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	1226	1445
10	976	2198	2597	3764	10	602	710	774	860
					20	785	1032	1204	1317
					30	817	1177	1406	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

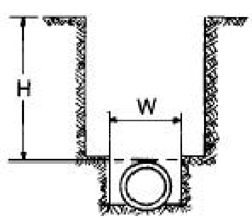
NOTE 1: Figures are calculated from minimum soil resistance values (E' = 200 psi for uncompacted sandy clay loam) and compacted soil (E' = 700 for side-fill that is compacted to 90% or more of Proctor Density for distance of two pipe diameters on each side of the pipe). If Wc' is less than Wc at a given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

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









Note: 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.

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HYDROSTATIC PRESSURE TESTING

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 back-filling which leaves joints exposed. Shallow back-filling eliminates expansion/ contraction problems. The test should last long enough to deter mine that there are no minute leaks anywhere in the system.

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. Since 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 43.

TEST PRESSURE

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

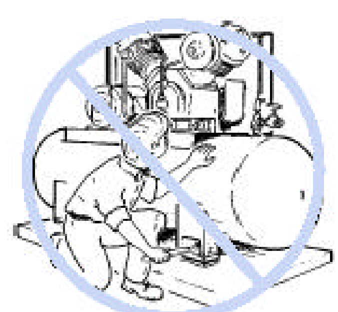
SAFETY PRECAUTIONS

(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. Since the two materials have different coefficients of expansion, the male plastic fitting will actually become tighter within the female metal fitting when expansion occurs.



DO NOT TEST WITH AIR OR COMPRESSED GAS.

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INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

HANDLING & STORAGE OF PLASTIC PIPE

PVC and CPVC are strong, lightweight materials, about one fifth the weight of steel or cast iron. Piping made of this material is easily handled and, as a result, there is a tendency for them to be thrown about on the job site. Care should be taken in handling and storage to prevent damage to the pipe.

PVC and CPVC pipe should be given adequate support at all times. It should not be stacked in large piles, especially in warm temperature conditions, as bottom pipe may become distorted and joining will become difficult.

For long-term storage, pipe racks should be used, providing continuous support along the length. If this is not possible, timber supports of at least 3" bearing width, at spacings not greater than 3' centers, should be placed beneath the piping. If the stacks are rectangular, twice the spacing at the sides is required. Pipe should not be stored more than seven layers high in racks. If different classes of pipe are kept in the same rack, pipe with the thickest walls should always be at the bottom. Sharp corners on metal racks should be avoided.

For temporary storage in the field when racks are not provided, care should be taken that the ground is level and free of sharp objects (i.e. loose stones, etc.). Pipe should be stacked to reduce movement, but should not exceed three to four layers high.

The above recommendations are for a temperature of approximately 80°F. Stack heights should be reduced if higher temperatures are encountered, or if pipe is nested (i.e. pipe stored inside pipe of a larger diameter). Reduction in height should be proportional to the total weight of the nested pipe, compared with the weight of pipe normally contained in such racks.

Since the soundness of any joint depends on the condition of the pipe end, care should be taken in transit, handling and storage to avoid damage to these ends.

The impact resistance and flexibility of PVC and especially CPVC pipe are reduced by lower temperature conditions. The impact strength for both types of piping materials will decrease as temperatures approach 32°F (0°C) and below. Care should be taken when unloading and handling pipe in cold weather. Dropping pipe from a truck or forklift will cause damage. Methods and techniques normally used in warm weather may not be acceptable at the lower temperature range.

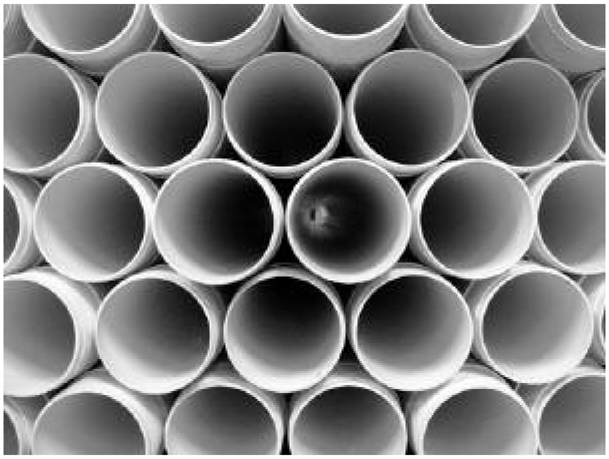
When loading pipe onto vehicles, care should be taken to avoid contact with any sharp corners (i.e. angle irons, nail heads, etc.), as the pipe may be damaged.

While in transit, pipe should be well secured and supported over the entire length and should never project unsecured from the back of a trailer.

Pipe may be off-loaded from vehicles by rolling them gently down timbers, ensuring that they do not fall onto one another or onto a hard, uneven surface.

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 to the pipe during shipping, unloading, storing, and stringing.



INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

JOINING TECHNIQUES

There are six 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- 93. The O.D. of the pipe and the I.D. of the fitting are primed, coated with special cement and joined together, as 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. However, threaded pipe must be derated by 50 percent 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.**

BUTT FUSION

This technique us used to connect all sizes of Poly-propylene (Proline), PVDF (Super Proline) and large diameter Fuseal. Butt fusion is an easy, efficient fusion method especially in larger diameters.

SOCKET FUSION

This technique is used to assemble PVDF and poly-propylene pipe and fittings for high-temperature, corrosive-service applications. (See each material Design Data section for recommended joining technique.)

FUSEAL HEAT FUSION

R & G Sloane's Fuseal is a patented method of elec-trically fusing pipe and fitting into a single homo-genous unit. This advanced technique is used for GF Fuseal polypropylene and PVDF corrosive waste-handling systems.

FUSEAL MECHANICAL JOINT

Mechanical Joint polypropylene drainage system is 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, grab-ring, and nut. It is quick and easy to install and can be disconnected just as easily. You will find it most suitable for under sink and under counter piping.

⚠ WARNING

- NEVER use compressed air or gas in PVC/CPVC/PP/PVDF pipe and fittings.
- NEVER test PVC/CPVC/PP/PVDF pipe and fittings with compressed air or gas, or air-over-water boosters.
- ONLY use PVC/CPVC/PP/PVDF pipe for water and approved chemicals.

Use of compressed air or gas in PVC/CPVC/PP/PVDF pipe and fittings can result in explosive failures and cause severe injury or death.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS
SOLVENT CEMENTING PVC AND CPVC PIPE AND FITTINGS

BASIC PRINCIPLES OF SOLVENT CEMENTING

To make consistently good joints the following should be clearly understood:

I. The joining surfaces must be softened and made semi-fluid.

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

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

4. 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.

Penetrating and softening can be achieved by the use of both primer and cement. A suitable primer will usually penetrate and soften the surfaces more quickly than the cement alone. Additionally, the use of a primer can provide a safety factor for the installer, for he can know, under various temperature conditions, when he has achieved sufficient softening. For example, in cold weather more time and additional applications are required.

PRIMERS AND CEMENTS

Primer
It is recommended that a high quality primer be used to prepare the surfaces of pipe and fittings for solvent welding. Do not use water, rags, gasoline, or any other substitutes for cleaning PVC or CPVC surfaces. A chemical cleaner such as MEK may be used.

Cement
Make sure the solvent cement used is suitable for the type and size of the pipes being installed. PVC cement must be used with PVC pipe and fittings. CPVC cement must be used with CPVC pipe and fittings. Also, cement with the proper viscosity for the type and size of pipe, must be used. Contact the supplier of the cement if there are any questions of the suitability of the cement for the intended application.

Solvent cements are formulated to be used “as received” in original containers. Adding of thinners to change viscosity is not recommended. If the cement is found to be jelly-like and is not free-flowing, it should not be used. Containers should be kept covered when not in actual use.

Solvent cements should be stored at temperatures between 40° F and 110° F and away from heat or open flame. The cements should be used within one year of the date stamped on the container. Stocks should be constantly rotated to prevent buildup of old cement inventories, If new cement is subjected to freezing it may become extremely thick or gelled. This cement can be placed in a warm area where, after a period of time, it will return to its original, usable condition. But such is not the case when gellation has taken place because of actual solvent loss; for example, when container was left open too long during use or not sealed properly after use. Cement in this condition has lost its formulation and should be discarded,

Solvent cements and primers are extremely flammable and should not be used or stored near heat or open flame. They should be used only with adequate ventilation. In confined or partially enclosed areas, a ventilating device should be used to remove vapors and minimize their inhalation. Containers should be kept tightly closed when not in use and covered as much as possible when in use. Avoid frequent contact with the skin. In case of eye contact, flush repeatedly with water. Keep out of reach of children.

Applicators
To properly apply the primer and cement, the correct size and type of applicator must be used. There are three basic types of applicators:

Daubers — should only be used on pipe sizes 2" and below, and should have a width equal to 1/2 the diameter of the pipe.

Brushes — can be used on any diameter pipe, should always have natural bristles and should have a width equal to at least 1/2 the diameter of tile pipe.

Rollers — can be used on 4" and larger diameter pipe and should have a length equal to at least 1/2 the diameter of the pipe.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING PVC AND CPVC PIPE AND FITTINGS

The table below shows the recommended applicator sizes

Table 1

Nominal Pipe Size (in.)	Applicator Type		
	Dauber	Brush Width (in.)	Roller Length (in.)
1/4	A	1/2	NR
3/8	A	1/2	NR
1/2	A	1/2	NR
3/4	A	1	NR
1	A	1	NR
1 1/4	A	1	NR
1 1/2	A	1 - 1 1/2	NR
2	A	1 - 1 1/2	NR
2 1/2	NR	1 1/2 - 2	NR
3	NR	1 1/2 - 2 1/2	NR
4	NR	2 - 3	3
5	NR	3 - 5	3
6	NR	3 - 5	3
8	NR	4 - 6	7
10	NR	6 - 8	7
12	NR	6 - 8	7
14	NR	7 - 8	7
16	NR	8+	8

A = Acceptable NR = Not Recommended

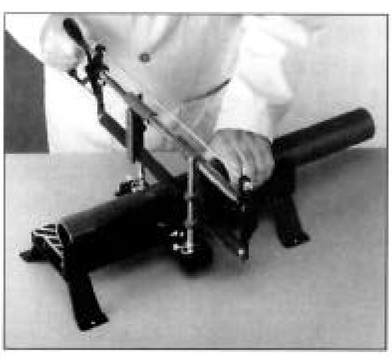
MAKING THE JOINTS

1. Preparation

Before starting to make any joints, the pipe and fittings should be visually inspected for any damage or defects. The fittings should be exposed to the same temperature conditions as the pipe, for at least one hour prior to installation, so that the pipe and fittings are basically at the same temperature when joined.

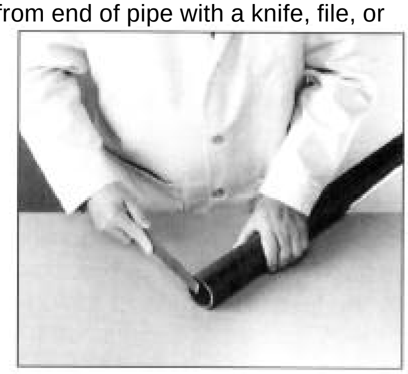
2. Cutting

Cut pipe square using a miter box or a plastic pipe cutting tool which DOES NOT flare up diameter at end of pipe.



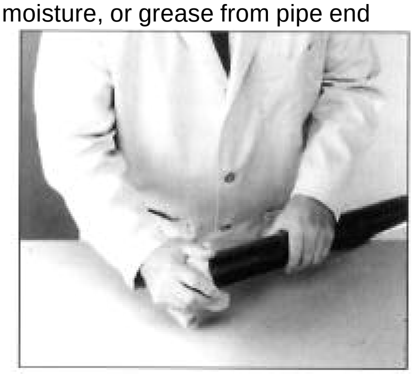
3. Deburring and Chamfering

Remove all burrs from end of pipe with a knife, file, or plastic pipe deburring tool. Chamfer (bevel) the end of the pipe 10°-15° as shown to the right.



4. Cleaning

Remove any dirt, moisture, or grease from pipe end and fitting sockets with a clean dry rag. A chemical cleaner must be used if the wiping fails to clean the surfaces.

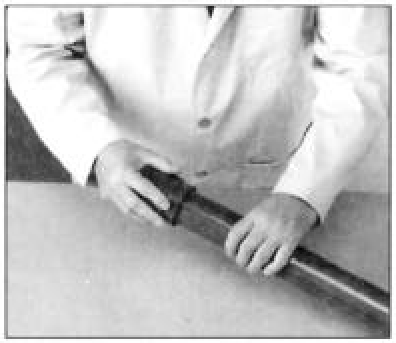


INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING PVC AND CPVC PIPE AND FITTINGS

5. Dry Fitting

Check dry fit of pipe and fitting by inserting pipe into fitting. With light pressure, pipe should easily go at least 1/3 of the way in. If it bottoms, it should be snug.



6. Priming

Using the correct applicator (as shown in chart), apply primer freely to fitting socket, keeping the surface and applicator wet until the surface has been softened. This will usually require 5-15 seconds. More time is needed for hard surfaces and in cold weather conditions. Redip the applicator in primer as required. When the surface is primed, remove any puddles of primer from the socket.

A second application in the socket is recommended if it has unusually hard surfaces. These hard surfaces are often found in bellied-ends and in fittings made from pipe stock.

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 on the fitting socket.

7. Cementing

While the surfaces of the pipe and fitting are still wet with primer, immediately apply a full even layer of cement to the pipe using the proper size applicator shown in chart) equal to the depth of the socket.

Apply a medium layer of cement to the fitting socket. Do not let the cement puddle. Also, when joining belled-end pipe, do not coat beyond the bell depth or allow the cement to run down the inside of the pipe.

Apply a second full even layer of cement to the pipe. Assemble parts QUICKLY! Parts must be assembled while cement is still fluid. If assembly is interrupted, recoat parts and assemble. Push pipe FULLY into fitting, using a turning motion, if possible, of 1/8 to 1/4 turn, until it bottoms. Hold them together for 15 - 30 seconds to offset tendency of pipe to move out of fittings. With a rag, wipe off excess bead of cement from juncture of pipe and fitting.

Note: For pipe sizes 6" and larger, two people will be required, a mechanical forcing device should be used, and the joint should be held together for up to 3 minutes.

JOINT CURING

The joint should not be disturbed until it has initially set. The table below shows the recommended initial set times.

Table 2
Recommended Initial Set Times

Temperature Range	Pipe Sizes 1/2" to 1 1/4"	Pipe Sizes 1 1/2" to 3"	Pipe Sizes 4" to 8"	Pipe Sizes 10" to 16"
60° - 100° F	15 min	30 min	1 hr	2 hr
40° - 60° F	1 hr	2 hr	4 hr	8 hr
0° - 40° F	3 hr	6 hr	12 hr	24 hr

The joint should not be pressure tested until it has cured. The exact curing time varies with temperature, humidity, and pipe size. The following table shows suggested curing times.

Table 3
Recommended Curing Time Before Pressure Testing

RELATIVE HUMIDITY 60% or Less*	CURE TIME Pipe Sizes 1/2" to 1 1/4"		CURE TIME Pipe Sizes 1 1/2" to 3"		CURE TIME Pipe Sizes 4" to 8"		CURE TIME Pipe Sizes 10" to 16"
Temperature Range During Assembly and Cure Periods	Up to 180 psi	Above 180 to 370 psi	Up to 180 psi	Above 180 to 315 psi	Up to 180 psi	Above 180 to 315 psi	Up to 100 psi
60° - 100° F	1 hr	6 hr	2 hr	12 hr	6 hr	24 hr	24 hr
40° - 60° F	2 hr	12 hr	4 hr	24 hr	12 hr	48 hr	48 hr
0° - 40° F	8 hr	48 hr	16 hr	96 hr	48 hr	8 days	8 days

*For relative humidity above 60%, allow 50% more cure time.

The above data are based on laboratory tests and are intended as guidelines.
For more specific information, contact should be made with the cement manufacturer.

Pressure Testing

1. Prior to testing, safety precautions should be instituted to protect personnel and property in case of test failure,

2. Conduct pressure testing with water. DO NOT USE AIR OR OTHER GASES for pressure testing.

3. The piping system should be adequately anchored to limit movement. The system may require thrust blocking at changes of direction.

4. The piping system should be slowly filled with water, taking care to prevent surge and air entrapment. The flow velocity should not exceed 1 foot per second (see charts on pages 24-29).

5. All trapped air must be slowly released. Vents must be provided at all high points of the piping system. All valves and air relief mechanisms should be opened so that the air can be vented while the system is being filled. Trapped air is extremely dangerous and it must be slowly and completely vented prior to testing.

6. The piping system can be pressurized to 125% of its designed working pressure. However, care must be taken to ensure the pressure does not exceed the working pressure of the lowest rated component in the system (valves, unions, flanges, threaded parts, etc.)

7. The pressure test should not exceed one hour. Any leaking joints or pipe must be cut out and replaced and the line recharged and retested using the same procedure.

INSTALLATION OF THERMOPLASTIC PIPING SYSTEMS

SOLVENT CEMENTING PVC AND CPVC PIPE AND FITTINGS

TIPS TO FOLLOW IN SOLVENT CEMENTING DURING COLD WEATHER:

1. Prefabricate as much of the system as is possible in a heated working area.
2. Store cements and primers in a warmer area when not in use and make sure they remain fluid.
3. Take special care to remove moisture, including ice and snow.
4. Use extra primer to soften the joining surfaces before applying cement.
5. Allow a longer initial set and cure period before the joint is moved or the system is tested.
6. 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.

PHYSICAL DATA
P-70 PRIMER FOR PVC AND CPVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=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

SOLUBILITY IN WATER 100%

APPEARANCE AND ODOR - Purple Color, - Ethereal Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Left	Used
(T.C.C.) 6°F		1.8	11.8

EXTINGUISHING MEDIA
Dry chemical Carbondioxide - 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 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.920 ±0.02
VAPOR PRESSURE (mm Hg.) THF @ 25°C	190	PERCENT, VOLATILE BY VOLUME (%) APPROX.	85 to 90%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPROX.	5.5 to 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipitates

APPEARANCE AND ODOR - Clear Thin syrupy liquid, Ethereal odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Left	Used
(T.O.C.) 10°F		1.8	1.8

EXTINGUISHING MEDIA
Dry chemical Carbondioxide - 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
711 GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.958± 0.008
VAPOR PRESSURE (mm Hg.) THF @ 25°C	190	PERCENT, VOLATILE BY VOLUME (%) APPROX.	90%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPROX.	5.0 to 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipitates

APPEARANCE AND ODOR - Gary color, medium syrupy liquid - Ethereal Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Left	Used
(T.O.C.) 8°F	% in Air	2.0	11.8

EXTINGUISHING MEDIA
Dry chemical, Carbondioxide - 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
719 GRAY CEMENT FOR PVC

BOILING POINT (°F) Based on 1st boiling Comp. THF.	151°F	SPECIFIC GRAVITY (H_2O=1)	0.009 ±0.004
VAPOR PRESSURE (mm Hg.) THF @	190	PERCENT, VOLATILE BY VOLUME (%)	80%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) APPORX. Initial	5 - 8

SOLUBILITY IN WATER Solvent portion PVC resin & filler - Precipitates

APPEARANCE AND ODOR - Gray color, paste like, Ethereal Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Left	Used
(T.C.C.) 8°F		2	11.8

EXTINGUISHING MEDIA
Carbondioxide, Dry chemicals

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) The lowest boiling point	151°	SPECIFIC GRAVITY (H_2O=1)	
VAPOR PRESSURE (mm Hg.) THF @ 25	190	PERCENT, VOLATILE BY VOLUME (%)	85-90%
VAPOR DENSITY (AIR = 1) APPROX.	2.49	EVAPORATION RATE (BUAC = 1) Initially	8.0

SOLUBILITY IN WATER Resin precipates

APPEARANCE AND ODOR -Gray color, Medium syrupy liquid - Ethereal Odor

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Left	Used
(T.O.C.) 6°F		1.8 %	11.8%

EXTINGUISHING MEDIA
Dry chemical, Carbondioxide - 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.

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.

CORR TECH INCORPORATED

THREADING INSTRUCTIONS
PVC AND CPVC PIPE

Only Schedule 80 Pvc and CPVC pipe can be safely threaded. Schedule 40 PVC and CPVC pipe and PVC SDR pipe should **not** be threaded.

Due to the reduction in wall thickness at the point of threading, the pressure rating of the pipe is reduced by 50%. Therefore, threaded connections are not recommended for high pressure applications.

THREADING PROCEDURE

1. Cutting
The pipe must be cut square using a power saw, a miter box, or a plastic pipe cutter. Burrs should be removed using a knife or deburring tool.

2. Threading
Threads can be cut using either hand held or power threading equipment. The cutting dies should be clean, sharp, and in good condition. Special dies for cutting plastic pipe are available and are recommended.

When using a hand threader, the dies should have a 5° to 10° negative front rake. When using a power threader, the dies should have a 5° negative front rake and the die heads should be self-opening. A slight chamfer to lead the dies will speed production. However, the dies should not be driven at high speeds or with heavy pressure.

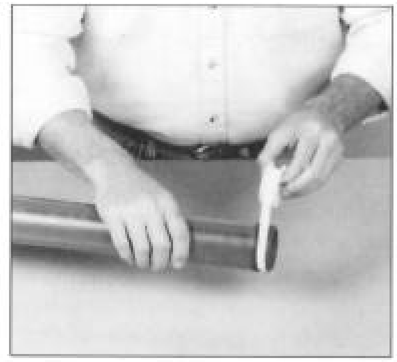
When using a hand held threader, the pipe should be held in a pipe vise. To prevent crushing or scoring of the pipe, a protective wrap such as emery paper, canvas, rubber, or a light metal sleeve should be used.

Insert a tapered plug into the end of the pipe to be threaded. This plug will provide additional support and prevent distortion of the pipe in the threading area.

It is recommended that a cutting lubricant, such as a soap and water solution or a water soluble machine oil, be used during the threading operation. Also, clearing the cuttings from the die is highly recommended.

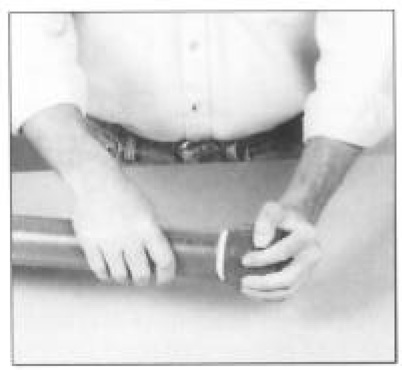
Do not over-thread the pipe. The diagram and table on the following page show the ASTM F 1498 dimensions for American Standard Taper Pipe Threads. Periodically check the threads with a ring gauge to ensure that the threads are accurate. The tolerance is ±11/2 turns.

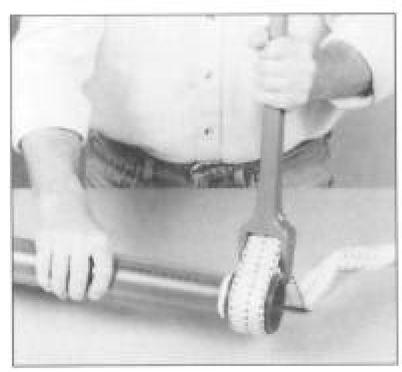
3. Installation
Brush the threads clean and wrap PTFE thread tape around the entire length of the threads.[1] Start with the second full thread and wrap in the direction of the threads to prevent unraveling when the fitting is tightened onto the pipe. Overlap each wrap by one half the width of the tape.



[1] Pipe joint compounds, pastes, or other thread lubricants are **not** recommended for use with PVC and CPVC pipe.

Thread the fitting onto the pipe and hand tighten. Further tighten the fitting (one to two turns past hand tight) by using a strap wrench only. Avoid over tightening as this may cause thread or fitting damage. When combining plastic and metallic threaded systems, it is recommended that plastic male threads be screwed into metallic female threads rather than metallic male threads into plastic female threads.





THREADING INSTRUCTIONS

PVC - CPVC - PP - PVDF

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:

DO NOT THREAD SCHEDULE 40 PIPE

Taper Pipe Thread Dimensions Diagram

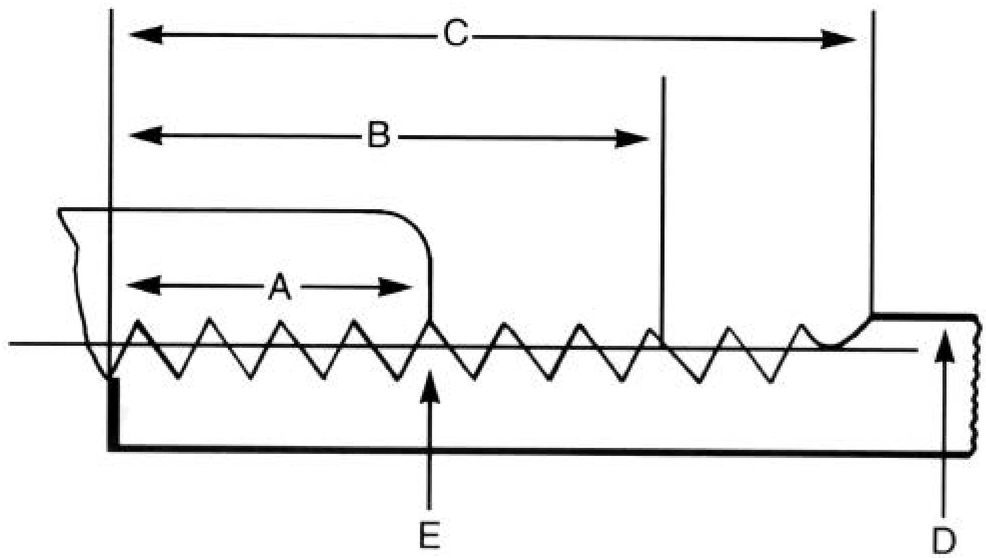


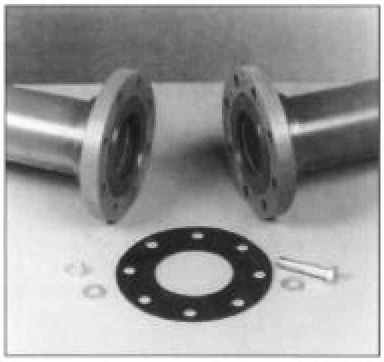
Table 4

PIPE		THREADS					
Nominal Size In Inches	Outside Diameter In Inches (D)	Number of Threads Per Inch	Normal Engagement By Hand In Inches (A)	Length of Effective Thread In Inches (B)	Total Length: End of Pipe to Vanish Point In Inches (C)	Pitch Diameter at end of Internal Thread In Inches (E)	Maximum Depth of Thread In Inches
1/4	.540	18	.228	.4018	.5946	.49163	.04444
3/8	.675	18	.240	.4078	.6006	.62701	.04444
1/2	.840	14	.320	.5337	.7815	.77843	.05714
3/4	1.050	14	.339	.5457	.7935	.98887	.05714
1	1.315	11 1/2	.400	.6828	.9845	1.23863	.06957
1 1/4	1.660	11 1/2	.420	.7068	1.0085	1.58338	.06957
1 1/2	1.900	11 1/2	.420	.7235	1.0252	1.82234	.06957
2	2.375	11 1/2	.436	.7565	1.0582	2.29627	.06957
2 1/2	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

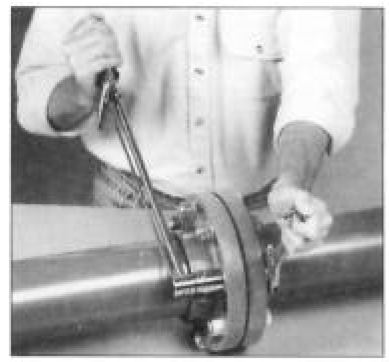
FLANGING

PVC AND CPVC PIPE

For systems where dismantling is required, flanging is a convenient joining method. It is also an easy way to join plastic and metallic systems.



5. Use a torque wrench to tighten the bolts to the torque values shown below.



INSTALLATION

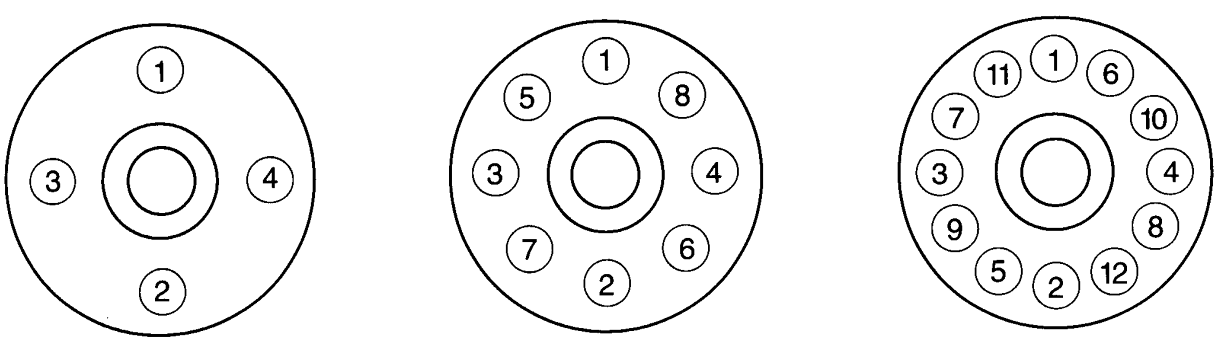
1. Join the flange to the pipe using the procedures shown in the solvent cementing or threading sections (see pages 43-49).
2. Use a full faced elastomeric gasket which is resistant to the chemicals being conveyed in the piping system. A gasket 1/8" thick with a Durometer, scale "A", hardness of 55 -80 is normally satisfactory.
3. Align the flanges and gasket by inserting all of the bolts through the mating flange bolt holes. Be sure to use properly sized flat washers under all bolt heads and nuts.
4. Sequentially tighten the bolts corresponding to the patterns shown below.

RECOMMENDED TORQUE

Table 5

Pipe Size In Inches	No. Bolt Holes	Bolt Diameter	Recommended Torque ft/lbs
1/2	4	1/2	10 - 15
3/4	4	1/2	10 - 15
1	4	1/2	10 - 15
1 1/4	4	1/2	10 - 15
1 1/2	4	1/2	10 - 15
2	4	5/8	20 - 30
2 1/2	4	5/8	20 - 30
3	4	5/8	20 - 30
4	8	5/8	20 - 30
6	8	3/4	33 - 50
8	8	3/4	33 - 50
10	12	7/8	53 - 75
12	12	7/8	53 - 75

FLANGE BOLT TIGHTENING PATTERNS



FLANGED JOINTS

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 6

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 2-1/2, 3 and 4-inch threaded must be back welded for the above pressure capability to be applicable.

** Threaded PP flanges size 1/2 through 4" as well as the 6" back weld socket flange are not recommended for pressure applications (drainage only).

CONVERSION CHARTS

PRESSURE CONVERSION

MULTIPLY GIVEN NUMBER OF

BY FACTOR TO OBTAIN

Given	lb./in.²	in.H_2O (at +39.2°F)	cmH_2O (at +4°C)	in. Hg (at +32°F)	mm Hg (Torr) (at 0°C)	dyne/cm² (1μ bar)	newton/m² (PASCAL)	kgm/cm²	bar	atm. (A_n)	lb./ft.²	ft.H_2O (at +39.2°F)
lb./in.2	1.000	2.7680×10^{1}	7.0308×10^{1}	2.0360	5.1715×10^{1}	6.8948×10^{4}	6.8948×10^{3}	7.0306×10^{-2}	6.8947×10^{-2}	6.8045×10^{-2}	1.4400×10^{2}	2.3067
in.H_2O (at +39.2°F)	3.6127×10^{-2}	1.0000	2.5400	7.3554×10^{-2}	1.8683	2.49808×10^{3}	2.4908×10^{2}	2.5399×10^{-3}	2.4908×10^{-3}	2.4582×10^{-3}	5.2022	8.3333×10^{-2}
cm H_2O (at +4°C)	1.4223×10^{-2}	0.3937	1.0000	2.8958×10^{-2}	0.7355	9.8064×10^{2}	9.8064×10^{1}	9.9997×10^{-4}	9.8064×10^{-4}	9.6781×10^{-4}	2.0481	3.2808×10^{-2}
in. Hg (at +32°F)	4.9116×10^{-1}	1.3596×10^{1}	3.4532×10^{1}	1.0000	2.5400×10^{1}	3.3864×10^{4}	3.3864×10^{3}	3.4532×10^{-2}	3.3864×10^{-2}	3.3421×10^{-2}	7.0727×10^{1}	1.1330
mm Hg (Torr) (at 0°C)	1.9337×10^{-2}	5.3525×10^{-1}	1.3595	3.9370×10^{-2}	1.0000	1.3332×10^{3}	1.3332×10^{2}	1.3595×10^{-3}	1.3332×10^{-3}	1.3158×10^{-3}	2.7845	4.4605×10^{-2}
dyne/cm² (1μ bar)	1.4504×10^{-5}	4.0147×10^{-4}	1.0197×10^{-3}	2.9530×10^{-5}	7.5006×10^{-4}	1.0000	1.0000×10^{-1}	1.0197×10^{-6}	1.0000×10^{-6}	9.8692×10^{-7}	2.0886×10^{-3}	3.3456×10^{-5}
newton/m² (PASCAL)	1.4504×10^{-4}	4.0147×10^{-3}	1.0197×10^{-2}	2.9530×10^{-4}	7.5006×10^{-3}	1.0000×10^{1}	1.0000	1.0197×10^{-5}	1.0000×10^{-5}	9.8692×10^{-6}	2.0885×10^{-2}	3.3456×10^{-4}
kgm/cm²	1.4224×10^{1}	3.9371×10^{2}	1.00003×10^{3}	2.8959×10^{1}	7.3556×10^{2}	9.8060×10^{5}	9.8060×10^{4}	1.0000	9.8060×10^{-1}	9.678×10^{-1}	2.0482×10^{3}	3.2809×10^{1}
bar	1.4504×10^{1}	4.0147×10^{2}	1.0197×10^{3}	2.9530×10^{1}	7.5006×10^{2}	1.0000×10^{6}	1.0000×10^{5}	1.0197	1.0000	9.8692×10^{-1}	2.0885×10^{3}	3.3456×10^{1}
atm. (A_n)	1.4696×10^{1}	4.0679×10^{2}	1.0333×10^{3}	2.9921×10^{1}	7.6000×10^{2}	1.0133×10^{6}	1.0133×10^{5}	1.0332	1.0113	1.0000	2.1162×10^{3}	3.3900×10^{1}
lb./ft.²	6.9445×10^{-3}	1.9223×10^{-1}	4.882×10^{-1}	1.4139×10^{-2}	3.591×10^{-1}	4.7880×10^{2}	4.7880×10^{1}	4.8824×10^{-4}	4.7880×10^{-4}	4.7254×10^{-4}	1.0000	1.6019×10^{-2}
ft. H_2O (at +39.2°F)	4.3352×10^{-1}	1.2000×10^{1}	3.0480×10^{1}	8.826×10^{-1}	2.2419×10^{1}	2.9890×10^{4}	2.9890×10^{3}	3.0479×10^{-2}	2.9890×10^{-2}	2.9499×10^{-2}	6.2427×10^{1}	1.0000

DECIMAL AND MILLIMETER EQUIVALENTS OF FRACTIONS

Inches		Milli-meters	Inches		Milli-meters	Inches		Milli-meters	Inches		Milli-meters
Fractions	Decimals		Fractions	Decimals		Fractions	Decimals		Fractions	Decimals	
1/64	.015625	.397	17/64	.265625	6.747	33/64	.515625	13.097	49/64	.765625	19.447
1/32	.03125	.794	9/32	.28125	7.144	17/32	.53125	13.494	25/32	.78125	19.844
3/64	.046875	1.191	19/64	.296875	7.541	35/64	.546875	13.891	51/64	.796875	20.241
1/16	.0625	1.588	5/16	.3125	7.938	9/16	.5625	14.288	13/16	.8125	20.638
5/64	.078125	1.984	21/64	.328125	8.334	37/64	.578125	14.684	53/64	.828125	21.034
3/32	.09375	2.381	11/32	.34375	8.731	19/32	.59375	15.081	27/32	.83475	21.431
7/64	.109375	2.778	23/64	.359375	9.128	39/64	.609375	15.478	55/64	.859375	21.828
1/8	.125	3.175	3/8	.375	9.525	5/8	.625	15.875	7/8	.875	22.225
9/64	.140625	3.572	25/64	.390625	9.922	41/64	.640625	16.272	57/64	.890625	22.622
5/32	.15625	3.969	13/32	.40625	10.319	21/32	.65625	16.669	29/32	.90625	23.019
11/64	.171875	4.366	27/64	.421875	10.716	43/64	.671875	17.066	59/64	.921875	23.416
3/16	.1875	4.763	7/16	.4375	11.113	11/16	.6875	17.463	15/16	.9375	23.813
13/64	.203125	5.159	29/64	.453125	11.509	45/64	.703125	17.859	61/64	.953125	24.209
7/32	.21875	5.556	15/32	.46875	11.906	23/32	.71875	18.256	31/32	.96875	24.606
15/64	.23475	5.953	31/64	.484375	12.303	47/64	.734375	18.653	63/64	.984375	25.003
1/4	.250	6.350	1/2	.500	12.700	3/4	.750	19.050	1	1.000	25.400

CONVERSION CHARTS

Units of Length	Multiply units in left column by proper factor below							
	in.	ft.	yd.	mile	mm	cm	m	km
1 inch	1	0.0833	0.0278	-	25.4	2.540	0.0254	-
1 foot	12	1	0.3333	-	304.8	30.48	0.3048	-
1 yard	36	3	1	-	914.4	91.44	0.9144	-
1 mile	-	5280	1760	1	-	-	1609.3	1.609
1 millimeter	0.0394	0.0033	-	-	1	0.100	0.001	-
1 centimeter	0.3937	0.0328	0.0109	-	10	1	0.01	-
1 meter	39.37	3.281	1.094	-	1000	100	1	0.001
1 kilometer	-	3281	1094	0.6214	-	-	1000	1

(1 micron = 0.001 millimeter)

Units of Weight	Multiply units in left column by proper factor below						
	grain	oz.	lb.	ton	gram	kg	metric ton
1 grain	1	-	-	-	0.0648	-	-
1 ounce	437.5	1	0.0625	-	28.35	0.0283	-
1 pound	7000	16	1	0.0005	453.6	0.4536	-
1 ton	-	32,000	2000	1	-	907.2	0.9072
1 gram	15.43	0.0353	-	-	1	0.001	-
1 kilogram	-	35.27	2.205	-	1000	1	0.001
1 metric ton	-	35,274	2205	1.1023	-	1000	1

Units of Density	Multiply units in left column by proper factor below				
	lb./in.^{3}	lb./ft.^{3}	lb./gal.	g/cm^3	g/liter
1 pound/in.^{3}	1	1728	231.0	27.68	27,680
1 pound/ft.^{3}	-	1	0.1337	0.0160	16.019
1 pound/gal.	0.00433	7.481	1	0.1198	119.83
1 gram/cm^3	0.0361	62.43	8.345	1	1000.0
1 gram/liter	-	0.0624	0.00835	0.001	1

Units of Area	Multiply units in left column by proper factor below						
	in.^{2}	ft.^{2}	acre	mile^2	cm^2	m^2	hectare
1 inch^2	1	0.0069	-	-	6.452	-	-
1 foot^2	144	1	-	-	929.0	0.0929	-
1 acre	-	43,560	1	0.0016	-	4047	0.4047
1 mile^2	-	-	640	1	-	-	259.0
1 centimeter^2	0.1550	-	-	-	1	0.0001	-
1 meter^2	1550	10.76	-	-	10,000	1	-
1 hectare	-	-	2.471	-	-	10,000	1

Units of Volume	Multiply units in left column by proper factor below							
	in.^{3}	ft.^{3}	yd.^{3}	cm.^{3}	meter^3	liter	U.S. gal.	Imp. gal.
1 inch^3	1	-	-	16.387	-	0.0164	-	-
1 foot^3	1728	1	0.0370	28,317	0.0283	28.32	7.481	6.229
1 yard^3	46,656	27	1	-	0.7646	764.5	202.0	168.2
1 centimeter^3	0.0610	-	-	1	-	0.0010	-	-
1 meter^3	61,023	35.31	1.308	1,000,000	1	999.97	264.2	220.0
1 liter	61.025	0.0353	-	1000.028	0.0010	1	0.2642	0.2200
1 U.S. gallon	231	0.1337	-	3785.4	-	3.785	1	0.8327
1 Imp. gallon	277.4	0.1605	-	4546.1	-	4.546	1.201	1

CONVERSION CHARTS

Units of Pressure	Multiply units in left column by proper factor below						
	lbs./in.^{2}	lb./ft.^{2}	Int. etc.	kg/cm^2	mm Hg at 32°F	in. Hg at 32°F	ft. water at 39.2°F
1 pound/in.^{2}	1	144	-	0.0703	51.713	2.0359	2.307
1 pound/ft.^{2}	0.00694	1	-	-	0.3591	0.01414	0.01602
1 in./cm/atmosphere	14.696	2116.2	1	1.0333	760	29.921	33.90
1 kilogram/centimeter^2	14.223	2048.1	0.9678	1	735.56	28.958	32.81
1 millimeter-mercury - 1 torr (torricelli)-	0.0193	2.785	-	-	1	0.0394	0.0446
1 inch mercury	0.4912	70.73	0.0334	0.0345	25.400	1	1.133
1 foot water	0.4335	62.42	-	0.0305	22.418	0.8826	1

Units of Energy	Multiply units in left column by proper factor below					
	ft.-lb.	BTU	g. cal.	Joule	kw-hr.	hp-hr.
1 foot-pound	1	0.001285	0.3240	1.3556	-	-
1 BTU	778.2	1	252.16	1054.9	-	-
1 gram calorie	3.0860	0.003966	1	4.1833	-	-
1 Int. Joule	0.7377	0.000948	0.2390	1	-	-
1 Int. kilowatt-hour	2,655,656	3412.8	860,563	-	1	1.3412
1 horsepower-hour	1,980,000	2544.5	641,617	-	0.7456	1

Units of Specific Pressure	Multiply units in left column by proper factor below				
	Absolute Joule/g	Int. Joule/g	cal/g	Int. cal/g	BTU/lb.
1 absolute Joule/gram	1	0.99984	0.23901	0.23885	0.42993
1 Int. Joule/gram	1.000165	1	0.23904	0.23892	0.43000
1 calorie/gram	4.1840	4.1833	1	0.99935	1.7988
1 int. calorie/gram	4.1867	4.1860	1.00065	1	1.8000
1 BTU/lb.	2.3260	2.3256	0.55592	0.55556	1

Units of Power (rates of energy use)	Multiply units in left column by proper factor below							
	hp	watt	kw	BTU/min.	ft.-lb./sec.	ft.-lb./min.	g. cal/sec.	metric hp
1 horsepower	1	75.7	0.7475	42.41	550	33.000	178.2	1.014
1 watt	-	1	0.001	0.0569	0.7376	44.25	0.2390	0.00136
1 kilowatt	1.3410	1000	1	56.88	737.6	44,254	239.0	1.360
1 BTU per minute	-	-	-	1	12.97	778.2	4.203	0.0239
1 metric hp	0.9863	735.5	0.7355	41.83	542.5	32.550	175.7	1

Units of Refrigeration	Multiply units in left column by proper factor below					
	BTU (IT) /min.	BTU (IT) /hr.	kg cal/hr.	ton (U.S.) comm	ton (Brit.) comm	Frigorie/hr.
1 ton (U.S.) comm	200	12,000	3025.9	1	0.8965	3025.9
1 ton (Brit.) comm	223.08	13,385	3375.2	1.1154	1	3375.2
1 frigorie/hr.	0.06609	3.9657	1	0.0003305	0.0002963	1

NOTE: BTU is International Steam Table BTU (IT).
1 frigorie = 1 kg cal. (IT)

CONVERSION CHARTS

TemperatureConversion

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
-459.4	-273	1	-17.2	61	16.1	300	149	900	482
-450	-268	2	-16.7	62	16.7	310	154	910	488
-440	-262	3	-16.1	63	17.2	320	160	920	493
-430	-257	4	-15.6	64	17.8	330	166	930	499
-420	-251	5	-15.0	65	18.3	340	171	940	504
-410	-246	6	-14.4	66	18.9	350	177	950	510
-400	-240	7	-13.9	67	19.4	360	182	960	516
-390	-234	8	-13.3	68	20.0	370	188	970	521
-380	-229	9	-12.8	69	20.6	380	193	980	527
-370	-223	10	-12.2	70	21.1	390	199	990	532
-360	-218	11	-11.7	71	21.7	400	204	1000	538
-350	-212	12	-11.1	72	22.2	410	210	1020	549
-340	-207	13	-10.6	73	22.8	420	215	1040	560
-330	-201	14	-10.0	74	23.3	430	221	1060	571
-320	-196	15	-9.4	75	23.9	440	227	1080	582
-310	-190	16	-8.9	76	24.4	450	232	1100	593
-300	-184	17	-8.3	77	25.0	460	238	1120	604
-290	-179	18	-7.8	78	25.6	470	243	1140	616
-280	-173	19	-7.2	79	26.1	480	249	1160	627
-273	-169	20	-6.7	80	26.7	490	254	1180	638
-270	-168	21	-6.1	81	27.2	500	260	1200	649
-260	-162	22	-5.6	82	27.8	510	266	1220	660
-250	-157	23	-5.0	83	28.3	520	271	1240	671
-240	-151	24	-4.4	84	28.9	530	277	1260	682
-230	-146	25	-3.9	85	29.4	540	282	1280	693
-220	-140	26	-3.3	86	30.0	550	288	1300	704
-210	-134	27	-2.8	87	30.6	560	293	1350	732
-200	-129	28	-2.2	88	31.1	570	299	1400	760
-190	-123	29	-1.7	89	31.7	580	304	1450	788
-180	-118	30	-1.1	90	32.2	590	310	1500	816
-170	-112	31	-0.6	91	32.8	600	316	1550	843
-160	-107	32	0.0	92	33.3	610	321	1600	871
-150	-101	33	0.6	93	33.9	620	327	1650	899
-140	-96	34	1.1	94	34.4	630	332	1700	927
-130	-90	35	1.7	95	35.0	640	338	1750	954
-120	-84	36	2.2	96	35.6	650	343	1800	982
-110	-79	37	2.8	97	36.1	660	349	1850	1010
-100	-73	38	3.3	98	36.7	670	354	1900	1038
-90	-68	39	3.9	99	37.2	680	360	1950	1066
-80	-62	40	4.4	100	37.8	690	366	2000	1093
-70	-57	41	5.0	110	43	700	371	2050	1121
-60	-51	42	5.6	120	49	710	377	2100	1149
-50	-46	43	6.1	130	54	720	382	2150	1177
-40	-40	44	6.7	140	60	730	388	2200	1204
-30	-34	45	7.2	150	66	740	393	2250	1232
-20	-29	46	7.8	160	71	750	399	2300	1260
-10	-23	47	8.3	170	77	760	404	2350	1288
0	-17.8	48	8.9	180	82	770	410	2400	1316
		49	9.4	190	88	780	416	2450	1343
		50	10.0	200	92	790	421	2500	1371
		51	10.6	210	99	800	427	2550	1399
		52	11.1	212	100	810	432	2600	1427
		53	11.7	220	104	820	438	2650	1454
		54	12.2	230	110	830	443	2700	1482
		55	12.8	240	116	840	449	2750	1510
		56	13.3	250	121	850	454	2800	1538
		57	13.9	260	127	860	460	2850	1566
		58	14.4	270	132	870	466	2900	1593
		59	15.0	280	138	880	471	2950	1621
		60	15.6	290	143	890	477	3000	1649

The following formulas may also be used for converting Centigrade or Fahrenheit degrees into the other scales.

Degrees Cent. $°C = \frac{5}{9}(°F - 32)$

Degrees Fahr. $°F = \frac{9}{5}\,°C + 32$

Degrees Kelvin $°T = °C + 273.2$

Degrees Rankine $°R = °F + 459.7$

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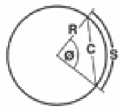
FORMULAS

Circle



Circumference = $\pi D = 2\pi R$

Area = πR^2

Length of Arc, S = Ø R

Length of Cord, C = 2 R sine (Ø / 2)

Area of Sector = (R S) / 2

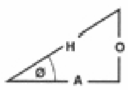
Ø = Angle in Radians

Quadratic Equation

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$ax^2 = bx = c = 0$

Trig Functions



sine Ø = O / H

cosine Ø = A / H

tan Ø = O / A

Pressure Rating

$\frac{2S}{P} = \frac{OD - T}{T}$ $\frac{2S}{P} = \frac{ID + T}{T}$

S = Design Stress

T = Minimum Wall thickness

P = Pressure Rating

Pipe Stiffnes

$PS = 4.47 \times \frac{E}{(SDR - 1)^3}$

E = Tensile Modulus, psi

Moment of Inertia (pipe)

$= (\pi / 64) \times (OD^4 - ID^4)$

Pipe Weight (kg/m)

= (OD – T) x T x 0.003134 x SG

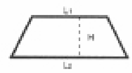
= (ID + T) x T x 0.003134 x SG

OD & ID are average dimensions, mm

T = Average Wall Thickness, mm

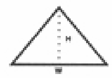
SG = Specific Gravity @ 73°F

Trapezoid



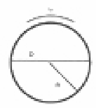
$A = H \times \frac{L_1 + L_2}{2}$

Triangle



$A = \frac{W \times H}{2}$

Circle



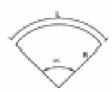
A = 3.142 x R x R

C = 3.142 x D

$R = \frac{D}{2}$

D = 2 x R

Sector of Circle



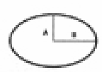
$A = \frac{3.142 \times R \times R \times \alpha}{360}$

$L = .01745 \times R \times \alpha$

$\alpha = \frac{L}{.01745 \times R}$

$R = \frac{L}{.01745 \times \alpha}$

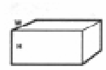
Ellipse



A = 3.142 x A x B

$C = 3.142 \sqrt{2 (A^2 + B^2)}$

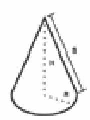
Rectangular Solid



A = 2 [W x L + L x H + H x W]

V = W x L x H

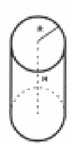
Cone



A = 3.142 x R x S + 3.142 x R x R

V = 1.047 x R x R x H

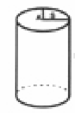
Cylinder



A = 6.283 x R x H + 6.283 x R x R

V = 3.142 x R x R x H

Elliptical



V = 3.142 x A x B x H

$A = 6.282 \times \sqrt{\frac{A_2 + B_2}{2}} \times H + 6.283 \times A \times B$

Sphere

A = 12.56 x R x R

V = 4.188 x R x R x R

For above containers:

Capacity in gallons = $\frac{V}{231}$ when V is in cubic inches.

Capacity in gallons = 7.48 x V when V is in cubic feet.

Flow Coefficients Conversion Factors

TO / FROM	Cv	Kv	Kv_{100}	f	Av
	MULTIPLY BY				
Cv	1	0.865	14.28	0.84	24×10^{-6}
Kv	1.156	1	16.50	0.96	28×10^{-6}
Kv_{100}	0.07	0.06	1	0.068	1.68×10^{-6}
F	1.2	1.038	17.13	1	29×10^{-5}
Av	41.67×10^3	35.72×10^3	59.52×10^3	34.5×10^3	1

Bending Moment or Torque

To Convert From	To	Multiply By
dyne-centimeter	newton-meter (N•m)	$1.000\,000 \times 10^{-7}$
kilogram-force-meter	newton-meter (N•m)	9.806 650
ounce-force-inch	newton-meter (N•m)	$7.061\,552 \times 10^{-3}$
pound-force-inch	newton-meter (N•m)	$1.129\,848 \times 10^{-1}$
pound-force-foot	newton-meter (N•m)	1.355 818

DIMENSIONS, WEIGHTS & PRESSURE RATINGS

FOR PVC AND CPVC PIPE

U.S. UNITS

SCHEDULE (DR) SDR	Nominal pipe size (inches)	Outside dia. (inches)	Max. working pressure (PSI at 73°F)	Min. wall thickness (inches)	Average inside dia. (inches)	Weight of pipe (lbs./ft.) plain end CPVC	Weight of pipe (lbs./ft.) plain end PVC
SCHD 80 (DR 4.5)	1/4	.540	1130	.119	.302	-	.10
SCHD 80 (DR 5.4)	3/8	.675	920	.126	.423	-	.14
SCHD 40 (DR 8)	1/2	.840	600	.109	.602	.18	.17
SCHD 80 (DR 6)			850	.147	.526	.23	.21
SDR 21			200	.080	.660		.13
SCHD 40 (DR 10)	3/4	1.050	480	.113	.804	.24	.22
SCHD 80 (DR 7)			690	.154	.722	.31	.28
SDR 21			200	.060	.870		.13
SCHD 40 (DR 10)	1	1.315	450	.133	1.029	.35	.33
SCHD 80 (DR 8)			630	.179	.936	.45	.41
SDR 21			200	.080	1.135		.21
SCHD 40 (DR 12)	1 1/4	1.660	370	.141	1.360	.48	.44
SCHD 80 (DR 9)			520	.191	1.255	.62	.57
SDR 21			200	.080	1.480		.27
SCHD 40 (DR 13)	1 1/2	1.900	330	.145	1.590	.57	.52
SCHD 80 (DR 10)			470	.200	1.476	.76	.69
SDR 21			200	.090	1.700		.35
SDR 26			160	.080	1.720		.32
SCHD 40 (DR 16)	2	2.375	280	.154	2.047	.77	.70
SCHD 80 (DR 11)			400	.218	1.913	1.05	.96
SDR 21			200	.113	2.129		.54
SDR 26			160	.091	2.173		.45
SCHD 40 (DR 14)	2 1/2	2.875	300	.203	2.445	1.21	1.11
SCHD 80 (DR 11)			420	.276	2.290	1.60	1.46
SDR 21			200	.137	2.581		.78
SDR 26			160	.110	2.635		.64
SCHD 40 (DR 16)	3	3.500	260	.216	3.042	1.58	1.45
SCHD 80 (DR 12)			370	.300	2.864	2.14	1.96
SDR 21			200	.167	3.146		1.14
SDR 26			160	.135	3.210		.94
SDR 32.5			125	.108	3.264		.77
SDR 41			100	.085	3.310		.63
SCHD 40 (DR 19)	4	4.500	220	.237	3.998	2.25	2.07
SCHD 80 (DR 13)			320	.337	3.786	3.12	2.87
SDR 21			200	.214	4.046		1.88
SDR 26			160	.173	4.133		1.54
SDR 32.5			125	.138	4.204		1.25
SDR 41			100	.110	4.260		1.02
SCHD 40 (DR 22)	5	5.563	190	.258	5.016	3.06	2.81
SCHD 80 (DR 15)			290	.375	4.768	4.34	4.02
SDR 21			200	.265	5.001		2.88
SDR 26			160	.214	5.107		2.35
SDR 32.5			125	.171	5.199		1.89
SDR 41			100	.136	5.271		1.53
SCHD 40 (DR 24)	6	6.625	180	.280	6.031	3.97	3.65
SCHD 80 (DR 16)			280	.432	5.709	5.96	5.48
SDR 21			200	.315	5.955		4.09
SDR 26			160	.255	6.084		3.33
SDR 32.5			125	.204	6.193		2.69
SDR 41			100	.161	6.281		2.15

METRIC UNITS

Nominal pipe size (mm)	Outside dia. (mm)	Max. working pressure (kPa at 23°C)	Min. wall thickness (mm)	Average inside dia. (mm)	Weight of pipe (kg/m) plain end CPVC	Weight of pipe (kg/m) plain end PVC
6	13.7	7 790	3.02	7.67	-	.150
10	17.1	6 340	3.20	10.74	-	.210
12	21.3	4 140	2.76	15.26	.268	.253
		5 860	3.72	13.34	.342	.313
		1 380	2.02	16.74		.193
20	26.70	3 300	2.86	20.46	.357	.327
		4 760	3.90	18.38	.461	.417
		1 380	2.02	22.14		.194
25	33.40	3 100	3.38	26.14	.520	.491
		4 340	4.54	23.78	.670	.610
		1 380	2.02	28.84		.313
32	42.15	2 550	3.56	34.53	.714	.655
		3 590	4.84	31.87	.923	.848
		1 380	2.02	37.59		.402
40	48.25	2 280	3.68	40.37	.848	.774
		3 240	5.08	37.49	1.131	1.026
		1 380	2.28	43.17		.521
		1 100	2.02	43.69		.476
50	60.35	1 930	3.90	52.03	1.146	1.042
		2 760	5.54	48.61	1.563	1.429
		1 380	2.86	54.11		.804
		1 100	2.30	55.23		.670
65	73.00	2 070	5.16	62.08	1.801	1.652
		2 900	7.00	58.16	2.381	2.173
		1 380	3.48	65.54		1.161
		1 100	2.78	66.92		.952
75	88.90	1 790	5.48	77.28	2.351	2.158
		2 550	7.62	72.74	3.185	2.917
		1 380	4.24	79.92		1.697
		1 100	3.42	81.54		1.399
		860	2.74	82.90		1.146
		690	2.16	84.08		.938
100	114.30	1 520	6.02	101.58	3.349	3.081
		2 210	8.56	96.16	4.643	4.271
		1 380	5.44	102.76		2.798
		1 100	4.38	105.00		2.292
		860	3.50	106.78		1.860
		690	2.78	108.22		1.518
125	141.30	1 310	6.54	127.42	4.554	4.182
		2 000	9.52	121.12	6.459	5.982
		1 380	6.72	127.04		4.286
		1 100	5.44	129.74		3.497
		860	4.34	132.08		2.813
		690	3.44	133.90		2.277
150	168.30	1 240	7.10	153.22	5.908	5.432
		1 930	10.96	145.04	8.870	8.155
		1 380	8.02	151.28		6.087
		1 100	6.48	154.56		4.956
		860	5.18	157.32		4.003
		690	4.12	159.56		3.200

CORR TECH INCORPORATED

DIMENSIONS, WEIGHTS & PRESSURE RATINGS

FOR PVC AND CPVC PIPE

U.S. UNITS

SCHEDULE (DR) SDR	Nominal pipe size (inches)	Outside dia. (inches)	Max. working pressure (PSI at 73°F)	Min. wall thickness (inches)	Average inside dia. (inches)	Weight of pipe (lbs./ft.) plain end CPVC	PVC
SCHD 40 (DR 27)	8	8.625	160	.322	7.941	5.98	5.50
SCHD 80 (DR 17)			250	.500	7.565	9.05	8.32
SDR 21			200	.411	7.756		6.91
SDR 26			160	.332	7.921		5.65
SDR 32.5			125	.266	8.063		4.55
SDR 41			100	.210	8.180		3.63
SCHD 40 (DR 30)	10	10.750	140	.365	9.976	8.26	7.78
SCHD 80 (DR 18)			230	.593	9.493	12.85	11.81
SDR 21			200	.512	9.667		10.73
SDR 26			160	.413	9.874		8.76
SDR 32.5			125	.331	10.048		7.08
SDR 41			100	.262	10.195		5.64
SCHD 40 (DR 32)	12	12.750	130	.406	11.888	11.20	10.30
SCHD 80 (DR 19)			230	.687	11.294	18.46	16.98
SDR 21			200	.607	11.465		15.10
SDR 26			160	.490	11.711		12.35
SDR 32.5			125	.392	11.919		9.94
SDR 41			100	.311	12.091		7.94
SCHD 40 (DR 32)	14	14.000	130	.438	13.072		12.18
SCHD 80 (DR 19)			220	.750	12.412		20.34
SDR 21			200	.665	12.590		18.18
SDR 26			160	.538	12.859		14.88
SDR 32.5			125	.431	13.100		11.83
SDR 41			100	.342	13.277		9.58
SCHD 40 (DR 32)	16	16.000	130	.500	14.936		15.96
SCHD 80 (DR 19)			220	.843	14.224		26.03
SDR 21			200	.760	14.388		23.76
SDR 26			160	.615	14.696		19.41
SDR 32.5			125	.492	14.970		15.47
SDR 41			100	.391	15.172		12.52
SCHD 40 (DR 32)	18	18.000	130	.562	16.809		20.11
SCHD 80 (DR 19)			220	.937	16.014		32.76
SDR 21			200	.857	16.182		30.11
SDR 26			160	.693	16.531		24.62
SDR 32.5			125	.554	16.825		19.86
SDR 41			100	.440	17.065		15.92
SCHD 40 (DR 34)	20	20.000	120	.593	18.743		23.62
SCHD 80 (DR 19)			220	1.031	17.814		40.09
SDR 21			200	.952	17.982		37.17
SDR 26			160	.770	18.368		30.37
SDR 32.5			125	.615	18.696		24.47
SDR 41			100	.489	18.963		19.61
SCHD 40 (DR 35)	24	24.000	120	.687	22.544		32.87
SCHD 80 (DR 20)			210	1.218	21.418		56.88
SDR 21			200	1.143	21.576		53.54
SDR 26			160	.924	22.041		43.77
SDR 32.5			125	.740	22.431		35.35
SDR 41			100	.585	22.760		28.12

METRIC UNITS

Nominal pipe size (mm)	Outside dia. (mm)	Max. working pressure (kPa at 23°C)	Min. wall thickness (mm)	Average inside dia. (mm)	Weight of pipe (kg/m) plain end CPVC	PVC
200	219.05	1 100	8.18	201.71	8.900	8.185
		1 720	12.70	192.13	13.469	12.382
		1 380	10.40	196.99		10.283
		1 100	8.42	201.79		8.408
		860	6.72	204.79		6.771
		690	5.32	207.77		5.402
250	273.05	970	9.26	253.41	12.293	11.578
		1590	15.06	241.13	19.124	17.576
		1380	12.98	245.55		15.968
		1100	10.48	250.81		13.036
		860	8.40	255.23		10.536
		690	6.66	258.95		8.393
300	323.90	900	10.30	302.04	16.668	15.328
		1590	17.44	286.92	27.473	25.269
		1380	15.38	291.28		22.471
		1100	12.44	297.52		18.379
		860	9.96	302.78		14.792
		690	7.90	307.16		11.816
350	355.60	910	11.13	332.03		18.130
		1540	19.05	315.22		30.270
		1380	16.88	319.80		27.065
		1100	13.66	326.62		22.144
		860	10.76	332.78		17.615
		690	8.66	337.24		14.260
400	406.40	910	12.70	379.38		23.75
		1540	21.41	361.29		38.74
		1380	19.30	365.48		35.36
		1100	15.62	373.28		28.89
		860	12.32	380.24		22.99
		690	9.90	385.38		18.63
450	457.20	910	14.27	429.46		29.93
		1540	23.80	406.76		48.75
		1380	21.72	411.14		44.81
		1100	17.60	419.88		36.64
		860	14.06	427.36		29.55
		690	11.14	433.46		23.69
500	508.00	840	15.06	476.07		35.15
		1450	26.19	452.48		59.66
		1380	24.12	456.86		55.32
		1100	19.56	466.54		45.20
		860	15.62	474.88		36.42
		690	12.42	481.66		29.18
600	609.60	840	17.45	572.62		48.92
		1470	30.94	544.02		84.65
		1380	28.96	548.20		79.68
		1100	23.46	559.86		65.14
		860	18.80	569.74		52.61
		690	14.86	578.10		41.84

Pressure ratings in accordance with ASTM D 1785.

ADDITIONAL HELPFUL FORMULAS

Area of outside surface	(sq.ft./linear foot)	$= .2618\ D$
Weight of PVC pipe	(lbs./foot)	$= 1.941t\ (D - t)$
Weight of CPVC pipe	(lbs./foot)	$= 2.110t\ (D - t)$
Weight of water	(lbs./foot)	$= 0.3405\ d^2$
Moment of inertia	(inches^4)	$= 0.0491\ (D^4 - d^4)$
Section modulus	(inches^3)	$= \frac{0.0982\ (D^4 - d^4)}{D}$

Where: t = mean pipe wall thickness (inches)
D = outside diameter (inches)
d = inside diameter (inches)

NOTES:

1. **PVC and CPVC are not recommended for compressed air or gas service.**
2. For threaded systems, reduce maximum working pressure by 50%.
3. For services exceeding 73°F, see temperature correction chart, page 22.
4. For flanged systems, the maximum working pressure is 150 psi @ 73°F.

GLOSSARY OF PIPING TERMS

ABRASION RESISTANCE— The measure of a material's ability to withstand erosion when subjected to rubbing, scraping, wearing, scouring, etc., conditions.

ACETAL PLASTICS—A group of plastics made from resins which have been obtained by heating aldehydes or ketones with alcohols.

ACIDS—Normally a water-soluble compound containing hydrogen and other elements that are capable of reacting with a base to form a salt. They turn blue litmus paper red.

ACRYLONITRILE-BUTADIENE-STYRENE (ABS) PLASTICS—A group of plastics made from polymers with prescribed percentages of acrylonitrile, butadiene, and styrene.

ADHESIVE—A substance capable of holding materials together by surface attachment.

AGING—The effect on materials exposed to an environment for a period of time. Also, the act of exposing materials to an environment for a period of time.

ALKALIES—Compounds capable of neutralizing acids.

ANTIOXIDANT—A substance added to a plastic compound to retard degradation due to contact with air (oxygen).

BEAM LOADING—The process of applying a specified force (load) to a piece of pipe which is supported at two points. It is usually expressed in pounds per the distance between the centers of the supports.

BELLED-END—A term used to describe a pipe end which has been enlarged to have the same inside dimensions as a fitting socket. It acts as a coupling when joining pipe.

BLISTER—An undesirable air or gas filled bubble (bump) on the surface of a plastic part.

BOND—To attach by the use of an adhesive.

BURST STRENGTH—The amount of internal pressure a piece of pipe or a fitting will hold before breaking.

CALENDERING —A process for making thin sheets of plastic or rubber in which a heated plastic or rubber compound is squeezed between heavy rollers.

CELLULOSE ACETATE—A type of resin made from the reaction of acetic acid or acetic anhydride with a cellulose base (cotton and/or wood pulp).

CEMENT (SOLVENT CEMENT)—An adhesive used to bond plastics which is a "solution" of a plastic resin and a volatile solvent.

CHEMICAL RESISTANCE—The ability of a plastic to withstand the effects of chemicals at various concentrations and temperatures.

COLD FLOW—A change in the shape or the dimensions of a plastic part when subjected to a load (weight or pressure) at room temperature.

COMPOUND—The mixture of ingredients, consisting of a plastic resin and specified additives, used to manufacture a plastic part.

CONDENSATION—A chemical reaction involving the combination of molecules with the result being the elimination of a simple molecule, such as water, and the formation of a more complex compound of greater molecular weight.

COPOLYMER—The product formed by the simultaneous polymerization of two or more polymerizeable chemicals (monomers).

CRAZING—Small, fine cracks on or under the surface of a plastic.

CREEP—The dimensional change, beyond the initial elastic elongation caused by the application of a load, over a specified period of time. It is normally expressed in inches per inch per unit of time.

CURE—To change the properties of a polymer to a stable, usable, and final state by the use of chemical agents, heat, or radiation.

DEFLECTION TEMPERATURE (HEAT DISTORTION)— The temperature which will cause a plastic specimen to deflect a certain distance when a specified load is applied.

DEGRADATION—A deleterious change in the chemical structure, physical properties, or appearance of a plastic.

DELAMINATION —The separation of the layers of material in a laminate.

DETERIORATION—A permanent change in the physical properties of a plastic evidenced by impairment of these properties.

DIELECTRIC STRENGTH—The force required to drive an electric current through a specific thickness of a material.

DIFFUSION—The movement of gas or liquid particles or molecules in a body of fluid through or into a medium and away from the main body of fluid.

DIMENSIONAL STABILITY—The capability of a plastic part to maintain its original shape and dimensions under conditions of use.

DRY- BLEND—A dry compound prepared without fluxing or the addition of a solvent.

ELASTICITY—The property of a plastic which allows it to return to its original dimensions after deformation.

ELASTIC LIMIT—The load point at which a material will not return to its original shape and size after the load has been released.

ELASTOMER—A substance which when stretched to approximately twice its length, at room temperature, will quickly return to its original length when the stretching load is relieved.

ELECTRICAL PROPERTIES—The resistance of a plastic to the passage of electricity.

ELONGATION—The percentage of the original length which a material will deform, under tension, without failing.

EMULSION—A dispersion of one insoluble liquid into another insoluble liquid.

CORR TECH INCORPORATED

GLOSSARY OF PIPING TERMS

ENVIRONMENTAL STRESS CRACKING—Cracks which develop when a plastic part is subjected to incompatible chemicals and put under stress.

ESTER—The compound formed during the reaction between an alcohol and an acid.

ETHYLENE PLASTIC—Plastics based on polymers or copolymers of ethylene and other monomers in which ethylene is the greatest amount by weight.

EXTRUSION—The process used to continuously form a shape by forcing a heated or unheated plastic through a shaping orifice (die).

FILLER—A relatively inert material added to a plastic to modify its strength, permanence, working properties, other qualities, or to lower costs.

FLEXURAL STRENGTH—The measure of a material's ability to withstand a specified deformation under a beam load (bending) at 73°F. Normally expressed in PSI.

FORMING—A process in which the shape of plastic pieces such as sheets, rods, or tubes are changed to a desired configuration.

FORMULATION—The combination of ingredients used to make a finished plastic product. Also see compound.

FUSE—To join plastic parts by softening the material with heat or solvents.

GATE—The constriction in the flow channel between the runner and the mold cavity in an injection mold.

GLASS TRANSITION—The reversible change in an amorphous polymer from (or to) a viscous condition to (or from) a hard and relatively brittle one.

GLASS TRANSITION TEMPERATURE—The approximate midpoint of the temperature range over which the glass transition takes place.

GUSSET—A piece used to give additional size or strength to a plastic part at a particular location.

HARDNESS—The measure of a material's ability to resist indentation.

HEAT RESISTANCE—The ability of a material to withstand the effects of exposure to high temperatures.

HOOP STRESS—The circumferential stress, imposed on a pipe wall when exposed to an internal pressure load. Usually expressed in PSI.

IMPACT STRENGTH—A measure of a plastic part's ability to withstand the effects of dropping and/or striking. There are two commonly used test methods, Notched Izod and Tup. Notched Izod uses a pendulum type machine to strike a notched specimen. Tup testing uses a falling weight (tup) to strike a pipe or fitting specimen.

INJECTION MOLDING—The process used to form a shape by forcing a heated plastic, in a fluid state and under pressure, into the cavity of a closed mold.

ISO EQUATION—The equation which shows the relationship between stress, pressure, and dimensions in pipe.

JOINT—The point where a pipe and fitting or two pieces of pipe are connected together.

KETONES—A group of compounds having two alkyl groups attached to a carbonyl (CO) group.

LIGHT STABILITY—A feature of a plastic which allows it to retain its original color and physical properties when exposed to sun or artificial light.

LIGHT TRANSMISSION—The amount of light which a plastic will allow to pass through.

LONGITUDINAL STRESS—A tensile or compressive force placed upon the long axis of a plastic part.

LUBRICANT—Any substance which reduces the friction between moving solid surfaces.

MODULUS—A term used to describe the load required to cause a specified percentage of elongation. It is usually expressed in PSI or kilos per square centimeter.

MONOMER—A low-molecular-weight substance whose molecules can react with other molecules to form a polymer.

NON-FLAMMABLE— Incapable of supporting combustion.

NON-TOXIC—Non-poisonous.

NYLON PLASTICS—Plastics based on resins composed principally of a long-chain synthetic polymeric amide which has recurring amide groups as an integral part of the main polymer chain.

OLEFIN PLASTICS—A group of plastics based on polymers made by the polymerization or copolymerization of olefins with other monomers, with the olefins being at least 50% of the weight. Polypropylene, polyethylene, and polybutylene are examples.

ORGANIC CHEMICAL—Any chemical which contains carbon.

PHENOLIC PLASTICS-A group of plastics based on resins made by the condensation of phenols with aldehydes.

PLASTIC—A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow.

PLASTICITY—The property of plastics which allows them to be formed, without rupture, continuously and permanently by the application of a force which exceeds the yield value of the material.

PLASTICIZER—A substance incorporated in a plastic to increase its workability, flexibility, or distensibility.

PLASTIC PIPE—A hollow cylinder of a plastic material in which the wall thicknesses are usually small when compared to the diameter and in which the inside and outside walls are essentially concentric.

POLYBUTYLENE PLASTICS—Plastics based on polymers made with butene as essentially the sole monomer.

POLYETHYLENE PLASTICS—Plastics based on polymers made with ethylene as essentially the sole monomer.

GLOSSARY OF PIPING TERMS

POLYMER—A product formed by the chemical reaction of the addition of a large number of small molecules which have the ability to combine and reach high molecular weights.

POLYMERIZATION—A chemical reaction in which the molecules of monomers are linked together to form polymers.

POLYOLEFIN PLASTICS—Plastics based on polymers made with an olefin(s) as essentially the sole monomer(s).

POLYPROPYLENE PLASTICS—Plastics based on polymers made-with propylene as essentially the sole monomer.

POLYSTYRENE—A polymer prepared by the polymerization of styrene as the sole monomer.

POLYVINYL CHLORIDE PLASTICS—Plastics obtained by the polymerization of vinyl chloride. The addition of various ingredients, such as stabilizers, colorants, lubricants, and fillers enhance the processability and performance.

POROSITY—A term describing a plastic part which has many visible voids.

PRESSURE RATING—The maximum pressure at which a plastic part can safely function without failing.

QUICK BURST—A term used to describe the amount of internal pressure required to burst a pipe or fitting when the pressure is built up over a 60-70 second interval of time.

REINFORCED PLASTIC—A plastic with high strength fillers imbedded in the composition, causing some mechanical properties to be superior to those of the base resin.

RESIN—A solid or pseudosolid organic material, often having a high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally.

RUNNER—The secondary feed channel in an injection mold that runs from the inner end of the sprue to the cavity gate. Also, the solidified piece of plastic which forms in the feed channel when the injection molded part cools.

SAMPLE—A small part or portion of a material or product intended to be representative of the whole.

SCHEDULE—A pipe sizing system for the outside diameter and wall thickness dimensions which was started by the iron pipe industry. Normally, as the diameter increases, the pressure rating decreases for any given schedule of pipe.

SELF-EXTINGUISHING—A term describing a plastic material which stops burning when the source of the burning is removed.

SHRINK MARK—A depression in the surface of a molded plastic part where it has retracted from the mold.

SOFTENING POINT—The temperature at which a plastic changes from rigid to soft.

SOLVENT—A medium into which a substance is dissolved.

SOLVENT CEMENT—An adhesive consisting of a plastic dissolved into a solvent and used to bond plastic surfaces.

SOLVENT CEMENTING—Using a solvent cement to make pipe joint.

SPECIFIC GRAVITY—The ratio of the mass of a material to the mass of an equal volume of water.

SPRUE—The primary feed channel that runs from the outer face of an injection mold to the runner or the gate.

STABILIZER—An ingredient added to a plastic compound to inhibit or retard undesirable changes in the material.

STANDARD DIMENSION RATIO (SDR) PIPE—A type of pipe in which the dimension ratios are constant for any given class. Unlike "schedule" pipe, as the diameter increases the pressure rating remains constant for any given class of pipe.

STIFFNESS FACTOR—A term describing the degree of flexibility in a piece of pipe when subjected to an external load.

STRESS-CRACK—An external or internal crack in a plastic caused by tensile stresses less than its short-time mechanical strength.

SUSTAINED PRESSURE TEST—A test in which a plastic part is subjected to a constant internal pressure load for 1000 hours.

TEAR STRENGTH—A measure of a material's ability to resist tearing.

TENSILE STRENGTH—The measure of a plastic's ability to resist a stretching force. It is normally expressed in the PSI required to rupture a test specimen.

THERMAL CONDUCTIVITY—A measure of a plastic's ability to conduct heat.

THERMAL CONTRACTION—The decrease in length of a plastic part due to a change in temperature.

THERMAL EXPANSION—The increase in length of a plastic part due to a change in temperature.

THERMOPLASTICS—A group of plastics which can repeatedly be softened by heating and hardened by cooling.

THERMOSETTING PLASTICS—A group of plastics which, having been cured by heat, chemicals, or other means, are substantially infusible and insoluble. They are permanently hardened.

VINYL CHLORIDE PLASTICS—Plastics based on polymers or copolymers of vinyl chloride with other monomers, with the vinyl chloride being the greatest amount by weight.

VISCOSITY—A term describing a material's resistance to flow.

VOLATILE—A property of liquids in which they pass away by evaporating.

WELD LINE (KNIT LINE)—A term used to describe a mark on a molded plastic part formed by the union of two or more streams of plastic flowing together.

YIELD POINT—The point at which a plastic material will not withstand a stretching force. It will continue to elongate with no increase in load after reaching that point.