FABCO PRODUCTS
FABCO PLASTICS

SECTION 10: ENGINEERING INFORMATION

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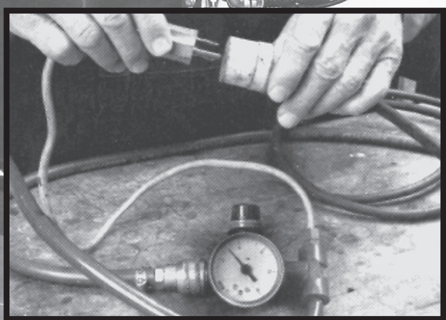


Plastic Material Digest

PVC

(Polyvinyl Chloride) conforming to ASTM D-1784 Class 12454-B, formerly designated Type 1 Grade 1, PVC is the most frequently specified of all thermoplastic materials. It has been used successfully for over 30 years in such areas as chemical processing, industrial plating, chilled water distribution, deionized water lines, chemical drainage, and irrigation systems. PVC is characterized by high physical properties and resistance to corrosion and chemical attack by acids, alkalies, salt solutions and many other chemicals. It is attacked, however, by polar solvents such as ketones, some chlorinated hydrocarbons and aromatics. The maximum service temperature of PVC is 140°F. With a design stress of 2,000 PSI, PVC has the highest long term hydrostatic strength at 73°F of any of the major thermoplastic being used for piping systems. PVC is joined by solvent cementing threading or flanging.

CPVC

(Chlorinated Polyvinyl Chloride) conforming to ASTM D-1784 Class 23447-B, formerly designated Type IV, Grade 1, CPVC has physical properties at 73°F similar to those of PVC, and its chemical resistance is similar to that of PVC. CPVC, with a design stress of 2,000 psi and maximum service temperature of 210°F has, over a period of about 25 years, proven to be excellent material for hot corrosive liquids, hot and cold water distribution and similar applications above the temperature range of PVC. CPVC is joined by solvent cementing, threading or flanging.

Polypropylene

(PP) Polypropylene homopolymer, conforming to ASTM D-4101 Class PP110 B67154, formerly designated Type 1, is a member of the polyolefin family of plastics. Although PP has less physical strength than PVC, it is chemically resistant to organic solvents as well as acids and alkalies. Generally, polypropylene should not be used in contact with strong oxidizing acids, chlorinated hydrocarbons and aromatics. Polypropylene has gained wide acceptance where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal lines, crude oil piping, and low pressure gas gathering systems. Polypropylene has also proved to be an excellent material for laboratory and industrial drainage where mixtures of acids, bases and solvents are involved. Polypropylene is joined by the thermo-seal fusion process, threading or flanging.

PVDF (Kynar®)

(Polyvinylidene Fluoride) PVDF is a strong, tough, and abrasion resistant fluoro carbon material. It resists distortion and retains most of its strength to 280°F. It is chemically resistant to most acids, bases, and organic solvents and is ideally suited for handling wet or dry chlorine, bromine and other halogens. No other solid thermoplastic piping components can approach the combination of strength, chemical resistance and working temperatures of PVDF. PVDF is joined by the thermo-seal fusion process, threading or flanging.

FRP

FIBERGLASS REINFORCED PLASTICS commonly manufactured by hand lay up (HLU) in accordance with CGSB-41-GP-22 in Canada and NBS PS 15-69 in the United States. Also manufactured according to ASTM D-3299 for machine made Filament Wound (FW) construction. FRP constructions are on a custom designed basis allowing the designer to select many different resin systems and laminate constructions. As an engineered system FRP generally displays higher physical properties than thermoplastics with a wide chemical and temperature resistance. Joining methods are by Flanging, Butt and Strap joined or bell and spigot connection.

FRP Reinforced Thermoplastics

These plastics commonly referred to as thermoplastic lined FRP such as PVC, CPVC, PP, PVDF, FEP, ECTFE chemically or mechanically bonded to an FRP structural overlay. This custom engineered system offers the unique properties of the thermoplastic liner with the superior physical properties of the FRP. Joining methods include Flanging, Fusion and Solvent Cementing of the LINER and OVERLAYING WITH FRP.

FPM (Viton® or Florel®)

(Fluoroelastomer) FPM is inherently compatible with a broad spectrum of chemicals. Because of extensive chemical compatibility which spans considerable concentration and temperature ranges, fluorocarbons have gained wide acceptance as a material of construction for butterfly valve O-rings and seats. Fluorocarbons can be used in most applications involving mineral acids (with the exception of HCI), salt solutions, chlorinated hydrocarbons and petroleum oils.

EPDM (EPT)

EPDM 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 alkalines. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids (with the exception of HCI), or strong alkalines.

Teflon®

PTFE (Polytetrafluoroethylene) has outstanding resistance to chemical attack by most chemicals and solvents. PTFE has a temperature rating of -200°F to +500°F. PTFE, a self-lubricating compound, is used as a seat material in Fabco Ball Valves.

Neoprene® (CR)

Neoprene® was the first commercial synthetic rubber. It is a moderately oil-resistant material with good ozone-resisting properties. Neoprene is not recommended for use with aromatic hydrocarbons or chlorinated solvents. It is specifically recommended for use with higher concentrations of sodium hydroxide. It can be used in continuous service up to 180°F.

Thermoplastic Fabrication

INTRODUCTION

The preparation of thermoplastics for assembly by welding or other fastening methods is similar to the procedures used in metal fabrication. The pieces are laid out, cut, machined and joined with the same tools, equipment, and skills employed in the metal working trades. There are, however, special forming requirements for thermoplastics, not encountered in metal work. The degree of skill and the quality of preparatory work in layout and in various machining operations on components for fit up are very important in assuring accurate assembly and successful fabrication.

Fabrication of thermoplastics covers a wide field of operations on sheet, rod, tube, and special shapes in making them into finished products: cutting, sawing, machining, forming and joining or fastening together for the completed object. Machining may include beveling, routing, grinding, turning, milling, drilling, tapping, and threading. Once the different parts are shaped, they then may have to be joined.

Assembly techniques include use of self-tapping screws, threaded inserts, press fitting, snap fitting, cold heating, heat joining (like hotplate welding, hot-wire welding, induction heating, thermal-impulse heating, resistance-wire welding, or hot flaring, spin welding), cementing, and hot gas welding. Each operation requires its own tools and equipment.

CUTTING

Thermoplastic rods and shapes can be readily cut with an ordinary hand hacksaw, or power saws can be used. Using a circular power saw, a cutting speed of 6,000 rpm. Using hand pressure is recommended. With bandsaws, this should be reduced to 3,600 fpm with hand pressure. Under some circumstances a lathe can be used. Best results are obtained with fine-toothed saw blades (6 to 9 teeth per in.) and little or no set (maximum 0.025 in.).

THREADING

Thermoplastic pipe, rod and shapes can easily be threaded using either standard hand pipe stocks or power operated equipment. For optimum results in threading, use of new taps and dies is recommended; but in any case they should be clean and sharp and maintained in good condition. Power threading machines should be fitted with dies having 5° negative front rake and ground especially for this application, tapered guide sleeves are not required. For hand stocks, the dies should have a negative front rake angle of 5 to 10°. Dies which have been designed for use on brass or copper pipe may be successfully used. Carboloy dies give longer service.

Taps should be ground with a 0 to 10° negative rake, depending upon the size and pitch of the thread. Die chasers should have a 33° chamfer on the lead: a 10° front or negative rake; and a 5° rake on the back of relief edge. Self-opening die heads and collapsable taps, power threading machines and a slight chamfer to lead the tap or dies will speed production, however, taps and dies should not be driven at high speeds or with heavy pressure.

A tapered plug should be inserted into tubular ends when threading to hold the pipe round and to prevent the die from distorting or digging into the pipe wall. This insures uniform circumferential depth of threads. Pipe for threading should be held in a pipe vice since sawtooth jaws will leave marks. Thermoplastic materials are readily threaded without use of external lubricants. However, ordinary lubrication or cutting oil will be beneficial to the operation. In a pipe-threading machine, water soluble oil or plain cold water is used. Clearing of cuttings from the die is strongly recommended.

HEAT WELDING

The most important and most versatile of welding methods is hot gas and air welding which, in principle, is similar to oxyacetylene welding of metals, but with a difference in the technique involved. Specialized welding equipment has been developed in which the pressure and the rate and area of heating are precisely controlled in order to provide strong, tight bonds. Welding rods are available in different sizes to suit the individual jobs.

Hot gas welding of thermoplastics is accomplished with a welding torch and tips or tools. It is divided into three basic types of welding: tack welding, hand welding and high speed welding. Each type requires different tips or high speed tools.

FUSION WELDING

Industrial thermoplastics such as PVC, PP, PE, and PVDF can be fusion welded using modern temperature and pressure controlled fusion equipment. This relatively simple equipment is available to fuse PIPE and Tube products to 24” diameter. SHEETS and Plates can also be fused using micro processor controlled fusion machines. Weld efficiency, when using modern equipment, will develop weld strength of up to 98% of the unwelded parent material.

SOLVENT CEMENT WELDING

Cementing is a convenient technique for bonding PVC and CPVC (High-Temp) stock. Surfaces to be cemented must be clean and dry. They should be cut square and smooth and wiped clean of dirt, grease, etc. with a small amount of Fabco Pipe Cleaner.

When solvent-cementing, it is important to have close clearances between the surfaces to be joined. Solvent-cement should be applied with an ordinary small paint brush to each member. (Do not use synthetic hair brushes). Then the cemented surfaces should immediately be pushed snugly together. After the cemented joint has been pressed together the initial set takes place within several minutes.

Handling strength, however, is not developed for approximately 30 minutes. Relative motion between the cemented surfaces during the initial set period is undesirable. It is good practice to apply no more than 10% of the rated stress for four hours. Full strength of the joint is developed after about 48 hours.

FLANGING

One of the earliest methods of joining thermoplastics piping, flanging continues to be used extensively for process lines. Thermoplastic flanges and flanged fittings are available in a full size range and may be attached to pipe by solvent welding, by threading, or by thermal bonding, as required by the particular thermoplastics material.

MACHINING, CUTTING AND SAWING

Thermoplastics may be turned, threaded, grooved, milled, or polished to very close tolerances, with the same tools as are used for wood or metal.

The only requirement for machining of plastic that differs from metal machining is compensation for heating up of materials due to its poor heat-conductivity. The limitation of heat build-up is accomplished by use of sharp, high-speed tools, streams of air or water/soda cooling, and proper machine feeds.

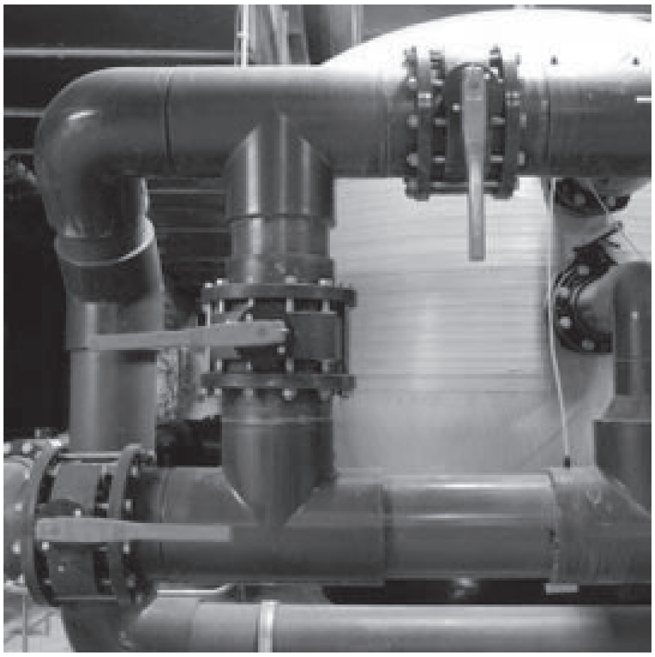
In machining plastics on a lathe, tool bits should be sharpened as for machining brass. The tool should be ground with a front clearance of 10°, a 2° negative back-rake and no side rake. The tool should have a 10° side-clearance. Chips should be blown or washed away from the work to reduce frictional heat to a minimum.

The piece is set up in the lathe for turning or thread cutting as in metal work but with special protection provided for the plastic where it is held in the chuck jaws. The plastic should be wrapped in several heavy layers of heavy cardboard, held in place by masking tape, before being inserted into chuck.

A cutting speed of 200 fpm is recommended. Lathe speed for machining different diameters of plastic can be calculated as: 4 times the cutting speed (fpm) divided by the diameter of the plastic in inches. Example: With a plastic rod 1- in. diameter, the lathe speed would be 200 times 4 divided by 1 or 800 rpm. Light cuts are recommended - 0.030 to 0.060 in. cross-feed at a time.

In sawing plastic sheet, there is likely to be concentrated heat build-up in the saw blades. To allow for this, the blade used should be selected in accordance with the gauge of the material. The saw blade for cutting thicker materials should be heavier and should be hollow ground. The saw should make a slicing cut in the material: to do this, the teeth should have negative rake, with little or no set. The rate of feed should be very slow. The blade of a circular saw should just show through the material. If it extends too far through, it will increase the heat build-up, by increasing friction.

In cutting polyethylene and polypropylene on a circular saw, the saw blade required is different from that used in cutting PVC. PE and PP do not require a hollow ground blade and are cut by a well-set saw blade. Shears can be used for cutting of light gauge thermoplastic sheets. All shearing should be accomplished at room temperature. A cold sheet will crack or shatter. A 1/8-in. sheet of Type 1 PVC can be sheared easily. Heavier-gauge Type 1 PVC will tend to cut off-square and also show stress marks. Type 2 PVC, PP, PE and modified high impact PVC shear better and to a higher gauge than Type 1 PVC. In drilling plastics, the same problems are experienced as in drilling metal. The non-conducting characteristics of the material and the heat concentration in the tool must be allowed for. This is accomplished by grinding the drill differently than for drilling metals. If the holes are to be drilled in the fabrication at hand, the drill should be reground to a negative rake and the lip angle increased for 59° to 70°. The margin on the drill should be smooth and highly polished to reduce friction. Drilling speeds should be reduced: 50 to 150 rpm is a safe range, with 120 rpm being optimum. Very slow feeds should be used.



Guidelines For Processing and Machining Plastics

General Remarks

- Non-reinforced thermoplastics can be machined with cutting tools of highspeed steel. For reinforced materials, hard metal tools are required.
- In all cases, only properly sharpened tools are to be used.
- Due to the poor thermal conductivity of plastics, provision has to be made for good heat dissipation. Heat is best dissipated via the chips.

Dimensional Stability

- Dimensional stability of parts is conditional on stress-relieved, semi-finished materials which have to be annealed. The heat generated by the cutting tool otherwise inevitably leads to the release of processing stresses and deformation of the part. In the case of high material removal volumes, intermediate heating may be necessary after the main machining operation so as to remove the arising thermal stresses.
- Materials with high moisture absorption (e.g. polyamides) may require conditioning before machining.
- Plastics require larger finishing tolerances than metals. Furthermore, allowance has to be made for the many times greater thermal expansion.

Machining Operations

1. Turning

Guide values for cutting tool geometry are given in the table. For particularly high quality surface finishes, the tip is to be shaped as a broad-nosed finishing tool as shown in Figure 1.

For cutting off, the tool should be ground to the profile shown in Figure 2 so as to avoid a remaining stump.

On thin walled and particularly flexible workpieces, on the other hand, it is better to work with tools that are ground to a knife-like cutting geometry. Figures 3 and 4.

2. Milling

For plane surfaces, face milling is more economical than peripheral milling. For perpheral milling and profiling, the cutting tools should not have more than two cutting edges so that vibrations due to the number of teeth are kept to a minimum and chip widths are sufficiently large.

Optimum removal rates and surface finish are obtained with single-point tools.

3. Drilling and boring

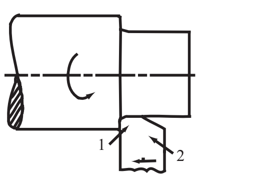
As a general rule it is possible to use twist drills; these should have an angle of twist of 12-16° and very smooth helical flutes for good chip removal. Larger diameters should be rough-drilled or produced by trepanning or internal turning.

On drilling into solid material, care must be taken to ensure that the tools are properly sharpened; otherwise, the developing compressive strain can build up and cause the material to split.

Reinforced plastics possess higher residual processing stresses with lower impact strength than unreinforced plastics and are thus particularly susceptible to cracking. Where possible, these should be heated to about 120°C before drilling or sawing (heating time approximately 1 hour per 10 mm cross-section). This procedure is also recommended in the case of polyamide 6/6.

4. Sawing

Unnecessary generation of heat by friction is to be avoided, since sawing is generally used to cut off thickwalled parts with relatively thin tools. Well-sharpened and heavily crossed sawblades are therefore advised.



1 Finishing tip 2 Turning tool

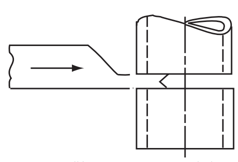


Figure 2: Profile prevents remaining stump

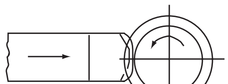


Figure 3.

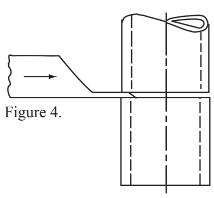
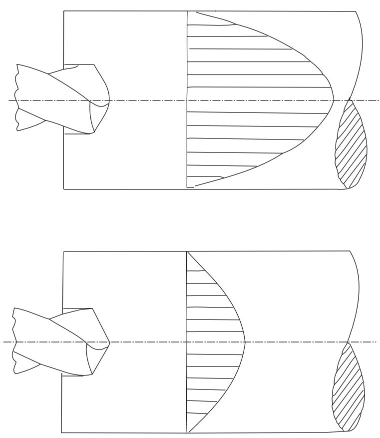


Figure 4.



MACHINING OPERATIONS	TURNING					MILLING			DRILLING AND BORING					SAWING				SPECIAL MEASURES
	α Clearance angle (°) γ Rake angle (°) X Side angle (°) V Cutting speed ft/min S Feed mils/rev The nose radius r must be at least 0.020 in.					α Clearance angle (°) γ Rake angle (°) V Cutting speed ft/min The feed can amount to up to 0.020 in./tooth			α Clearance angle (°) γ1 Rake angle (°)b Side angle (°) V Cutting speed ft/min S Feed mils/rev The angle of twist β of the drill bit should be approximately 12 to 16°.					α Clearance angle (°) γ Rake angle (°) V Cutting speedft/min t Pitch mils				
RAW MATERIAL GROUP	α	γ	X	V	S	α	γ	V	α	γ1	b	V	S	α	γ	V	t	
POLYCARBONATE	5-10	6-8	45-60	950	4-20	10-20	5-15	950	8-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	In the case of fluid cooling only use pure water
ABS (ACRYLONITRILE-BUTADIENE-STYRENE)	5-15	25-30	15	650-1600	8-20	5-10	0-10	950-1600	8-12	10-30	90	150-650	8-12	15-30	0-5	950	75-310	In the case of fluid cooling only use pure water
PPS (POLYPHENYLENE SULFIDE)	6-8	2-8	45-60	500-650	4-20	15-30	6-10	250-350	6	5-10	120	250-300	4-12	15-30	10-15	600-950	115-195	Preheat to 240°F before drilling or sawing
POLYSULFONE	6	0	45-60	1150-1300	4-12	2-10	1-5	800-1600	3-10	10-20	90	50-250	4-12	15-30	0-4	1600	75-195	Preheat to 240°F before drilling or sawing
PVDF (POLYVINYLIDENE FLUORIDE)	10	5-8	10	500-1600	4-12	5-15	5-15	800-1600	10-16	5-20	130	500-650	4-12	20-30	5-8	950	75-195	
NYLON 6/6	6-10	0-5	45-60	800-1600	4-20	10-20	5-15	800-1600	5-15	10-20	90	150-500	4-12	20-30	2-5	1600	115-310	
ACETAL	6-8	0-5	45-60	950-1950	4-16	5-15	5-15	800-1600	5-10	15-30	90	150-650	4-12	20-30	0-5	1600-2600	75-195	
PET (POLYETHYLENE TEREPHTHALATE)	5-10	0-5	45-60	950-1300	8-16	5-15	5-15	950	5-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	Preheat to 240°F before drilling or sawing
ACETAL HOMOPOLYMER (DELRIN®)	6-8	0-5	45-60	950-1950	4-16	5-15	5-15	800-1600	5-10	15-30	90	150-650	4-12	20-30	0-5	1600-2600	75-195	
PPO (POLYPHENYLENE OXIDE) (NORYL®)	5-10	6-8	45-60	950	4-20	10-20	5-15	950	8-10	10-20	90	150-300	8-12	15-30	5-8	950	115-310	In the case of fluid cooling only use pure water
POLYETHERETHERKE-TONE (PEEK)	6-12	5	45-60	950	15	5-15	5-15	550-750	12	10-20	118	400	2-8	15-30	10-15	600-950	115-195	Preheat to 240°F before drilling or sawing
POLYETHERIMIDE (ULTEM®)	15	5	5	1000-2000	5-20	15	5	650-1300	5-10	5-20	70-90	300	5-15	15-30	5-10	3000-5000	100	In the case of fluid cooling only use pure water
REINFORCED ENGINEERING PLASTICS*	6-8	2-8	45-60	500-650	4-20	15-30	6-10	250-350	6	5-10	120	250-300	4-12	15-30	10-15	600-950	115-195	Use hard metal cutting tools

Thermoplastic Installation Instructions

SCOPE

One of the more important features of industrial thermoplastics is the ease with which they lend themselves to a variety of fabricating techniques. This versatility, plus the wide selection of piping components now available, make possible fast and economical installation, maintenance and modification of industrial piping systems. It is the objective of this section to provide detailed instructions on all known techniques of joining, maintaining and handling thermoplastics in order to permit maximum integrity of your piping system.

SOLVENT WELDING

The generally preferred method of joining rigid thermoplastics such as PVC and CPVC is solvent welding. This process gives a stronger joint than threading and is also considered faster and simpler. Additionally, solvent welding permits the use of thinner walls when compared to threaded connections for equivalent pressure ratings.

THERMO-SEALING (SOCKET FUSION)

Polypropylene (PP), a thermoplastic polyolefin and PVDF (Kynar), cannot be dissolved by even the strongest of organic solvents. Since solvent attack (or bite) by dissolution is necessary to effect a solvent cement bond with thermoplastics, it is not possible to join polypropylene or PVDF by solvent cementing. Therefore, polypropylene and PVDF pressure systems can only be joined using heat fusion techniques. A thermal sealing procedure is used when joining using heat fusion techniques. A thermal sealing procedure is used when joining 1/2" through 4" sizes. When joining 6" polypropylene systems, which are recommended for drainage applications only, a fillet welding procedure is utilized.

THREADING

Threaded joints are sometimes used when a piping system must be dismantled for occasional cleaning or modifications. Since threading results in a reduction in the effective wall thickness of the pipe, the pressure rating of threaded pipe is reduced to one-half that of unthreaded pipe, ie. pipe joined by solvent cementing or thermal sealing. This reduction in wall thickness resulting from threading can seriously affect the pressure carrying capability and mechanical strength of Schedule 40 or lighter pipe and therefore, only Schedule 80 or heavier pipe should be threaded when the pipe is used for pressure applications. Also, threading is not recommended for plastic pipe above 4 inches in diameter nor is it recommended for pressure polypropylene piping systems.

FLANGING

One of the earliest methods for joining thermoplastic piping, flanging continues to be used extensively for process lines. Thermoplastic flanges and flanged fittings are available in a full size range and mat be attached to pipe by solvent welding, by threading, or by thermal sealing, as required by the particular thermoplastic material.

Storage and Handling of Thermoplastic Piping Components

SCOPE

Industrial thermoplastic piping components are designed and manufactured for use in severe duty systems involving the transport of aggressive liquids. In order to ensure their integrity, once installed, they must be handled with reasonable care prior to installation.

STORAGE

1. Pipe - When pipe is received in standard lifts it should remain in the lift until ready for use. Lifts should not be stacked more than three high and should always be stacked wood on wood. Loose pipe should be stored on racks with a minimum support spacing of three feet. Pipe should be shaded but not covered when stored outside in high ambient temperatures. This will provide for free circulation of air and reduce the heat build-up due to direct sunlight exposure.
2. Fittings - Fittings should be stored in their original cartons to keep them free of dirt and reduce the possibility of damage. If possible, fittings should be stored indoors.
3. Solvent Cements and Primers - Solvent cements have a definite shelf life and each can and carton is clearly marked with a date of manufacture. Stock should be rotated to ensure that the oldest material is used first. Primer does not have a shelf life but it is good practice to rotate this stock also. Solvent cements and primers should be stored in a relatively cool shelter away from direct sun exposure.

CAUTION: SOLVENT CEMENTS AND PRIMERS ARE COMPOSED OF VARIOUS SOLVENTS AND REQUIRE SPECIAL CONDITIONS FOR STORAGE. BECAUSE OF THEIR FLAMMABILITY THEY MUST NOT BE EXPOSED TO IGNITION, HEAT, SPARKS OR OPEN FLAMES.

HANDLING

1. Pipe and Fittings - Care should be exercised to avoid rough handling of thermoplastic pipe and fittings. They should not be dragged over sharp projections, dropped or have objects dropped upon them. Pipe ends should be inspected for cracks resulting from such abuse. Transportation by truck or pipe trailer will require that the pipe be continuously supported and all sharp edges on the trailer bed that could come in contact with the pipe must be padded.
2. Solvent Cements and Primers - Keep containers for solvent cements tightly closed except when in use. Avoid prolonged breathing of solvent vapors, and when pipe and fittings are being joined in partially enclosed areas use a ventilating device to attenuate

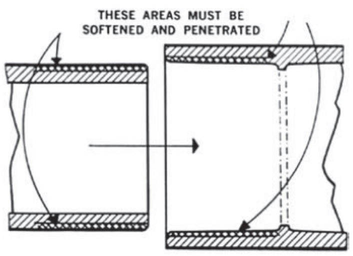
vapor levels. Keep solvent cements, primers and cleaners away from all sources of ignition, heat, sparks and open flames. Avoid repeated contact with the skin by wearing proper gloves impervious to the solvents. Application of the solvents or cements with rags and bare hands is not recommended; natural fiber brushes and other suitable applicators can produce satisfactory results.

DANGER: EXTREMELY FLAMMABLE. VAPOR HARMFUL. MAY BE HARMFULIF SWALLOWED. MAY CAUSE SKIN OR EYE IRRITATION.

Instructions for Solvent Welding

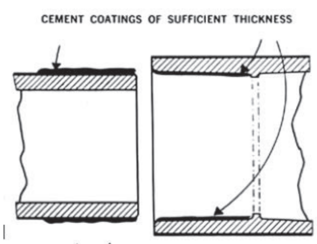
To make consistently good joints, the following points should be clearly understood.

1. The joining surfaces must be softened and made semifluid.
2. Sufficient cement must be applied to fill gap between pipe and fitting.
3. Assembly of pipe and fittings must be made while the surfaces are still wet and cement is still 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.



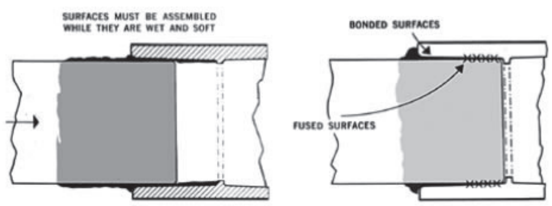
FABCO recommends the use of a primer for all applications. A suitable primer will usually penetrate and soften the surfaces more quickly than cement alone. Additionally, the use of a primer can provide a safety factor for the installer, for he can know under various temperature conditions when sufficient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

Sufficient cement to fill the loose part of the joint must be applied. Besides filling the gap, adequate cement layers will penetrate the surfaces and also remain wet until the joint is assembled. Prove this for yourself. Apply on the top surface of a piece of pipe two separate layers of cement.



First apply a heavy layer of cement; then along side it, apply a thin brushed out layer. Test the layers every 15 seconds or so by a gentle tap with your finger. You will note that the thin layer becomes tacky and then dries quickly (probably within 15 seconds); the heavy layer will remain wet much longer. A few minutes after applying these layers check for penetration. Scrape the surface of both with a knife. The thin layer will have achieved little or no penetration; the heavy one will have achieved much more penetration.

If the cement coatings on the pipe and fittings are wet and fluid when assembly takes place, they will tend to flow together and become one cement layer. Also, if the cement is wet, the surfaces beneath them will still be soft and these softened surfaces in the tight part of the joint will tend to fuse together. As the solvent dissipates, the cement layer and the softened surfaces will harden with a corresponding increase in joint strength. A good joint will take the required working pressure long before the joint is fully dry and final joint strength is obtained. In the tight (fused) part of the joint, strength will develop more quickly than in the looser (bonded) part of the joint. Information about the development of bond strength of solvent welded joints is available in this manual.



SOLVENT WELDING WITH PRIMER

1. Assemble proper materials for the job (proper primer, cement, if necessary - cleaner, and applicator for the size of pipe and fittings to be assembled).
2. Pipe must be cut as square as possible. Use a miter box saw or power saw. Check the end of the pipe with a square to make sure it has been cut squarely. A diagonal cut reduces bonding area in the most effective and critical part of the joint.

3. Plastic tubing cutters may also be used for cutting plastic pipe; however, some produce a raised bead at the end of the pipe. This bead must be removed with a file or deburring tool, as it will scrape the cement away when pipe is inserted into the fitting.

4. Remove inside diameter burrs or raised beads with an internal deburring tool or knife. Remove the burrs or raised beads on the outside diameter of the pipe by using a file or external deburring tool that will produce a 3/32", 10-15° chamfer (bevel). Burrs can scrape channels into pre-softened surfaces or create hang-ups across the inside fitting diameter.

5. With a clean-dry rag, remove any dirt, grease, shavings or moisture from the inside and outside of the pipe and fitting. A thorough wipe is usually sufficient. (Moisture will retard cure and dirt, grease, or any foreign material can prevent proper fusion).

6. Check pipe and fittings for dry fit before cementing. For proper interference fit, fitting should go over end of pipe easily but become tight about 1/3 to 2/3 of the way on. Too tight a fit is not desirable; you must be able to fully bottom the pipe in the socket during assembly. If the pipe and fittings are not out of round, a satisfactory joint can be made if there is a "net" fit, that is, the pipe bottoms in the fitting socket with no interference, but without slop. A quick, dry fit "slop" test: Hold a short length of pipe vertically with a fitting "bottomed" on the pipe. If the fitting falls off the end of the pipe, do not start assembly. Contact your pipe or fitting supplier. Measure the fitting socket length and mark this distance on the pipe OD to insure the fitting has been fully inserted, add a couple inches to this distance and make a second check mark on the pipe, as the primer and cement will remove the first mark. All pipe and fittings must conform to ASTM or other recognized product standards.

7. Use the right applicator for the size of pipe or fittings being joined. The applicator size should be approximately 1/2 the pipe diameter. It is important that a satisfactory size applicator be used to help ensure that sufficient layers of cement are applied.

8. Priming; the purpose of a primer is to penetrate and soften the surfaces so they can fuse together. The proper use of a primer and checking its softening capability provides assurance that the surfaces are prepared for fusion in a wide variety of conditions. Check the penetration or softening on a piece of scrap pipe before you start the installation or if the weather changes during the day.

Using a knife or other sharp object, drag the edge over the coated surface. Proper penetration has been made if you can scratch or scrape a few thousandths of the primed surface away. Because weather conditions do affect priming and cementing action, repeated applications to both surfaces may be necessary. In cold weather more time is required for proper penetration.

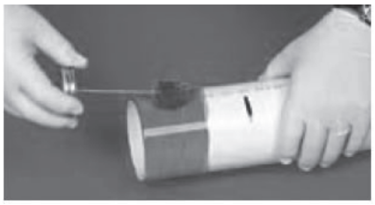
NOTE: WITHOUT HESITATION, COMPLETE STEPS 9 THROUGH 16.

FOR PIPE DIAMETERS OF 6" AND LARGER, THE SIZE OF THE JOINING CREW SHOULD BE INCREASED (SEE JOINING LARGE DIAMETER PIPE AND FITTINGS).

9. Using the correct applicator (as outlined in step #7), aggressively apply the primer into fitting socket, keeping the surface and applicator wet until the surface has been softened. More applications may be needed for hard surfaces and cold weather conditions. Re-dip the applicator in primer as required. When the surface is primed, remove any puddles of primer from the socket.

10. Next, aggressively apply the primer to the end of the pipe to a point 1/2" beyond the depth of the fitting socket.

SOLVENT WELDING INSTRUCTIONS



11. Apply a second application of primer to the fitting socket. Do not allow primer to run down the inside of the fitting or pipe.

12. With the proper size and type of applicator, while surfaces are still wet, immediately apply the appropriate Weld-On® cement.

PLEASE NOTE: THE ADDING OF PRIMERS, CLEANERS OR OTHER THINNERS TO THIN THE VISCOSITY OF SOLVENT CEMENT IS NOT RECOMMENDED.

13. Cementing: (Stir or shake the cement before using.) Aggressively apply a full, even layer of cement to the pipe-end equal to the depth of the fitting socket – do not brush it out to a thin paint type layer, as this will dry too quickly.

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

15. Apply a second, full even layer of cement on the pipe. Most joint failures are caused by insufficient application of cement.

16. Immediately, while cement is still wet, assemble the pipe and fittings. If not completely wet, recoat parts before assembly. If cement coatings have hardened, cut pipe, dispose of fitting and start over. Do not assemble partially cured surfaces. While inserting, twist 1/8 to 1/4 turn until reaching socket bottom. Do not continue to rotate after the pipe has reached the socket bottom.

17. Hold the pipe and fitting together for a minimum of 30 seconds to eliminate movement or pushout.

18. After assembly, a joint should have a ring or bead of cement completely around the juncture of the pipe and fitting. If voids (gaps) in this ring are present, sufficient cement was not applied and the joint may be defective.

19. Using a rag, remove the excess cement from the pipe and fitting, including the ring or bead around the socket entrance, as it will needlessly soften the pipe and fitting, and does not add to joint strength. Excess cement around the socket entrance will also extend the cure time. Avoid disturbing or moving the joint.

20. Handle newly assembled joints carefully until initial set has taken place. Follow Weld-On® set and cure times before handling or hydro-testing piping system.

Joining Large Diameter Pipe and Fittings

6" Diameter and Larger

As pipe diameter increases, so does the difficulty in installing it. The professional installer should be able to successfully assemble large diameter pipe and fittings by following the Weld-On Solvent Welding with Primer instructions listed in the beginning of this guide along with the following additional recommendations.

1. Use of proper size applicators is even more necessary to ensure enough cement is applied to fill the larger gap that exists between the pipe and fittings.
2. Of equal importance is the use of the applicable cement for the size of pipe and fittings being installed. We recommend the following:
   up to 12" PVC Sch 40 or Sch 80 - Weld-On 711™ & 717 ™
   up to 30" PVC Sch 40 or Sch 80 - Weld-On 719™
   up to 12" CPVC - Weld-On 714™ & 724™
   up to 24" CPVC Duct - Weld-On 729™
3. End of pipe must be cut square and chamfered (beveled). (See photo beside)
4. Increase size of joining crew:
   6"- 8": 2-3 people per joint
   10"- 30": 3-4 people per joint

It is important in large diameter joining that the primer and cement be applied simultaneously to the pipe and fittings.

5. Make sure to apply a second, full layer of cement to the pipe.
6. Because of the short sockets in many large diameter fittings, IT IS VERY IMPORTANT TO HAVE PIPE BOTTOMED INTO THE FITTING. Large diameter pipe is heavy and can develop significant resistance during insertion, before reaching socket bottom. It is for this reason that we recommend above 4" diameter the use of a pipe-puller such as the one pictured. (Available at FABCO PLASTICS).

7. Large diameter pipe and fittings require longer set and cure times. *(In cold weather, a heat blanket may be used to speed up the set and cure times.)
8. Prefabricate as many joints as possible.
9. If pipe is to be buried, make as many joints as possible above ground, then after joints have cured, carefully lower into trench.
10. Never bury empty cans, brushes, or anything else containing wet cement, primer, or cleaner next to the pipe.

*Contact FABCO PLASTICS for further information.

Chemical Applications

Installations of plastic pipe and fittings for chemical applications requires a higher degree of skill than other installations; joint failures in these systems could be life threatening. It is for this reason we recommend the following tips for these applications.

Tips for Installation:

1. Installers should attend a Weld-On® Installation Seminar.
2. Allow at least two to three times the normal set and cure times on page 22.
3. Flush system before putting into operation.
4. Installers should use extra care during assembly to ensure proper installation of system.
5. Make sure the proper cement for the specific application is used.
6. If there is any doubt about compatibility of materials (pipe, fittings or cement) with chemicals in system, manufacturers of materials should be contacted.

Repairs

Taking into consideration the cost of materials, time involved and labor costs, in most cases the installer is better off cutting out the defective joint, replacing it with new materials and taking greater care in the joining process.

If the joint cannot be cut out, the following repair is somewhat successful. This repair is for leaks only, not cases where pipe has separated from fitting. Leak area should be dry and clean of debris, oil or grease.

1. Apply Weld-On® 810™/811™ to area to be repaired. Let the adhesive set.
2. Cut a fiberglass mat or tape, providing sufficient coverage/wrap to the leak area. Saturate mat/tape with adhesive.
3. Cover or wrap repair area with saturated mat/tape. Work air bubbles out of the fiberglass mat/tape.
4. Let repaired area cure before pressurizing. Although not a guaranteed fix, this process has proven very successful in most applications.

Joining Plastic Pipe in Hot Weather

There are many occasions when solvent welding plastic pipe at 95°F (38°C) temperatures and above cannot be avoided. If special precautions are taken, problems can be avoided.

Solvent cements for plastic pipe contain high strength solvents which evaporate faster at elevated temperatures. This is especially true when there is a hot wind blowing. If the pipe is stored in direct sunlight, the pipe surface temperatures may be from 20°F to 30°F (10°C to 15°C) higher than the ambient temperature. Solvents attack these hot surfaces faster and deeper, especially inside a joint. Therefore, it is very important to avoid puddling the cement inside the fitting socket and to wipe off any excess cement outside the joint.

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

Tips to Follow when Solvent Welding in High Temperatures:

1. Store solvent cements and primers in a cool or shaded area prior to use.
2. If possible, store fittings and pipe or at least the ends to be solvent welded, in a shady area before cementing.
3. Cool the surfaces to be joined by wiping with a damp rag. Make sure that surface is dry prior to applying solvent cement.
4. Try to do the solvent welding during the cooler morning hours.
5. Make sure that both surfaces to be joined are still wet with cement when putting them together. With large diameter pipe, more people on the crew may be necessary.
6. Using a primer and a heavier, high viscosity cement will provide a little more working time. Vigorously shake or stir the cement before using.

As you know, during hot weather there can be a greater expansion-contraction factor. We suggest you follow the advice of the pipe manufacturer regarding this condition. Anchored, and final connections should be made during the cooler hours of the day.

By using Weld-On® products as recommended and by following these hot weather tips, making strong, leakproof joints even during very hot weather conditions can be achieved.

Joining Plastic Pipe in Cold Weather

Working in freezing temperatures is never easy. But sometimes the job is necessary. If that unavoidable job includes solvent welding plastic pipe, you can do it successfully with Weld-On® Solvent Cements.

By following our standard instructions and using a little extra care as outlined below, successful solvent welded joints can be made at temperatures even as low as -15°F (-26°C). In cold weather, solvents penetrate and soften the plastic pipe and fitting surfaces more slowly than in warm weather. Also the plastic is more resistant to solvent attack. Therefore it becomes even more important to presoften surfaces with an aggressive primer. And, because of slower evaporation, a longer cure time is necessary. Our cure schedules allow a margin for safety, but for colder weather more time should be allowed.

Tips to Follow in Solvent Welding during Cold Weather:

1. Prefabricate as much of the system as is possible in a heated work area.
2. Store cements and primers in a warmer area when not in use and make sure they remain fluid. If possible, store the fittings & valves the same way.
3. Take special care to remove moisture including ice and snow from the surfaces to be joined, especially from around the ends of the pipe.
4. Use the most aggressive Weld-On Primer available to soften the joining surfaces before applying cement. More than one application may be necessary.
5. Vigorously shake or stir cement before using. Allow a longer cure period before the system is tested and used. *A heat blanket may be used to speed up the set and cure times.
6. Read and follow all of our directions carefully before installation. All Weld-On cements are formulated to have well balanced drying characteristics and to have good stability in subfreezing temperatures.

For all practical purposes, good solvent welded joints can be made in very cold conditions with proper care and a little common sense.

AVERAGE INITIAL SET SCHEDULE FOR WELD-ON PVC/CPVC SOLVENT CEMENTS™					
TEMPERATURE RANGE	PIPE SIZES 1/2″ TO 1 1/4″	PIPE SIZES 1 1/2″ TO 2″	PIPE SIZES 2 1/2″ TO 8″	PIPE SIZES 10″ TO 15″	PIPE SIZES 15″+
60°-100°F	2 min.	5 min.	30 min.	2 hrs.	4 hrs.
40°-60°F	5 min.	10 min.	2 hrs.	8 hrs.	16 hrs.
0°-40°F	10 min.	15 min.	12 hrs.	24 hrs.	48 hrs.

Note - Initial set schedule is the necessary time to allow before the joint can be carefully handled. In damp or humid weather, allow 50% more set time.

FABCO PLASTICS

AVERAGE JOINT CURE SCHEDULE FOR WELD-ON PVC/CPVC SOLVENT CEMENTS™								
RELATIVE HUMIDITY 60% OR LESS	CURE TIME PIPE SIZES 1/2" TO 1 1/4"		CURE TIME PIPE SIZES 1 1/2" TO 2"		CURE TIME PIPE SIZES 2 1/2" TO 8"		CURE TIME PIPE SIZES 10" TO 15"	CURE TIME PIPE SIZES 15"+
Temperature range during assembly and cure periods	up to 160 psi	above 160 psi to 370 psi	up to 160 psi	above 160 psi to 315 psi	up to 160 psi	above 160 psi to 315 psi	up to 100 psi	up to 100 psi
60°-100°F	15 min.	6 hrs.	30 min.	12 hrs.	1 1/2 hrs.	24 hrs.	48 hrs.	72 hrs.
40°-60°F	20 min.	12 hrs.	45 min.	24 hrs.	4 hrs.	48 hrs.	96 hrs	6 days
0°-40°F	30 min.	48 hrs.	1 hr.	96 hrs.	72 hrs.	8 days	8 days	14 days

Note - Joint cure schedule is the necessary time to allow before pressurizing system. In damp or humid weather allow 50% more cure time.

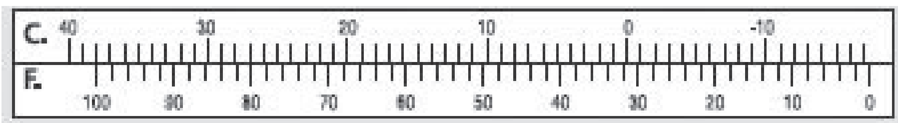
**These figures are estimates based on testing done under laboratory conditions. Field working conditions can vary significantly. This chart should be used as a general reference only.

AVERAGE NUMBER OF JOINTS/QT. OF WELD-ON CEMENT®													
PIPE DIAMETER	1/2"	3/4"	1"	1 1/2"	2"	3"	4"	6"	8"	10"	12"	15"	18"
NUMBER OF JOINTS	300	200	125	90	60	40	30	10	5	2-3	1-2	3/4	1/2

*For Primer: Double the number of joints shown for cement. These figures are estimates based on our laboratory tests. Due to the many variables in the field, these figures should be used as a general guide only. Note: 1 Joint = 1 Socket

PIPE SIZE EQUIVALENT CHART - INCHES/MILLIMETERS																	
IN.	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	4"	6"	8"	10"	12"	14"	18"	24"	30"
MM.	20	25	32	40	50	63	75	90	110	160	200	250	315	355	450	600	800

Fahrenheit to Celsius Conversion Chart



Helpful Hints

We are all aware that a properly cemented joint is a most critical part of the installation of plastic pipe and fittings. And no matter how many times we join pipe and fittings, it's very easy to overlook something. So, we just want to remind you of a few things you may already know.

1. Have you reviewed all of the instructions on the cement container label or in ASTM D-2855?
2. Are you using the proper cement for the job – for the type and size of pipe and correct fittings being joined?
3. Do you need to take special precautions because of unusual weather conditions?
4. Do you have sufficient manpower? Do you need more help to maintain proper alignment and to bottom pipe in fitting?
5. Do you have the proper tools, applicators and sufficient quantities of Weld-On® cements and primer and is cement in good condition?

Please Note: The adding of primers, cleaners or other thinners to thin the viscosity of solvent cement is not recommended.

6. Remember, primer is NOT to be used on ABS pipe or fittings.
7. Be sure to use a large enough applicator to quickly spread cement generously on pipe and fittings. Then assemble immediately.
8. Avoid puddling excess primer and cement inside the fitting socket, especially on thin wall, bell-end PVC pipe.
9. Do NOT allow primer or cement to run through a valve-socket into the valve body. The solvents can cause damage to interior valve components and cause valve malfunction.
10. Be aware at all times of good safety practices. Solvent cements for pipe and fittings are flammable, so there should be no smoking or other sources of heat, spark or flame in working or storage areas. Be sure to work only in a well ventilated space and avoid unnecessary skin contact with all solvents. More detailed safety information is available from us.
11. Take advantage of our free literature on joining techniques. We offer DVDs/CDs on joining PVC/CPVC pipe and fittings, and individual bulletins.

Special Precautions

WELD-ON® SOLVENT CEMENTS MUST NEVER BE USED IN A PVC OR CPVC SYSTEM USING OR BEING TESTED BY COMPRESSED AIR OR GASES!

Do not use any type of dry granular calcium hypochlorite as a disinfecting material for water purification in potable water piping systems. The introduction of granules or pellets of calcium hypochlorite with PVC and CPVC solvent cements and primers (including their vapors) may result in a violent chemical reaction if a water solution is not used. It is advisable to purify lines by pumping chlorinated water into the piping system – this solution will be nonvolatile. Furthermore, dry granular calcium should not be stored or used near solvent cements and primers. All systems should be flushed before start-up to remove excess fumes from piping system.

New or repaired potable water systems shall be purged of deleterious matter and disinfected prior to utilization. The method to be followed shall be that prescribed by the health authority having jurisdiction or, in the absence of a prescribed method, the procedure described in either AWWA C651 or AWWA C652.

CAUTION:

- USE CEMENTS AND PRIMERS ONLY IN WELL VENTED AREAS
- SEE MSDS SECTION II (AVAILABLE ON REQUEST) FOR EXPOSURE LIMITS AND FIRST AID INSTRUCTIONS
- CEMENTS AND PRIMERS ARE VOLATILE, KEEP AWAY FROM ANY SOURCE OF IGNITION

Storage and Handling

Store in the shade between 40°F and 110°F (5°C and 44°C) or as specified on label. Keep away from heat, spark, open flame and other sources of ignition. Keep container closed when not in use. If the unopened container is subjected to freezing, it may become extremely thick or jelled. 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 jelling has taken place because of actual solvent loss – for example, when the container was left open too long during use or not properly sealed after use. Cement in this condition should not be used and should be properly discarded.

Weld-On® solvent cements are formulated to be used “as received” in original containers. Adding thinners or primers to change viscosity is not recommended. If the cement is found to be jelly-like and not free flowing, it should not be used. Containers of cement should be shaken or stirred before using. Do not shake primers.

Listings and Standards

Weld-On products are NSF, CSA, and/or UPC listed and meet one or more of the following ASTM Standards: D-2235, D-2564, D-2846, D-3122, D-3138, F-493, F-656.

Thermo-Sealing (Socket Fusion) Instructions
For Polypropylene and PVDF Pressure Piping Systems

SCOPE

The socket fusion joining method which is detailed herein applies to all FABCO polypropylene and PVDF pressure piping systems including molded socket fittings, and socket type valve connections. This procedure involves the application of regulated heat uniformly and simultaneously to pipe and fitting mating surfaces so that controlled melting occurs at these surfaces.

All recommendations and instructions presented herein for socket fusion are based upon the use of a Thermo-Seal fusion tool for applying uniform heat to pipe and fittings.

Joining Equipment and Materials

- Cutting tools
- Cotton rags
- Deburring tool
- Thermo-Seal tool
- Electric Model NA with 1/2” - 2” tool pieces or
- Electric Model NB with 1/2” - 4” tool pieces
- Vise

TYPES OF JOINING TOOLS

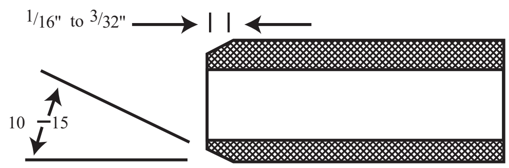
ELECTRIC MODEL tools are available for making socket fusion joints. They are the preferred socket fusion tools because the thermostatically controlled heat source automatically maintains fusion temperatures within the recommended range.

1. Electric Model NA. This tool which is electrically heated and thermostatically controlled, is used to join polypropylene and PVDF pipe, and valves and fittings in sizes 1/2” through 2”. This unit operates on 110 VAC (6.7 amps; 800 watts) electrically and is fitted with ground wires.
2. Electric Model NB. This tool is also electrically heated and thermostatically controlled and is used to join polypropylene pipe and fittings in sizes 1/2” through 4”. This unit operates on 110 VAC (1.38 amps; 1650 watts) electrically and is fitted with ground wires.

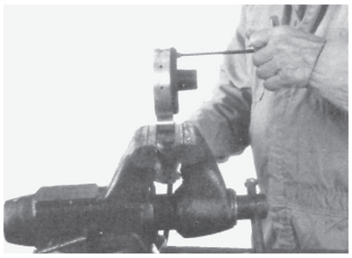
CAUTION: SOCKET FUSION AND FILLET WELDING INVOLVE TEMPERATURES IN EXCESS OF 540°F. SEVERE BURNS CAN RESULT FROM CONTACTING EQUIPMENT OR MOLTEN PLASTIC MATERIAL AT OR NEAR THESE TEMPERATURES.

PREPARATION FOR JOINING

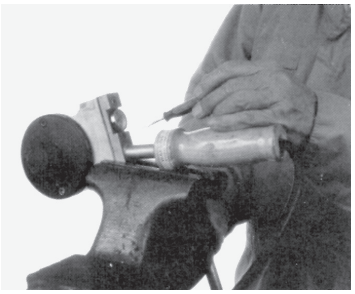
1. Cutting - Polypropylene or PVDF can be easily cut with a power or hand saw, circular or band saw. For best results, use the fine-toothed blades (16-18 teeth per inch). A circumferential speed of about 6,000 ft/min. is suitable for circular saws; band saw speed should be approximately 3,000 ft/min. Carbide-tipped blades are preferable when large quantities of pipe are to be cut. It is important that the pipe ends be cut square. To ensure square end cuts, a miter box, hold down or jig must be used. Pipe or tubing cutters can also be used to produce square, clean cuts, however, the cutting wheel should be specifically designed for plastic.
2. Deburring and Beveling - All burrs, chips, filing, etc., should be removed from both the pipe I.D. and O.D. before joining. Use a knife, deburring tool or half-round, coarse file to remove all burrs. All pipe ends should be beveled to approximately the dimensions shown below for ease of socketing and to minimize the chances of wiping melt material from the I.D. of the fitting as the pipe is socketed. The beveling can be done with a coarse file or a beveling tool.



3. Cleaning - Using a clean, dry cotton rag, wipe away all loose dirt and moisture from the I.D. and O.D. of the pipe end and the I.D. of the fitting. DO NOT ATTEMPT TO SOCKET FUSE WET SURFACES.
4. Joint Sizing - In order to provide excess material for fusion bonding, polypropylene and PVDF components are manufactured to socket dimensions in which the socket I.D. is smaller than the pipe O.D. Therefore, it should not be possible to easily slip the pipe into the fitting socket past the initial socket entrance depth and in no case should it ever be possible to bottom the pipe in the socket prior to fusion.
   Before making socket fusion joints, fittings should be checked for proper socket dimensional tolerances, based on the above discussion, by attempting to insert the pipe into the fitting socket. If a fitting socket appears to be oversize, it should not be used.
5. Planning Construction - Socket fusion joints are more easily made when there is sufficient space to properly secure the Thermo-Seal tool and to maneuver pipe and fittings into the Thermo-Seal tool. Therefore, it is recommended that the piping system be prefabricated, as much as possible, in an area where there is sufficient room to work, and that as few joints as possible should be made in areas where there is limited working space. Mechanical joints such as flanges or unions may be considered in extremely tight areas.
6. Thermo-Seal Tool Set Up
   a. Install the male and female tool pieces on either side of the Thermo-Seal tool and secure with set screws.



b. Insert the electrical plug into a grounded 110 VAC electrical source, and allow the tool to come to the proper operating temperature. The tool temperature is read directly from the mounted temperature gauge, and tool temperature can be adjusted by turning the thermostat adjustment screw with a screwdriver. (Counterclockwise) to raise the temperature and clockwise to lower the temperature.)



NOTE: One turn of the adjustment screw will give approximately a 25°F temperature change

IMPORTANT: Good socket fusion joints can be made only when the Thermo-Seal tool is operating at the proper temperature, and only when the length of time that the pipe and fittings remain on the heated tool pieces does not exceed those times recommended for the particular size of pipe and fitting to be joined. Please consult the user manual for your particular system.

Excessive temperatures and excessive heating times will result in excessive melting at and below the surfaces of the fitting socket I.D. and pipe O.D. When the pipe is inserted into the fitting socket, excessive melt material needed for socket fusion will be scraped from the socket wall and into the fitting waterway and the resulting joint will be defective. Low temperatures and insufficient heating times will result in a lack of or incomplete melting making it impossible to make a good socket fusion joint.

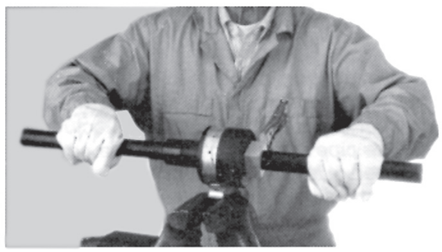
MAKING SOCKET FUSION JOINTS

1. Place the proper size depth gauge over the end of the pipe.

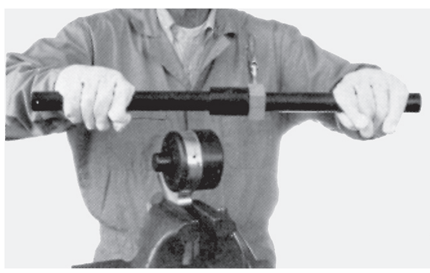
2. Attach the depth gauging clamp to the pipe by butting the clampup to the end of the depth gauge and locking it into place. Then remove the depth gauge.

3. Simultaneously place pipe and fitting squarely and fully on heat tool pieces so that the I.D. of the fitting and the O.D. of the pipe are in contact with the heating surfaces. Care should be taken to insure that the pipe and fitting are not cocked when they are inserted on the tool pieces.

4. Hold the pipe and fitting on the tool pieces for the prescribed amount of time. During this time a bead of melted material will appear around the complete circumference of the pipe at the entrance of the tool piece.



5. Simultaneously remove the pipe and fitting from the tool pieces and immediately insert the pipe, squarely and fully and without purposeful rotation, into the socket of the fitting. Hold the completed joint in place and avoid relative movement between components for at least 15 seconds.



6. Once a joint has been completed the clamp can be removed and preparation for the next joint can be started.

7. The surfaces of the female and male tool pieces are Teflon coated to prevent sticking of the hot plastic. It is important that the tool pieces be kept as clean as possible. Any residue left on the tool pieces should be removed immediately by wiping with a cotton cloth. CAUTION: HOT PLASTIC MATERIAL CAN CAUSE SEVERE BURNS; AVOID CONTACT WITH IT.

Procedures for making good socket fusion joints can be summarized into five basic principles as follows:

1. The tool must be operated at the proper temperature.
2. The pipe end must be beveled.
3. The fitting must be slipped squarely onto the male tool while the pipe is simultaneously inserted into the female tool.
4. The fitting and pipe must not remain on the heat tool for an excessive period of time. Recommended heating times must be followed.
5. The pipe must be inserted squarely into the fitting socket immediately after removal from the heated tools.
6. The Thermo-Seal tool must be kept clean at all times.

PRESSURE TESTING

The strength of a socket fusion joint develops as the material in the bonded area cools. One hour after the final joint is made, a socket fusion piping system can be pressure tested up to 100% of its hydrostatic pressure rating.

CAUTION: AIR OR COMPRESSED GAS IS NOT RECOMMENDED AND SHOULD NOT BE USED AS A MEDIA FOR PRESSURE TESTING OF PLASTIC PIPING SYSTEMS.

FILLET WELDING

SCOPE

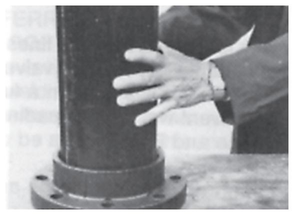
The joining procedure covered herein applies only to 6″ polypropylene drainage or non-pressure systems. Fillet Welding is not recommended as a primary joining technique for pressure rated systems.

Joining Equipment and Materials

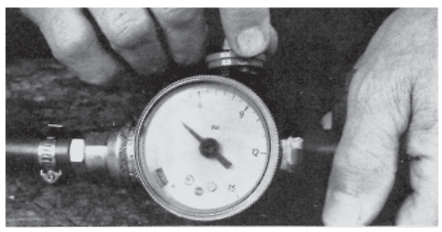
- Cutting and deburring tools
- Plastic welding gun with flexible hose, pressure regulator and gauge
- Welding and tacking tips
- Compresses air supply or bottled nitrogen (see note below)
- 1/8″ welding rod
- Cotton rags

Joining

NOTE: Fillet welding of thermoplastics is quite similar to the acetylene welding or brazing process used with metals. The fundamental differences are that the plastic rod must always be the same basic material as the pieces to be joined; and heated gas, rather than burning gas, is used to melt the rod and adjacent surfaces. Because of its economy, compressed air is normally the gas of choice for most plastic welding. A welding gun which generates itsown air supply is frequently desirable for field-made pipe joints where ultimate weld strength is not required. For welding guns which require compressed gas, nitrogen is preferable when the compressed plant air system does not contain adequate drying and filtration (Presence of moisture in the gas stream causes premature failure in the heater element of the welding gun. Impurities in the gas stream, particularly those in oil, may oxidize the plastic polymer, resulting in loss of strength. Polypropylene is known to be affected in this manner).



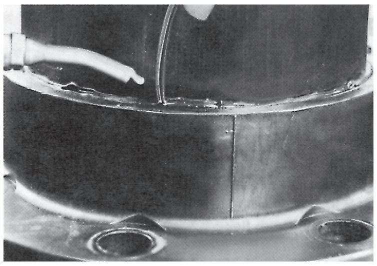
1. Insert pipe fully and squarely into the fitting after removing all dirt, oil, moisture and loose particles of plastic material from thewelding surfaces by wiping with a clean cotton cloth.



2. Adjust the nitrogen/air pressure between approximately 3 and 8 psi and further adjust the pressure as necessary to control both temperature and rate of welding.

NOTE: Tacking required prior to welding. 6″ polypropylene joints require a slip fit. Therefore, they must be dry fitted and tack welded to prevent movement of the pipe and fitting prior to the application of welding rod. Special welding gun tips are required for tacking. A low strength bond is accomplished by pulling the heated tacking tip along while directly in contact with the interface of pipe and fitting at an angle of 75° to 80° . Initially, joints are tack-fused at four intervals.

Then at least one complete revolution around the joint is made to provide a uniform groove for subsequent rod welding.



3. Holding the polypropylene welding rod at an angle of 75° to the joint and while maintaining pressure on the rod, apply heat uniformly to the rod and the pipe and fitting with an arching motionof the welding torch.

The degree of heating can be controlled by regulating the nitrogen/air flow to the welding gun or by regulating the distance from thetip of the welding gun to the work. Too much heat will over melt the polypropylene material and cause it to splash. Too little heat will result in incomplete fusion. Lay three separate weld beads in the following manner for a full fillet weld:

A. Pipe to fitting
B. Pipe to bead
C. Fitting to bead

When terminating each weld bead, the bead should be lapped ontop of (never along-side) itself for a distance of 3/8″ to 1/2″ insights to hot gas welding see REPAIRING THERMOPLASTIC PIPE JOINTS.

FLANGED JOINTS

SCOPE

Flanging is used extensively for plastic process lines that require periodic dismantling. Plastic flanges are factory flanged valves and fittings in PVC, CPVC, PVDF and polypropylene are available in a full range of sizes and types for joining to pipe by solvent welding, threading or socket fusion as in the case with polypropylene with PVDF.

Gasket seals between the flange faces should be an elastomeric full flat faced gasket with a hardness of 50 to 70 durometer. FABCO can provide neoprene gaskets in the 1/2″ through 12″ range having an 1/8″ thickness. For chemical environments too aggressive for neoprene another resistant elastomer should be used.

When it is necessary to bolt plastic and metal flanges - use flat face metal flanges - not raised face, and use recommended torques shown in table under "INSTALLATION TIPS".

DIMENSIONS

Bolt circle and number of bolt holes for the flanges are the same as Class 150 metal flanges per ANSI B16.5. Threads are tapered iron pipe size threads per ANSI B1.20.1. The socket dimensions conform to ASTM D-2467 which describes 1/2″ through 8″ sizes and ASTM D439 for Schedule 80 CPVC which gives dimensional data for 1/2″ through 6″. Internal Fabco specifications have been established for the 10″ and 12″ PVC patterns and 8″ CPVC design, as well as socket designs for polypropylene and PVDF.

PRESSURE RATING

As with all other thermoplastic piping components, the maximum non-shock operating pressure is a function of temperature.

Maximum pressure rating for FABCO valves, unions and flanges is 150 psi. Above 100°F refer to the TEMPERATURE CORRECTION FACTOR CHART HEREIN.

SEALING

The faces of flanges are tapered back away from the orifice area at a 1/2 to 1 degree pitch so that when the bolts are tightened the faces will be pulled together generating a force in the water way area to improve sealing.

INSTALLATION TIPS

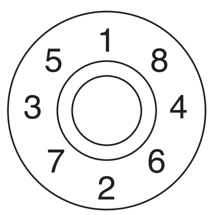
Once a flange is joined to pipe, the method for joining two flanges together is as follows:

1. Make sure that all the bolt holes of the mating flanges match up. It is not advisable to twist the flange and pipe to achieve this.
2. Use flat washers under bolt heads and nuts.
3. Insert all bolts. (Lubricate bolts.)
4. Make sure that the faces of the mating flanges are not separated by excessive distance prior to bolting down the flanges.
5. The bolts on the plastic flanges should be tightened by pulling down the nuts diametrically opposite each other using a torque wrench. Complete tightening should be accomplished in stages and the final torque values shown in the table should be followed for the various sizes of flanges. Uniform stress across the flange will eliminate leaky gaskets.

FLANGE SIZE	RECOMMENDED TORQUE*
1/2 - 1-1/2″	10 - 15 ft.lbs.
2 - 4″	20 - 30 ft.lbs.
6 - 8″	33 - 50 ft.lbs.
10″	53 - 75 ft.lbs.
12″	80 - 110 ft.lbs.

*For a well lubricated bolt with flat washers under bolt head and nut.

The following tightening pattern is suggested for the flange bolts.



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

Repairing Thermoplastic Pipe Joints

SCOPE

The most common method for repairing faulty and leaking joints is hot gas welding at the fillet formed by the junction of the fitting socket entrance and the pipe. Hot gas welding (which is similar to gas welding with metals except that hot gas is used for melting instead of a direct flame) consists of simultaneously melting the surface of a plastic filler rod and the surfaces of the base material in the fillet area while forcing the softened rod into the softened fillet. Welding with plastics involves only surface melting because plastics unlike metal must never be "puddled". Therefore, the resulting weld is not as strong as the parent pipe and fitting material. This being the case, fillet welding as a repair technique is recommended for minor leaks only. It is not recommended as a primary joining technique for pressure rated systems.

WELDING TOOLS AND MATERIALS

- Plastic welding gun with pressure regulator, gauge and hose.
- Filler rod
- Emery cloth
- Cotton rags
- Cutting pliers
- Hand grinder (optional)
- Compressed air supply of bottled nitrogen
- Source of compressed air

WELD AREA PREPARATION

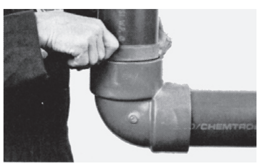
Wipe all dirt, oil and moisture from the joint area. A very mild solvent may be necessary to remove oil.

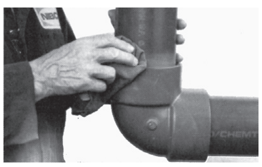
CAUTION: MAKE SURE THAT ALL LIQUID HAS BEEN REMOVED FROM THE PORTION OF THE PIPING SYSTEM WHERE THE WELD IS TO BE MADE.

If backwelding is required, all residual cement, which is easily scorched during welding, must be removed from the fillet by using emery cloth. If the weld is to seal a threaded joint, a file can be used to remove threads in the weld area in order to provide a smooth surface.

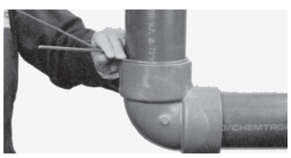
WELDING BACK JOINTS

1. Remove residual solvent cement from the weld area using emery cloth. When welding threaded joints, a file can be used to remove threads in the weld area.

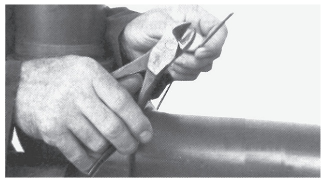




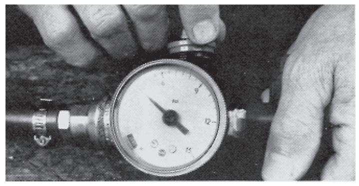
2. Wipe the weld area clean of dust, dirt and moisture.
3. Determine the amount for the correct filler rod necessary to make one complete pass around the joint by wrapping the rod around the pipe to be welded. Increase this length enough to allow for handling of the rod to the end of the pass.



4. Make about a 60° angular cut on the lead end of the filler rod. This will make it easier to initiate melting and will insure fusion of the rod and base material at the beginning of the weld.

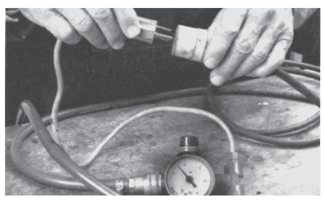


5. Welding temperatures vary for different thermoplastic materials (500°F - 550°F for PVC and CPVC, 550°F – 600°F for PP, 575°F - 600°F for PVDF). Welding temperatures can be adjusted for the various thermoplastic materials as well as any desired welding rate, by adjusting the pressure regulator (which controls the gas flow rate) between 3 and 8 PSI.



CAUTION: For welding guns which require compressed gas, nitrogen is preferred when the compressed plant air system does not contain adequate drying and filtration. (Presence of moisture in the gas stream causes premature failure in the heater element of the welding gun. Impurities in the gas stream, particularlythose in oil, may oxidize the plastic polymer, resulting in loss of strength. Polypropylene is known to be affected in this manner).

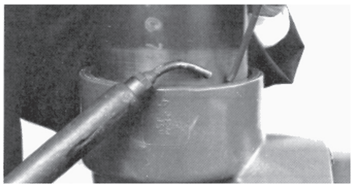
6. With air or an inert gas flowing through the welding torch, insert the electrical plug for the heating element into an appropriate electrical socket to facilitate heating of the gas and wait approximately 7 minutes for the welding gas to reach the proper temperature.



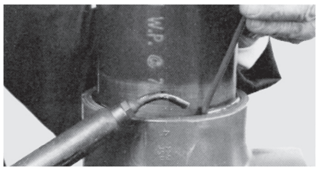
CAUTION: THE METAL BARREL OF THE WELDING TORCH HOUSES THE HEATING ELEMENT SO IT CAN ATTAIN EXTREMELY HIGH TEMPERATURES. AVOID CONTACT WITH THE BARREL AND DO NOT ALLOW IT TO CONTACT ANY COMBUSTIBLE MATERIALS.

7. Place the leading end of the filler rod into the fillet formed by the junction of the pipe and fitting socket entrance. Holding the filler rod at an angle of 90° to the joint for PVC, CPVC and Kynar, 75° to the joint for polypropylene, pre-heat the surfaces for the rod and base materials at the weld starting point by holding the welding torch steady at approximately

1/4 to 3/4 inches from the weld starting point and directing the hot gas in this area until the surfaces become tacky . While preheating, move the rod up and down slightly so that the rod slightly touches the base materials. When the surfaces become tacky, the rod will stick to the base material.

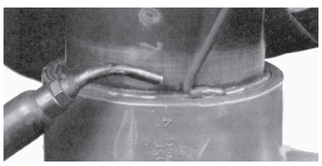


8. Advance the filler rod forward by applying a slight pressure to the rod. Simultaneously applying even heat to the surfaces of both the filler rod and base material by moving the torch with a fanning or arcing motion at a rate of about 2 cycles per second. The hot gas should be played equally on the rod and base material (along the weld line) for a distance of about 1/4 inch from the weld point.

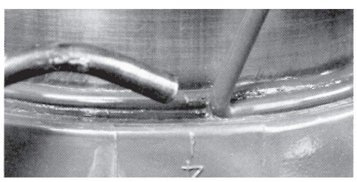


IMPORTANT: If charring of the base or rod material occurs, move the tip of the torch back slightly, increase the fanning frequency or increase the gas flow rate. If the rod or base materials do not melt sufficiently reverse the previously discussed corrective procedures. Do not apply too much pressure to the rod because this will tend to stretch the weld bead causing it to crack and separate after cooling.

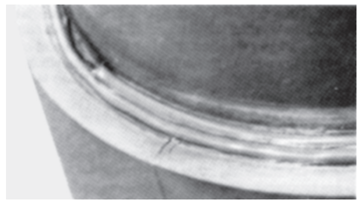
9. Since the starting point for a plastic weld is frequently the weakest part of the weld, always terminate a weld by lapping the bead on top of itself for a distance of 3/8 to 1/ 2 inches. Never terminate a bead by overlapping the bead side by side.



10. When welding large diameter pipe, three weld passes may be required. The first bead should be deposited at the bottom of the fillet and subsequent beads should be deposited on each side of the first bead. When making multiple pass welds, the starting points for each bead should be staggered and ample time must be allowed for each weld pass to cool before proceeding with additional welds.



11. Properly applied plastic welds can be recognized by the presence of small flow lines or waves on both sides of the deposited bead. This indicates that sufficient heat was applied to the surfaces of the rod and base materials to effect adequate melting and that sufficient pressure was applied to the rod to force the rod melt to fuse with base material melt. If insufficient heat is used when welding PVC, CPVC or PVDF, the filler rod will appear in its original form and can easily be pulled away from the base material. Excessive heat will result in a brown or black discoloration of the weld. In the case of polypropylene, excessive heat will result in a flat bead with oversized flow lines.



12. Always unplug the electrical connection to the heating element and allow the welding gun to cool before shutting off the gas or air supply to the gun.

WELDING PRINCIPLES

The procedures for making good thermoplastic welds can be summarized into four basic essentials:

1. Correct Heating – Excessive heating will char or overmelt. Insufficient heating will result in incomplete melting.
2. Correct Pressure – Excessive pressure can result in stress cracking when the weld cools. Insufficient pressure will result in incomplete fusion of the rod material with the base material.
3. Correct angle – Incorrect rod angle during welding will stretch the rod and the finished weld will crack upon cooling.
4. Correct speed – Excessive welding speed will stretch the weld bead and the finished weld will crack upon cooling.

Rod Size and Weld Passes

Filler rod size and the number of weld passes required to make a good plastic weld are dependent upon the size of the pipe to be welded as presented below. Do not use filler rod larger than 1/8″ in diameter when welding with CPVC. Also, when welding CPVC, the number of passes for pipe sizes 1″ through 2″ should be increased to three.

PIPE SIZE	ROD SIZE	NUMBER OF PASSES
1/2″ - 3/4″	3/32″	1
1″ - 2″	3/32″	1 or 3
2-1/2″ - 4″	1/8″	3
6″ - 8″	1/8″ or 5/32″	3
10″ - 12″	5/32″ or 3/16″	3

Pressure Testing

The strength of a plastic weld develops as it cools. Allow ample time for the weld to cool prior to 100% pressure testing.

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

Threading Instructions for Thermoplastic Pipe

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) B1.20.1 and presented in the table on the following page.

THREADING EQUIPMENT AND MATERIALS

- Pipe Dies
- Pipe Vise
- Threading ratchet or power machine
- Tapered plug
- Cutting lubricant (soap & water)
- Strap wrench
- Teflon tape
- Cutting and Deburring tools

Pipe Preparation

Plastic pipe can be easily cut with a handsaw, power hacksaw, circular or band saw. For best results, use a finetoothed blade (16-18 teeth per inch) with little or no set (maximum 0.025”). A circumferential speed of about 6,000 ft./ min. is suitable for circular saws; band saw speed should be approximately 3,000 ft./min. Carbide-tipped blades are preferable when quantities of pipe are to be cut. To ensure square-ends, a miter box hold-down or jig should be used. Pipe or tubing cutters can be used for smaller diameter pipe when the cutting wheel is specifically designed for plastic pipe.

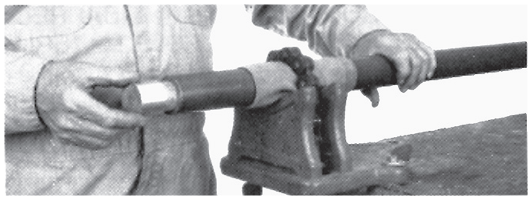
Threading Dies

Thread cutting dies should be clean, sharp and in good condition, and should not be used to cut materials other than plastics. Dies with a 5° negative front rake are recommended when using power threading equipment and dies with a 5° to 10° negative front rake are recommended when cutting threads by hand.

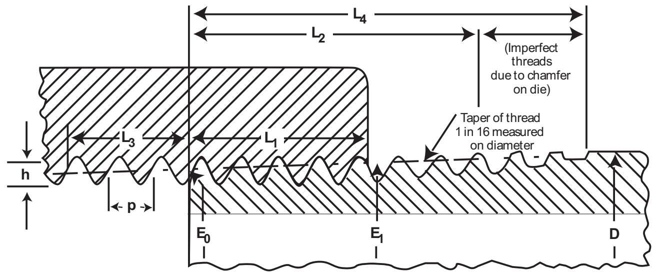
Threading and Joining

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

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



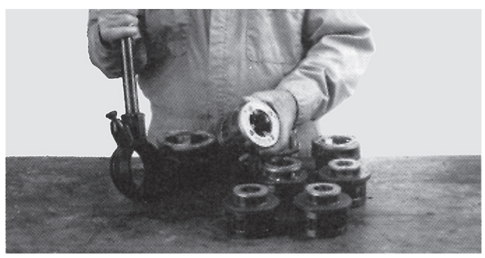
DO NOT THREAD SCHEDULE 40 PIPE



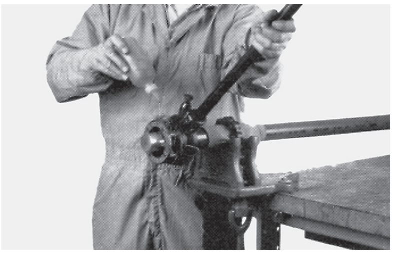
REINFORCING PLUG DIMENSIONS	
PIPE SIZE	**PLUG O.D.***
1/2”	.526
3/4”	.722
1”	.935
1-1/4”	1.254
2”	1.913
2-1/2	2.289
3	2.864
4	3.786

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

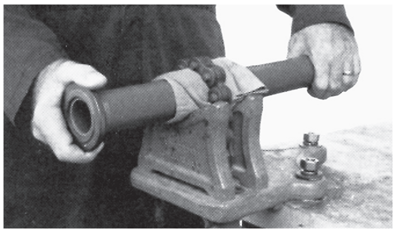
3. Use a die stock with a proper guide that is free of burrs or sharp edges, so the die will start and go on square to the pipe axis.



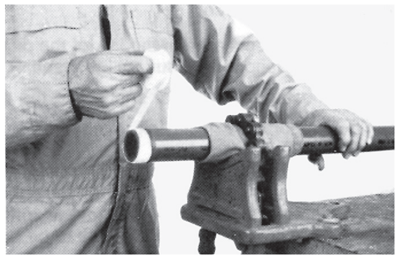
4. Push straight down on the handle, avoiding side pressure that might distort the sides of the threads. If power threading equipment is used, the dies should not be driven at high speeds or with heavy pressure. Apply an external lubricant liberally when cutting the threads. Advance the die to the point where the thread dimensions are equal to those listed in Table No. 1. Do not over thread.



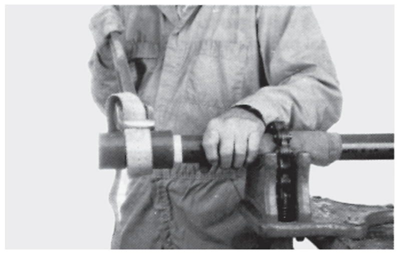
5. Periodically check the threads with a ring gauge to ensure that proper procedures are being followed. Thread dimensions are listed in Table 1 and the gauging tolerance is ± 1-1/2 turns.



6. Brush threads clean of chips and ribbons. Then starting with the second full thread, and continuing over the thread length, wrap TFE (Teflon) thread tape in the direction of the threads. Overlap each wrap by one half of the width of the tape. FABCO does not recommend the use of any thread lubricant/sealant other than TFE (Teflon) tape.



7. Thread the fitting onto the pipe and tighten by hand. Using a strap wrench only, further tighten the connection an additional one or two threads past hand tightness. Avoid excessive torque as this may cause thread damage or fitting damage.



PRESSURE TESTING

Threaded piping systems can be pressure tested up to 100% of thehydrostatic pressure rating as soon as the last connection is made.

CAUTION: AIR OR COMPRESSED GAS IS NOT RECOMMENDED AND SHOULD NOT BE USED AS A MEDIA FOR PRESSURE TESTING OF PLASTIC PIPING SYSTEMS.

PIPE AND FITTING THREADS AMERICAN STANDARD TAPER PIPE THREAD, NPT (EXCERPT FROM ANSI B1.20.1)

Nominal Size	Outside Diameter D	Number of Threads Per In. n	Pitch of Thread p	Normal Engagement By Hand L1	Normal Engagement By Hand L2	Wrench Makeup Length For Internal Thread L3	Total Length: End of Pipe to Vanish Point L4	Pitch Diameter at Beginning of External Thread E0	Pitch Diameter at Beginning of Internal Thread E1	Height of Thread (Max) h
IN	IN	IN	IN	IN	IN	IN	IN	IN	IN	IN
1/4	0.54	18	.05556	.228	.4018	.1667	.5946	.47739	.49163	.04444
1/2	0.84	14	.07143	.32	.5337	.2143	.7815	.75843	.77843	.05714
3/4	1.05	14	.07143	.339	.5457	.2143	.7935	.96768	.98887	.05714
1	1.315	11 1/2	.08696	.400	.6828	.2609	.9845	1.21363	1.23863	.06957
1 1/4	1.660	11 1/2	08696	.420	.7068	.2609	1.0085	1.55713	1.58338	06957
1 1/2	1.900	11 1/2	08696	.420	.7235	.2609	1.0252	1.79609	1.82234	06957
2	2.375	11 1/2	08696	.436	.7565	.2609	1.0582	2.26902	2.29627	06957
2 1/2	2.875	8	12500	.682	1.1375	.2500	1.5712	2.71953	2.76216	10000
3	3.500	8	12500	.766	1.2000	.2500	1.6337	3.34062	3.38850	10000
4	4.500	8	.12500	.844	1.3000	.2500	1.7337	4.33438	4.38712	10000

(NOTE: Special dies for threading plastic pipe are available). When cutting threads with power threading equipment, self opening die heads and a slight chamfer to lead the dies will speed production.

Temperature Rating of Fabco Products

Since the strength of plastic pipe is sensitive to temperature, the identical test method is used to determine the material strength at elevated temperature levels. The correction factor for each temperature is the ratio of strength at that temperature level to the basic strength at 73° F. Because the hoop stress is directly proportional to the internal pressure, which created that pipe stress, the correction factors may be used for the temperature correction of pressure as well as stress. For pipe and fitting applications above 73° F, refer to the table below for the Temperature Correction Factors. To determine the maximum non-shock pressure rating at an elevated temperature, simply multiply the base pressure rating obtained from the table in the preceding column by the correction factor from the table below. The allowable pressure will be the same as the base pressure for all temperatures below 73° F.

TEMPERATURE CORRECTION FACTORS

OPERATING TEMPERATURE (°F)	FACTORS PVC	CPVC	PP	PVDF
70	1.00	1.00	1.00	1.00
80	0.90	0.96	0.97	0.95
90	0.75	0.92	0.91	0.87
100	0.62	0.85	0.85	0.80
110	0.50	0.77	0.80	0.75
115	0.45	0.74	0.77	0.71
120	0.40	0.70	0.75	0.68
125	0.35	0.66	0.71	0.66
130	0.30	0.62	0.68	0.62
140	0.22	0.55	0.65	0.58
150	N.R.	0.47	0.57	0.52
160	N.R.	0.40	0.50	0.49
170	N.R.	0.32	0.26	0.45
180	N.R.	0.25	*	0.42
200	N.R.	0.18	N.R.	0.36
210	N.R.	0.15	N.R.	0.33
240	N.R.	N.R.	N.R.	0.25
280	N.R.	N.R.	N.R.	0.18

* Recommended for intermittent drainage pressure not exceeding 20 psi.
N.R. = Not Recommended.

Pressure Rating of Fabco Products

The pressure carrying capability of any pipe at a given temperature is a function of the material strength from which the pipe is made and the geometry of the pipe as defined by its diameter and wall thickness. The following expression, commonly known as the ISO equation, is used in thermoplastic pipe specifications to relate these factors:

$$P = 2S / (D_o/t - 1)$$

where: P = maximum pressure rating, psi
S = maximum hydraulic design stress (max. working strength), psi
Do = average outside pipe diameter, in.
t = minimum wall thickness, in.

The allowable design stress, which is the tensile stress in the hoop direction of the pipe, is derived for each material in accordance with ASTM D 2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials, at 73° F. The pressure ratings below were calculated from the basic Hydraulic Design Stress for each of the materials.

Pipe and Fittings

In order to determine the pressure rating for a product system, first find the plastic material and schedule of pipe and fittings in the heading of the Maximum Non-Shock Operating Pressure table below. Then, locate the selected joining method in the subheading of the table and go down the column to the value across from a particular pipe size, listed in the far left column. This will be the maximum non-shock operating pressure at 73° F for the defined product system.

MAX. NON-SHOCK OPERATING PRESSURE (PSI) AT 73°F

	SCHEDULE 40 PVC & CPVC	SCHEDULE 80 PVC & CPVC	
Nom. Pipe Size	Socket End	Socket End	Threaded End
1/2	600	850	420
3/4	480	690	340
1	450	630	320
1 1/4	370	520	260
1 1/2	330	470	240
2	280	400	200
2 1/2	300	420	210
3	260	370	190
4	220	320	160
6	180	280	N.R.
8	160	2502	N.R.
10	140	230	N.R.
12	130	230	N.R.

SCHEDULE 80 POLYPROPYLENE			SCHEDULE 80 PVDF	
Nom. Pipe Size	Thermo Seal Joint	Threaded	Thermo Seal Joint	Threaded
1/2	410	20	580	290
3/4	330	20	470	230
1	310	20	430	210
1 1/4	260	20	—	—
1 1/2	230	20	326	160
2	200	20	270	140
2 1/2	—	—	—	—
3	190	20	250	N.R.
4	160	20	220	N.R
6	140	N.R.	190	N.R.

N.R. = Not Recommended.

1. For more severe service, an additional correction factor may be required.
2. 8” CPVC Tee, 90° ELL and 45° ELL rated at 1/2 of value shown. Pressure rating of 175 psi can be obtained by factory overwrapping with glass and polyester. Consult Customer Service for delivery information.
3. Recommended for intermittent drainage pressure not exceeding 20 psi.

Valves, Unions, and Flanges

The maximum pressure rating for valves, flanges, and unions, regardless of size, is 150 psi at 73° F. As with all other thermoplastic piping components, the maximum non-shock operating pressure is related to temperature. Above 100° F refer to the chart below.

MAXIMUM NON-SHOCK OPERATING PRESSURE (PSI) VS. TEMPERATURE				
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	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
250	N.R.	N.R.	N.R.	50
280	N.R.	N.R.	N.R.	25

N.R. = Not Recommended.

Fabco Products in Vacuum or Collapse Loading Situations

Thermoplastic pipe is often used in applications where the pressure on the outside of the pipe exceeds the pressure inside. Suction or vacuum lines and buried pipe are examples of this type of service. As a matter of practical application, gauges indicate the pressure differential above or below atmospheric pressureHowever, scientists and engineers frequently express pressure on an absolute scale where zero equals a theoretically perfect vacuum and standard atmospheric pressure equals 14.6959 psia.

Solvent cemented or thermo-sealed joints are particularly recommended for vacuum service. In PVC, CPVC, PP, or PVDF vacuum systems, mechanical devices such as valves and transition joints at equipment will generally represent a greater intrusion problem than the thermoplastic piping system will. Experience indicates that PVC vacuum systems can be evacuated to pressures as low as 5 microns with continuous pumping. However, when the system is shut off, the pressure will rise and stabilize around 10,000 microns or approximately 10 mm of Mercury at 73° F. The following chart lists the allowable collapse loading for plastic pipe at 73° F. It shows how much greater the external pressure may be than the internal pressure. (Thus, a pipe with 100 psi internal pressure can withstand 100 psi more external pressure than a pipe with zero psi internal pressure.) For temperatures other than 73° F, multiply the values in the chart by the correction factors listed in the temperature correction table on the preceding page. The chart also applies to a vacuum. The external pressure is generally atmospheric pressure, or 0.0 psig, while the internal pressure is normally identified as a vacuum or negative gauge pressure. However, this negative value will never exceed −14.7 psig. Therefore, if the allowable pressure listed in the chart (after temperature correction) is greater than the difference for internal-to-external pressure, the plastic system is viable.

Pipe Size	Sch. 40 PVC	Sch. 80 PVC	Sch. 80 CPVC	Sch. 80 PP	Sch. 80 PVDF
1/2	450	575	575	230	391
3/4	285	499	499	200	339
1	245	469	469	188	319
1 1/4	160	340	340	136	—
1 1/2	120	270	270	108	183
2	75	190	190	76	129
2 1/2	100	220	220	—	—
3	70	155	155	62	105
4	45	115	115	46	78
6	25	80	80	32	54
8	16	50	50	—	—
10	12	43	—	—	—
12	9	39	—	—	—

Pressure Losses in a Piping System

Piping Calculations

As a fluid flows through a piping system, it will experience a headloss depending on, among other factors, fluid velocity, pipe wall smoothness and internal pipe surface area. The Tables on pages 9 and 10 give Friction Loss and Velocity data for Schedule 40 and Schedule 80 thermoplastic pipe based on the Williams and Hazen formula.

$$H=0.2083 \times (100/C)1.852 \times (q1.852/d4.8655)$$

Where: H = Friction Head Loss in Feet of Water/100 Feet of Pipe
C = Surface Roughness Constant (150 for all thermoplastic pipe)
q = Fluid Flow (gallons/min.)
d = Inside Diameter of Pipe

Fittings and valves, due to their more complex configurations, contribute significant friction losses in a piping system. A common method of expressing the losses experienced in fittings is to relate them to pipe in terms of equivalent pipe length. This is the length of pipe required to give the same friction loss as a fitting of the same size. Tables are available for the tabulation of the equivalent pipe length in feet for the various sizes of a number of common fittings. By using this Table and the Friction Loss Tables, the total friction loss in a plastic piping system can be calculated for any fluid velocity.

For example, suppose we wanted to determine the pressure loss across a 2” Schedule 40, 90° elbow, at 75 gpm. From the lower table we find the equivalent length of a 2” 90° elbow to be 5.5 feet of pipe. From the Schedule 40 Pipe Table we find the friction loss to be 3.87 psi per 100 feet of pipe when the flow rate is 75 gpm. Therefore, the solution is as follows:

5.5 Feet/90° Elbow x 3.87 psi/100 Feet
= 0.21 psi Pressure Drop/90° Elbow

which is the pressure drop across a 2” Schedule 40 elbow. But, what if it were a 2” Schedule 80 elbow, and we wanted to know the friction head loss? The solution is similar, except we look for the friction head in the Schedule 80 Pipe Table and find it to be 12.43 feet per 100 feet of pipe when the flow rate is 75 gpm. The solution follows:

5.5 Feet/90° Elbow x 12.43 Feet/100 Feet
= 0.68 Feet Friction Head/90° Elbow

which is the friction head loss across a 2” Schedule 80 elbow.

For a copy of the tables mentioned in this section, please contact customer service.

Valve Calculations

As an aid to system design, liquid sizing constants (Cv values) are shown for valves where applicable. These values are defined as the flow rate through the valve required to produce a pressure drop of 1 psi. To determine the pressure drop for a given condition the following formula may be used:

$$P=(Q^2 S.G.)/(Cv^2)$$

Where: P = Pressure drop across the valve in psi
Q = Flow through the valve in gpm
S.G. = Specific gravity of the liquid (Water=1.0)
Cv = Flow coefficient

See the solution of the following example problem. For Cv values for specific valves, contact customer service or consult the manufacturers catalog.

EXAMPLE:
Find the pressure drop across a 1 1/2” PVC ball check valve with a water flow rate of 50 gpm. The Cv is 56.

$P=(50^2 \times 1.0)/56^2$
$P=(50/56)^2$
$P=0.797$ psi

Hydraulic Shock

Hydraulic shock is the term used to describe the momentary pressure rise in a piping system which results when the liquid is started or stopped quickly. This pressure rise is caused by the momentum of the fluid; therefore, the pressure rise increases with the velocity of the liquid, the length of the system from the fluid source, or with an increase in the speed with which it is started or stopped. Examples of situations where hydraulic shock can occur are valves which are opened or closed quickly or pumps which start with an empty discharge line. Hydraulic shock can even occur if a highspeed wall of liquid (as from a starting pump) hits a sudden change of direction in the piping, such as an elbow.
The pressure rise created by the hydraulic shock effect is added to whatever fluid pressure exists in the piping system and, although only momentary, this shock load can be enough to burst pipe and break fittings or valves.

Proper design when laying out a piping system will limit the possibility of hydraulic shock damage.

The following suggestions will help in avoiding problems:

1. In a plastic piping system, a fluid velocity not exceeding 5 ft./sec. will minimize hydraulic shock effects, even with quickly closing valves, such as solenoid valves. (Flow is normally expressed in GALLONS PER MINUTE—GPM. To determine the fluid velocity in any segment of piping the following formula may be used:

$$V=(0.4085 \times GPM)/Di^2$$

Where: v = fluid velocity in feet per second

Di = inside diameter

GPM = rate of flow in gallons per minute

Flow Capacity Tables are available for the fluid velocities resulting from specific flow rates in Schedule 40 and Schedule 80 pipes. The upper threshold rate of flow for any pipe may be determined by substituting 5 ft./sec. Fluid velocity in the above formula and solving for GPM.

Upper Threshold Rate of Flow (GPM) = $12.24\ Di^2$

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 air-to-air and air-to-spring actuators, it will probably be necessary to place a flow control valve in the air line to slow down the valve operation cycle, particularly on valve sizes greater than 1 1/2".
3. If possible, when starting a pump, partially close the valve in the discharge line to minimize the volume of liquid that 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 hydraulic shock during pump start-up. Before initial start-up the discharge line should be vented of all air. Air trapped in the piping will substantially reduce the capability of plastic pipe withstanding shock loading.

Shock Surge Wave

Providing all air is removed from an affected system, a formula based on theory may closely predict hydraulic shock effect.

Where: p = maximum surge pressure, psi

v = fluid velocity in feet per second.

C = surge wave constant for water at 73° F.

*SG = specific gravity of liquid, *if SG is 1, then p = vC

EXAMPLE:

A 2" PVC Schedule 80 pipe carries a fluid with a specific gravity of 1.2 at a rate of 30 gpm and at a line pressure of 160 psi. What would the surge pressure be if a valve were suddenly closed?

From table: c = 24.2 v = 3.35

p = (3.35) (26.6) = 90 psi

Total line pressure = 90 + 160 = 250 psi

Schedule 80 2" PVC has a pressure rating of 400 psi at room temperature. Therefore, 2" Schedule 80 PVC pipe is acceptable for this application.

SURGE WAVE CONSTANT(C)

PIPE	PVC		CPVC		PP	PVDF
	Sch.40	Sch.80	Sch.40	Sch.80	Sch.80	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	18.3
4	17.8	21.8	18.8	22.9	15.4	17.0
6	15.7	20.2	16.8	21.3	14.2	15.8
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		

CAUTION: The removal of all air from the system in order for the surge wave analysis method to be valid was pointed out at the beginning of this segment. However, this can be easier said than done. Over reliance on this method of analysis is not encouraged. Our experience suggests that the best approach to assure a successful installation is for the design to focus on strategic placements of air vents and the maintenance of fluid velocity near or below the threshold limit of 5 ft./sec.

Expansion and Thermal Contraction of Plastic Pipe

Calculating Dimensional Change

All materials undergo dimensional change as a result of temperature variation above or below the installation temperature. The extent of expansion or contraction is dependent upon the coefficient of linear expansion for the piping material. These coefficients are listed below for the essential industrial plastic piping materials in the more conventional form of inches of dimensional change, per ° F of temperature change, per inch of length. They are also presented in a more convenient form to use. Namely, the units are inches of dimensional change, per 10° F temperature change, per 100 feet of pipe.

EXPANSION COEFFICIENT

MATERIAL	C(IN/IN/°F$\times 10^{-5}$)	Y(IN/10°F/100 FT)
PVC	3.0	.360
CPVC	3.8	.456
PP	5.0	.600
PVDF	7.9	.948

The formula for calculating thermally induced dimensional change, utilizing the convenient coefficient (Y), is dependent upon the temperature change to which the system may be exposed – between the installation temperature and the greater differential to maximum or minimum temperature – as well as, the length of pipe run between directional changes or anchors points.

the length of pipe run between directional changes or anchors points. Also, a handy chart is presented at the bottom of this column, which approximates the dimensional change based on temperature change vs. pipe length.

L=Yx(T1-T2)/10 X L/100

L = Dimensional change due to thermal expansion or contraction(in)
Y = Expansion coefficient (See table above) (in/10°/100 ft)
(T1-T2) = Temperature differential between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential (° F).
L = Length of pipe run between changes in direction (ft.)

EXAMPLE 1:
How much expansion can be expected in a 200 foot straight run of 3 inch PVC pipe that will be installed at 75° F when the piping system will be operated at a maximum of 120° F and a minimum of 40° F?

L=(120-75)/10x200/100=0.360x4.50x2.0=3.24 in.

TEMP	LENGTH OF PIPE TO CLOSEST ANCHOR POINT (FT.)									
T(°F)	10'	20'	30'	40'	50'	60'	70'	80'	90'	100'
10°	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36
20°	0.07	0.14	0.22	0.29	0.36	0.43	0.50	0.58	0.65	0.72
30°	0.11	0.22	0.32	0.43	0.54	0.65	0.76	0.86	0.97	1.08
40°	0.14	0.29	0.43	0.58	0.72	0.86	1.00	1.15	1.30	1.44
50°	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80
60°	0.22	0.43	0.65	0.86	1.08	1.30	1.51	1.73	1.94	2.16
70°	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
80°	0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.30	2.59	2.88
90°	0.32	0.65	0.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100°	0.36	0.72	1.08	1.44	1.80	2.16	2.52	2.88	3.24	3.60
110°	0.40	0.79	1.19	1.58	1.98	2.38	2.77	3.17	3.56	3.96
120°	0.43	0.86	1.30	1.73	2.16	2.59	3.02	3.46	3.89	4.32

Note: Temperature change (T) from installation to the greater of maximum or minimum limits.

To determine the expansion or contraction for pipe of a material other than PVC, multiply the change in length given for PVC in the table above by 1.2667 for the change in CPVC, by 1.6667 for the change in PP, or by 2.6333 for the change in PVDF.

Calculating Stress

If movement resulting from thermal changes is restricted by the piping support system or the equipment to which it is attached, the resultant forces may damage the attached equipment or the pipe itself. Therefore, pipes should always be anchored independently at those attachments. If the piping system is rigidly held or restricted at both ends when no compensation has been made for thermally induced growth or shrinkage of the pipe, the resultant stress can be calculated with the following formula.

St = EC (T1-T2)
St = Stress (psi)
E = Modulus of Elasticity (psi) (See table below for specific values at various temperatures)
C = Coefficient of Expansion (in/in/ ° F x 105) (see physical property chart on page 2 for values)
(T1-T2) = Temperature change (° F) between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential.

MODULUS OF ELASTICITY							
	73°F	90°F	100°F	140°F	180°F	210°F	250°F
PVC	4.20	3.75	3.60	2.70	N/A	N/A	N/A
CPVC	4.23	4.00	3.85	3.25	2.69	2.20	N/A
PP	1.79	1.25	1.15	.72	.50	N/A	N/A
PVDF	2.19	1.88	1.74	1.32	1.12	.81	.59

N/A - Not Applicable

The magnitude of the resulting longitudinal force can be determined by multiplying the thermally induced stress by the cross sectional area of the plastic pipe.

F = St x A
F = FORCE (lbs)
St = STRESS (psi)
A = CROSS SECTIONAL AREA (in²)

EXAMPLE 2:
What would be the amount of force developed in 2" Schedule 80 PVC pipe with the pipe rigidly held and restricted at both ends? Assume the temperature extremes are from 70° F to 100° F.

St = EC (T1 – T2)
St = EC (100 – 70)
St = (3.60 x 105) x (3.0 x 10-5) (30)
St = 324 psi

The Outside and Inside Diameters of the pipe are used for calculating the Cross Sectional Area (A) as follows: (See the Pipe Reference Table for the pipe diameters and cross sectional area for specific sizes of schedule 80 Pipes.)

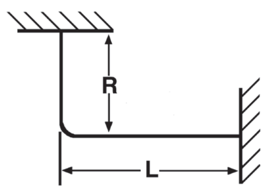
$$A=\pi/4(OD^2-ID^2)=3.1416/4(2.375^2-1.913^2)$$
$$=1.556 \text{ in}^2$$

The force exerted by the 2" pipe, which has been restrained, is simply the compressive stress multiplied over the cross sectional area of that pipe.

F = St x A
F = 324 psi x 1.556 in.2
F = 504 lbs.

Managing Expansion/Contraction in System Design

Stresses and forces which result from thermal expansion and contraction can be reduced or eliminated by providing for flexibility in the piping system through frequent changes in direction or introduction of loops as graphically depicted on this page.



Normally, piping systems are designed with sufficient directional changes, which provide inherent flexibility, to compensate for expansion and contraction. To determine if adequate flexibility exists in leg (R) (see Fig. 1) to accommodate the expected expansion and contraction in the adjacent leg(L) use the following formula:

$$R = 2.877\sqrt{D\,L} \quad \text{SINGLE OFFSET FORMULA}$$

Where: R = Length of opposite leg to be flexed (ft.)
D = Actual outside diameter of pipe (in.)
L = Dimensional change in adjacent leg due to thermal expansion or contraction (in.)

Keep in mind the fact that both pipe legs will expand and contract. Therefore, the shortest leg must be selected for the adequacy test when analyzing inherent flexibility in naturally occurring offsets.

EXAMPLE 3:

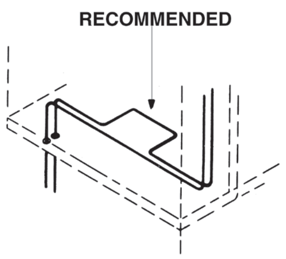
What would the minimum length of a right angle leg need to be in order to compensate for the expansion if it were located at the unanchored end of the 200 ft. run of pipe in Example 1 from the previous page?

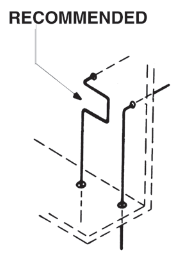
$$R = 2.877\sqrt{3.500 \times 3.24} = 9.69 \text{ ft.}$$

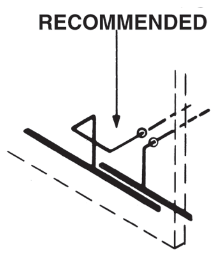
Flexibility must be designed into a piping system, through the introduction of flexural offsets, in the following situations:

1. Where straight runs of pipe are long.
2. Where the ends of a straight run are restricted from movement.
3. Where the system is restrained at branches and/or turns.

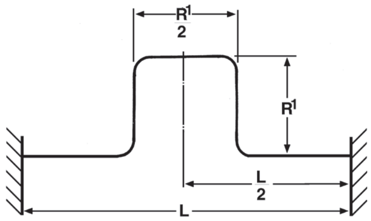
Several examples of methods for providing flexibility in these situations are graphically presented below. In each case, rigid supports or restraints should not be placed on a flexible leg of an expansion loop, offset or bend.







An expansion loop (which is fabricated with 90° elbows and straight pipe as depicted in Fig. above) is simply a double offset designed into an otherwise straight run of pipe.



The length for each of the two loop legs (R'), required to accommodate the expected expansion and contraction in the pipe run (L), may be determined by modification of the SINGLE OFFSET FORMULA to produce a LOOP FORMULA, as shown below:

$$R' = 2.041\sqrt{D\,L} \quad \text{LOOP FORMULA}$$

EXAMPLE 4:

How long should the expansion loop legs be in order to compensate for the expansion in Example 1 from the previous page?

$$R' = 2.041\sqrt{3.500 \times 3.24} = 6.87 \text{ ft.}$$

Minimum Cold Bending Radius

The formulae above for Single Offset and Loop bends of pipe, which are designed to accommodate expansion or contraction in the pipe, are derived from the fundamental equation for a cantilevered beam – in this case a pipe fixed at one end. A formula can be derived from the same equation for calculating the minimum cold bending radius for any thermoplastic pipe diameter.

$$RB = DO\,(0.6999\ E/SB - 0.5)$$

Where: RB = Minimum Cold Bend Radius (in.)
DO = Outside Pipe Diameter (in.)
E * = Modulus of Elasticity @ Maximum Operating Temperature (psi)
SB * = Maximum Allowable Bending Stress @ Maximum Operating Temperature (psi)

*The three formulae on this page provide for the maximum bend in pipe while the pipe operates at maximum long-term internal pressure, creating maximum allowable hydrostatic design stress (tensile stress in the hoop direction). Accordingly, the maximum allowable bending stress will be one half the basic hydraulic design stress at 73° F with correction to the maximum operating temperature. The modulus of elasticity, corrected for temperature may be found in the table in the second column of the preceding page.

EXAMPLE 5:

What would be the minimum cold radius bend, which the installer could place at the anchored end of the 200 ft. straight run of pipe in Examples 1 and 3, when the maximum operating temperature is 100° F instead of 140°F?

RB = 3.500 (0.6999 x 360,000/ 1/2 x 2000 x 0.62 – 0.5) =1,420.8 in. or 118.4 ft

Pipe Support Spacing

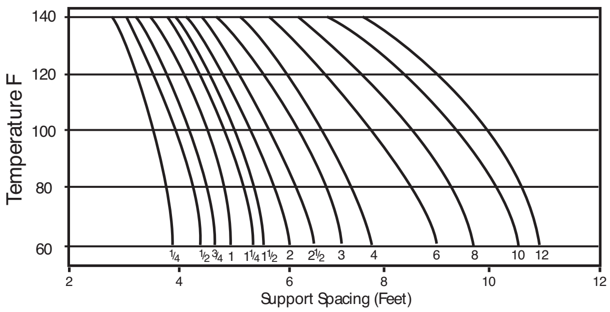
Correct supporting of a piping system is essential to prevent excessive bending stress and to limit pipe "sag" to an acceptable amount. Horizontal pipe should be supported on uniform centers, which are determined for pipe size, schedule, temperature, loading and material.

Point support must not be used for thermoplastic piping and, in general, the wider the bearing surface of the support the better. Supports should not be clamped in such a way that will restrain the axial movement of pipe that will normally occur due to thermal expansion and contraction. Concentrated loads in a piping system, such as valves must be separately supported.

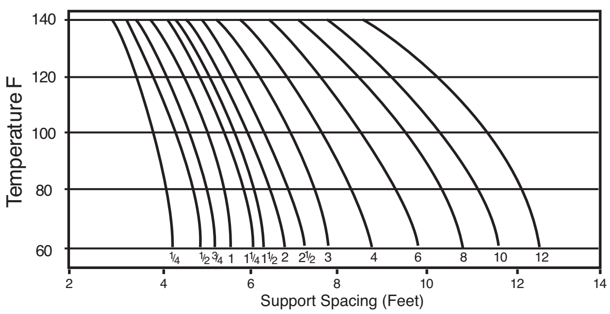
The graphs on this page give recommended support spacing for Chemtrol thermoplastic piping materials at various temperatures. The data is based on fluids with a specific gravity of 1.0 and permits a sag of less than 0.1" between supports. For heavier fluids, the support spacing from the graphs should be multiplied by the correct factor in the table below.

SPECIFIC GRAVITY	1.0	1.1	1.2	1.4	1.6	2.0	2.5
CORRECTION FACTOR	1.0	.98	.96	.93	.90	.85	.80

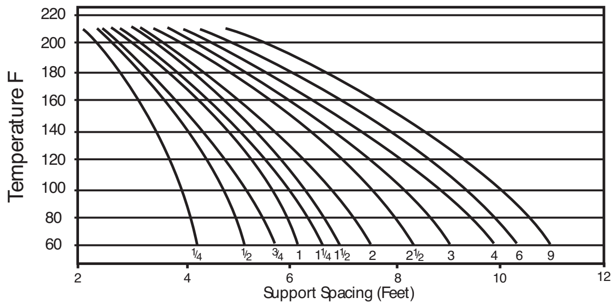
PVC Schedule 40



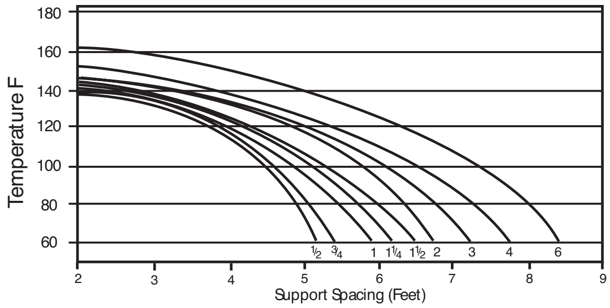
PVC Schedule 80



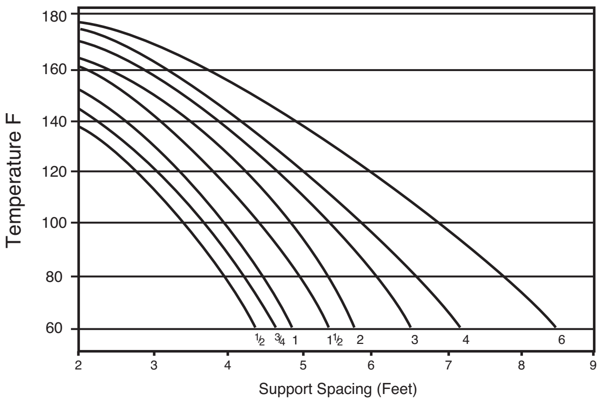
CPVC Schedule 80



Polypropylene Schedule 80



PVDF Schedule 80



The above data is for uninsulated lines. For insulated lines, reduce spans to 70% of graph values. For spans of less than 2 feet, continuous support should be used.

Plastic Piping Standards

Many commercial, industrial and governmental standards or specifications are available to assist the design engineer in specifying plastic piping systems. Standards most frequently referred to and most commonly called out in plastic piping specifications are ASTM Standards. These standards also often form the basis of other standards in existence. Below is a list and description of those standards most typically applied to industrial plastic piping.

ASTM Standard D-1784

(American Society for Testing and Materials)

This standard covers PVC and CPVC compounds used in the manufacture of plastic pipe, valves, and fittings. It provides a means for selecting and identifying compounds on the bases of a number of physical and chemical criteria. Conformance to a particular material classification in this standard requires meeting a number of minimum physical and chemical properties.

ASTM Standards D-1785 and F-441

These standards cover the specification and quality of Schedule 40, 80 and 120 PVC (D-1785) and CPVC (F-441) pressure pipe. Outlined in these standards are dimensional specifications, burst, sustained and maximum operating pressure requirements and test procedures for determining pipe quality with respect to workmanship and materials.

ASTM Standards D-2464 and F-437

These standards cover PVC (D-2464) and CPVC (F-437) Schedule 80 threaded pressure fittings. Thread dimensional specifications, wall thickness, burst, material quality, and identification requirements are specified.

ASTM Standard D-2466

These standards cover Schedule 40 PVC (D-2466) threaded and socket pressure fittings. Stipulated in the standard are thread and socket specifications, by lengths, wall thickness, burst material, quality and identification requirements.

ASTM Standards D-2467 and F-439

Standards D-2467 (PVC) and F-439 (CPVC) cover the specification of Schedule 80 socket type pressure fittings, including dimensions and physical requirements.

ASTM Standard D-4101

(Formerly D-2146)

This standard covers the specifications for propylene (PP) plastic injection and extrusion materials.

ASTM Standard D-3222

This standard covers the specifications for PVDF fluoroplastic molding and extrusions materials.

ASTM Standard D-2657

This standard covers the procedures for heat-fusion bonding of polyolefin materials.

ASTM Standards D-2564 and F-493

These standards set forth requirements for PVC (D-2564) and CPVC (F-493) Solvent Cement including a resin material designation and resin content quality standard. Also included in these standards are test procedures for measuring the cement quality by means of burst and lap shear tests.

ASTM Standard F-656

This standard covers the requirements for primers to be used for PVC solvent cemented joints of pipe and fittings.

ASTM Standard D-2855

This standard describes the procedure for making joints with PVC pipe and fittings by means of solvent cementing. The following are standards of other groups that are commonly encountered in industrial thermoplastic piping design.

ANSI B1.20.1 (was B2.1)

(American National Standards Institute)

This specification details the dimensions and tolerance for tapered pipe threads. This standard is referenced in the ASTM standard for threaded fittings mentioned above.

ANSI B16.5

This specification sets forth standards for bolt holes, bolt circle, and overall dimensions for steel 150# flanges.

NSF Standard 14

(National Sanitation Foundation)

This standard provides specifications for toxilogical and organoleptic levels to determine the suitability of plastic piping for potable water use. It additionally requires adherence to appropriate ASTM Standards and specifies minimum quality control programs. To meet this standard, a manufacturer must allow third party certification by NSF of the requirements of this standard.

Technical assistance regarding standards, applications, product performance, design, and installation tips are available from FABCO.

FABCO is also able to provide:

- Material and Performance Certification Letters
- Returned Product Evaluation
- Product, Installation, and Design Seminars
- Technical Reports on a variety of Subjects

Chemical Resistance Guide For Pipe, Valves & Fittings

This chemical resistance guide has been compiled to assist the piping system designer in selecting chemical resistant materials. The information given is intended as a guide only. Many conditions can affect the material choices. Careful consideration must be given to temperature, pressure and chemical concentrations before a final material can be selected. Thermoplastics and elastomers physical characteristics are more sensitive to temperature than metals. For this reason, a rating chart has been developed for each.

MATERIAL RATING FOR THERMOPLASTICS & ELASTOMERS

- Temp. in °F = "A" rating, maximum temperature which material is recommended, resistant under normal conditions.
- B to Temp. in °F = Conditional resistance, consult factory.
- C = Not recommended.
- Blank = No data available.

MATERIAL RATINGS FOR METALS

- A = Recommended, resistant under normal conditions.
- B = Conditional, consult factory.
- C = Not recommended.
- Blank = No data available.

Temperature maximums for thermoplastics, elastomers and metals should always fall within published temp/pressure ratings for individual valves. THERMOPLASTICS ARE NOT RECOMMENDED FOR COMPRESSED AIR OR GAS SERVICE. This guide considers the resistance of the total valve assembly as well as the resistance of individual trim and fitting materials. The rating assigned to the valve body plus trim combinations is always that of the least resistant part. In the cases where the valve body is the least resistant, there may be conditions under which the rate of corrosion is slow enough and the mass of the body large enough to be usable for a period of time. Such use should always be determined by test before installation of the component in a piping system. In the selection of a butterfly valve for use with a particular chemical, the liner, disc, and stem must be resistant. All three materials should carry a rating of "A". The body of a properly functioning butterfly valve is isolated from the chemicals being handled and need not carry the same rating.

ABS — (Acrylonitrile-Butadiene-Styrene) Class 4-2-2 conforming to ASTM D1788 is a time proven material. The smooth inner surface and superior resistance to deposit formation makes ABS drain, waste, and vent material ideal for residential and commercial sanitary systems. The residential DWV system can be exposed in service to a wide temperature span. ABS-DWV has proven satisfactory for use from -40°F to 180°F These temperature variations can occur due to ambient temperature or the discharge of hot liquids into the system. ABS-DWV is very resistant to a wide variety of materials ranging from sewage to commercial household chemical formulations. ABS-DWV is joined by solvent cementing or threading and can easily be connected to steel, copper, or cast iron through the use of transition fittings.

CPVC — (Chlorinated Polyvinyl Chloride) Class 23447-B, formerly designated Type IV, Grade 1 conforming to ASTM D-1784 has physical properties at 73°F similar to those of PVC, and its chemical resistance is similar to or generally better than that of PVC. CPVC, with a design stress of 2000 psi and maximum service temperature of 210°F, has proven to be an excellent material for hot corrosive liquids, hot and cold water distribution, and similar applications above the temperature range of PVC. CPVC is joined by solvent cementing, threading or flanging.

P.P. (Polypropylene) — (PP) Type 1 Polypropylene is a polyolefin which is lightweight and generally high in chemical resistance. Although Type 1 polypropylene conforming to ASTM D-2146 is slightly lower in physical properties compared to PVC, it is chemically resistant to organic solvents as well as acids and alkalies. Generally, polypropylene should not be used in contact with strong oxidizing acids, chlorinated hydrocarbons, and aromatics. With a design stress of 1000 psi at 73°F, polypropylene has gained wide acceptance where its resistance to sulfur-bearing compounds is particularly useful in salt water disposal lines, crude oil piping, and low pressure gas gathering systems. Polypropylene has also proved to be an excellent material for laboratory and industrial drainage where mixtures of acids, bases, and solvents are involved. Polypropylene is joined by the thermo-seal fusion process, threading or flanging. At 180°F., or when threaded, P.P. should be used for drainage only at a pressure not exceeding 20 psi.

PVC — (Polyvinyl Chloride) Class 12454-B, formerly designated Type 1, Grade 1. PVC is the most frequently specified of all thermoplastic materials. It has been used successfully for over 30 years in such areas as chemical processing, industrial plating, chilled water distribution, deionized water lines, chemical drainage, and irrigation systems. PVC is characterized by high physical properties and resistance to corrosion and chemical attack by acids, alkalies, salt solutions, and many other chemicals. It is attacked, however, by polar solvents such as ketones, some chlorinated hydrocarbons and aromatics. The maximum service temperature of PVC is 140°F. With a design stress of 2000 psi, PVC has the highest long term hydrostatic strength at 73°F of any of the major thermoplastics being used for piping systems. PVC is joined by solvent cementing, threading, or flanging.

PVDF — (KYNAR®) (Polyvinylidene Fluoride) is a strong, tough and abrasion resistant fluorocarbon material. It resists distortion and retains most of its strength to 280°F. It is chemically resistant to most acids, bases, and organic solvents and is ideally suited for handling wet or dry chlorine, bromine and other halogens. No other solid thermoplastic piping components can approach the combination of strength, chemical resistance and working temperatures of PVDF. PVDF is joined by the thermo-seal fusion process, threading or flanging.

EPDM — EPDM is a terpolymer elastomer made from ethylenepropylene diene monomer. EPDM has good abrasion and tear resistance and offers excellent chemical resistance to a variety of acids and alkalines. It is susceptible to attack by oils and is not recommended for applications involving petroleum oils, strong acids, or strong alkalines. It has exceptionally good weather aging and ozone resistance. It is fairly good with ketones and alcohols and has an excellent temperature range from -20°F to 250°F.

HYPALON® (CSM) — Hypalon has very good resistance to oxidation, ozone, and good flame resistance. It is similar to neoprene except with improved acid resistance where it will resist such oxidizing acids as nitric, hydrofluoric, and sulfuric acid. Abrasion resistance of Hypalon is excellent, about the equivalent of the nitriles. Oil and solvent resistance is somewhat between that of neoprene and nitrile Salts have little if any effect on Hypalon. Hypalon is not recommended for exposure to concentrated oxidizing acids, esters, ketones, chlorinated, aromatic and nitro hydrocarbons. Hypalon has a normal temperature range of -20°F to 200°F.

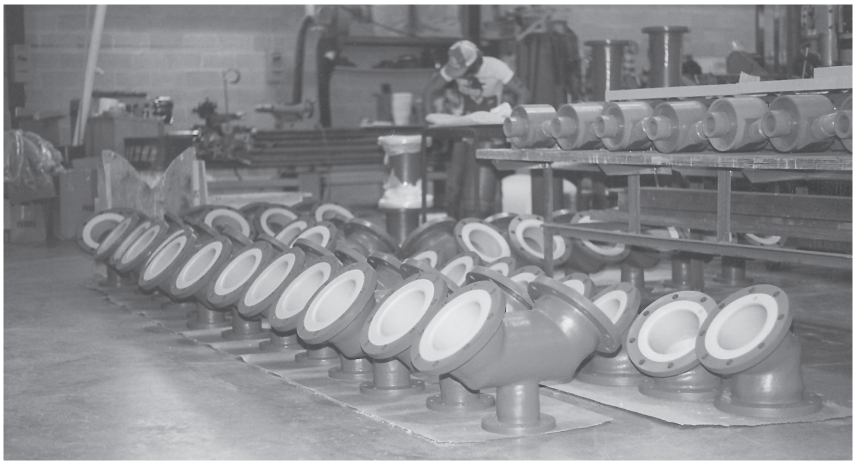
NEOPRENE (CR) — Neoprenes were one of the first synthetic rubbers developed. Neoprene is an all purpose polymer with many desirable characteristics and features high resiliency with low compression set, flame resistance, and is animal and vegetable oil resistant. Neoprene is principally recommended for food and beverage service. Generally, neoprene is not affected by moderate chemicals, fats, greases, and many oils and solvents. Neoprene is attacked by strong oxidizing acids, most chlorinated solvents, esters, ketones, aromatic hydrocarbons, and hydraulic fluids. Neoprene has a moderate temperature range of -20°F to 160°F.

NITRILE (NBR) — (BUNA-N) is a general purpose oil resistant polymer known as nitrile rubber. Nitrile is a copolymer of butadiene and acrylonitrile and has a moderate temperature range of -20°F to 180°F. Nitrile has good solvent, oil, water, and hydraulic fluid resistance. It displays good compression set, abrasion resistance and tensile strength. Nitrile should not be used in highly polar solvents such as acetone and methyl ethyl ketone, nor should it be used in chlorinated hydrocarbons, ozone or nitro hydrocarbons.

FLUOROCARBON (FKM) (VITON®) (FLUOREL®) — Fluorocarbon elastomers are inherently compatible with a broad spectrum of chemicals. Because of this extensive chemical compatibility, which spans considerable concentration and temperature ranges, fluorocarbon elastomers have gained wide acceptance as a material of construction for butterfly valve O-rings and seats. Fluorocarbon elastomers can be used in most applications involving mineral acids, salt solutions, chlorinated hydrocarbons, and petroleum oils. They are particularly good in hydrocarbon service. Fluorocarbon elastomers have one of the broadest temperature ranges of any of the elastomers, -20°F to 300°F, however, are not suitable for steam service.

TEFLON® (PTFE) — Polytetrafluoroethylene has outstanding resistance to chemical attack by most chemicals and solvents. PTFE has a temperature rating of -20°F to 400°F in valve applications. PTFE, a self lubricating compound, is used as a seat material in ball valves.

VITON is a registered trademark of the DuPont Company
TEFLON is a registered trademark of the DuPont Company
HYPALON is a registered trademark of the DuPont Company
KYNAR is a registered trademark of the Pennwalt Company
FLUOREL is a registered trademark of the 3M Company



Chemical Resistance Chart for Valves and Fittings

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Acetaldehyde CH_3CHO	Conc.		C	140	C		C		350	B to 200	C	C	C	A	C	C	C	C	B	B	A		B	B	A		C
Acetamide CH_3CONH_2									200	B to 200	B to 180	B to 200	C		A		A		A	A			A	A	A	A	
Acetic Acid CH_3COOH	25%	C	180	180	140		140	B to 73	350	176	C	70	C	A	C	C	C	C	C	C	C	C	C	A	A	A	C
Acetic Acid CH_3COOH	50%					B to 140	B to 176		350	140	C	C	C	A	C	C	C	C	C	C	C	C	C	A	A	A	C
Acetic Acid CH_3COOH	85%	C	C	120	73		73		350	70	C	C	C	A	C	C	C	C	C	C	C	C	C	A	A	A	C
Acetic Acid CH_3COOH	Glacial	C	C	120	73	B to 104	B to 68		350					A	C	C	C	C	C	C	C	C	C	C	A	B	C
Acetic Anhydride $(CH_3CO)_2O$		C	C	73	C	C	73		350	C	C	B to 70	C	A	C	C	C	C	C	C	C	C	C	C	B	B	C
Acetone CH_3COCH_3		C	C	B	C	B	C	C	350	B to 300	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Acetophenone $C_6H_5COCH_3$									350	B to 176	C	C	C		C	C	C	C	C	C	C	C	C	C	C		C
Acetyl Chloride CH_3COCl		C	C		C	C			200	C	C	C	B		A	A	A	A	C	C	A		C		A	A	A
Acetylene	Gas, 100%	73	C	73	C		73		250	B to 250	200	104	200		C	C	C	C	A	A	A	A	A		A	A	C
Acrylonitrile $H_2C{=}CHCN$			C		C		140		350	104	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	
Adipic Acid $COOH(CH_2)_4COOH$	Sat'd.		180	140	140	B to 176	140		350	140	B to 220	B to 160	176						C	C	B		C		B to 200		A
Allyl Alcohol $CH_2{=}CHCH_2OH$	96%		C	140	B to 73		C		250	B to 300	B to 180	B to 120	B to 70		A	A	A	A	A	A	A	A	A	A	A	A	
Allyl Chloride $CH_2{=}CHCH_2Cl$			C		C	140	C		350	C	B to 70	C	C								C						
Aluminum Acetate $Al(C_2H_4O_2)_3$	Sat'd.								350	176	C	C	C		C		C			C					A		
Aluminum Ammonium Sulfate (Alum) $AlNH_4(SO_4)_2 12H_2O$	Sat'd.		180	140	140		140		250	B to 200	B to 140	C	190	A	B	B	B	B			C			B	A		B
Aluminum Chloride (Aqueous) $AlCl_3$	Sat'd.	160	180	180	140	B to 212	140		250	176	B to 200	B to 200	176	A	C	C	C	C	C	C	C	C	C	C	A	C	C
Aluminum Fluoride AlF_3	Sat'd.	160	180	180	73	B to 212	140		250	B to 300	B to 200	B to 200	176	A	C	C	C	C	C	C	C		C	C	B	C	C
Aluminum Hydroxide $Al(OH)_3$	Sat'd.	160	180	180	140	B to 212	140		250	176	160	B to 180	176		C	C	C	C	B	B	C		B	B	A	A	C

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)					METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Aluminum Nitrate $Al(NO_3)_3 \cdot 9H_2O$	Sat'd.		180	180	140	B to 212	140		250	176	140	B to 200	B to 400	A	C	C	C	C	C	C	C	C	C		A	A	C
Aluminum Potassium Sulfate (Alum) $AlK(SO_4)_2 \cdot 12H_2O$	Sat'd.	160	180	140	140	B to 212	140		400	B to 200	B to 200	B to 200	248	A	B	B	B	B			C			B	A		B
Aluminum Sulfate (Alum) $Al_2(SO_4)_3$	Sat'd.	160	180	140	140	B to 212	140		250	B to 300	B to 300	B to 200	B to 390	A	C	C	C	C	C	C	C		C	C		B	
Ammonia Gas NH_3	100%	C	C	140	140		140		400	140	B to 140	140	C	A	B			C	A		A				A	A	B
Ammonia Liquid NH_3	100%	160	C	140	C		140		400	212	70	B to 160	C	A	C	C	C	C			A			A	A	A	C
Ammonium Acetate CH_3COONH_4	Sat'd.	120	180	73	140	B to 212	140		400	140	140	140			C	C	C	C							B		
Ammonium Bifluoride NH_4HF_2	Sat'd.		180	180	140		140		400	140	B to 140	C	140	A	C			C	C	C	C	C	C	C	B	B	B
Ammonium Carbonate $(NH_4)_2CO_3$	Sat'd.		180	212	140	B to 248	140		400	176	B to 200	B to 200	212		C			C			A to 140	C		B	B	B	B
Ammonium Chloride NH_4Cl	Sat'd.	120	180	212	140	B to 212	140		400	300	B to 200	B to 212	250	A	C			C	C	C	C	C	C	C	B	C	
Ammonium Fluoride NH_4F	10%	120	180	212	140	B to 212	140		400	300	B to 200	B to 100	140	A	C			C			C				C		C
Ammonium Fluoride NH_4F	25%	120	180	212	C		140		400	300	B to 120	B to 100	140	A	C			C			C				C		C
Ammonium Hydroxide NH_4OH	10%	120	C	212	140		140		400	B to 300	200	200	B to 190	A	C	C		C			C			B	A	A	C
Ammonia Hydroxide NH_4OH	Sat'd.								400	B to 300	C	200	B to 190	A	C	C					C			B to 70	A to 140		C
Ammonium Nitrate NH_4NO_3	Sat'd.	120	180	212	140	B to 212	140		400	B to 300	200	200	176	A	C	C		C								A	C
Ammonium Persulphate $(NH_4)_2S_2O_8$			180	140	140	B to 212	140		200	B to 70	C	70	B to 140		C	C	C	C	C	C	C	C	C	B	A		C
Ammonium Phosphate (Monobasic) $NH_4H_2PO_4$	All	120	180	212	140	B to 248	140		400	B to 200	200	B to 200	B to 180	A	C	C	C	C	B	B	C		B	A	A	A	C
Ammonium Sulfate $(NH_4)_2SO_4$		120	180	212	140	B to 212	140		400	300	200	200	176	A	C	C	C	C	B	B	C	B	B	B	B	B	C
Ammonium Sulfide $(NH_4)_2S$	Dilute	120	180	212	140		140		350	B to 300	B to 180	B to 160	B to 70		C	C	C	C	C	C	C		C		B		C
Ammonium Thiocyanate NH_4SCN	50 - 60%	120	180	212	140	B to 212	73			B to 300	B to 180	B to 200	B to 190		C	C	C	C	C	C	C		C		A	A	C
Amyl Acetate $CH_3COOC_5H_{11}$		C	C	C	C	B 122	73		100	210	C	C	C		B	B	B	B	B	B	B	A	B	A	A	A	
Amyl Alcohol $C_5H_{11}OH$			C		C	B to 212	B to 140		400	B to 300	B to 180	B to 200	B to 212	A	A	A	A	A	B	B	B		B	A	A	A	A

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)					METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
n-Amyl Chloride $CH_3(CH_2)_3CH_2Cl$		C	C	C	C		C		400	C	C	C	200		A	A	A	A	A	A	A	A	A	A	A	A	
Aniline $C_6H_5NH_2$		C	C		C	B to 68	C		200	B to 140	C	C	B to 70	A	C	C	C	C	B	B	C	B	B	A	A	A	C
Aniline Hydrocloride $C_6H_5NH_2{\bullet}HCl$	Sat'd.		C		C		140							C	C	C	C	C	C	C	C	C	C	C	C	C	
Anthraquinone $C_{14}H_8O_2$			180		140		C						C						C	C	C						
Anthraquinone Sulfonic Acid $C_{14}H_7O_2{\bullet}SO_3{\bullet}H_2O$			180	73	140		C																				
Antimony Trichloride $SbCl_3$	Sat'd.		180	140	140	B to 140	140			C	70	B to 70	70	A	C	C	C	C	C	C	C	C	C	C	C	C	
Aqua Regia (Nitrohydrochloric Acid)		C	B to 73	C	C	C	C		200	C	C	C	B to 190	C	C	C	C	C	C	C	C	C	C		B		
Argon Ar	Dry								350	B to 400	250	B to 100	B to 500		A		A		A		A				A	A	A
Arsenic Acid H_3AsO_4	80%		180	140	140	B to 248	140		400	B to 176	B to 200	B to 180	140	A	C	C	C	C	C	C	C		C	B	A	B	
Asphalt			C	73	C		73		350	C	C	C	212		A	A	A	A	A	A	A	A	A	A	A	A	A
Barium Carbonate $BaCO_3$	Sat'd.	120	180	140	140	B to 248	140		400	B to 300	140	B to 160	248		A	A	A	A	B	B	B	B	B	A	A	A	
Barium Chloride $BaCl_2{\bullet}2H_2O$	Sat'd.	120	180	140	140	B to 212	140		400	B to 300	B to 200	B to 160	B to 400	A	A	A	A	A	B	B	C	B	B	B	A		A
Barium Hydroxide $Ba(OH)_2$	Sat'd.	73	180	140	140				400	B to 300	B to 220	B to 200	248		C	C	C	C	B	B	C		B	A	A	A	
Barium Nitrate $Ba(NO_3)_2$	Sat'd.	73	180	140	73		140		250	176	140	B to 200	248	A	C	C	C	C	A	A	A		A		A		
Barium Sulfate $BaSO_4$	Sat'd.	73	180	140	140	B to 212	140		400	B to 300	B to 200	B to 200	B to 380	A	B	B	B	B	B	B	A		B	A	A	A	
Barium Sulfide BaS	Sat'd.	73	180	140	140				400	B to 310	B to 200	B to 200	B to 400		C	C	C	C	B	B	C		B	A	A	A	C
Beer		120	180	180	140	B to 248	B to 140		300	120	B to 250	B to 140	B to 300		A	A	A	A	C	C	C		C	A	A	A	A
Beet Sugar Liquors			180	180	140		73			B to 300	200	B to 180	B to 400				A		B	B	B				A	A	
Benzaldehyde C_6H_5CHO	10%	C	B to 73	73	B to 73		73			200	C	C	C	A	A	A	A	A	C	C	B		C	A	A	A	A
Benzene C_6H_6		C	C	C	C	C	B to 68	C	250	C	C	C	B to 140	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Benzene Sulfonic Acid $C_6H_5SO_3H$	10%		180	180	140		B to 73			C	C	B to 100	200		B	B	B	B	C	C	C		C	B	B	B	
Benzoic Acid C_6H_5COOH		160	180	73	140				350	C	C	B to 150	176		C	C	C	C	C	C		C	A	A	A	A	

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F): ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	SEAL MATERIALS MAX TEMPERATURE (°F): PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	METAL: BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI/IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Benzyl Alcohol $C_6H_5CH_2OH$			C	120	C	B to 122	140		400	C	C	B to 70	B to 250		A	A	A	A	B	B	B		B	A	A	A	A
Bismuth Carbonate $(BiO)_2CO_3$			180	180	140		140			70	70	70	B to 200														
Black Liquor	Sat'd.		180	140	140		120		225	220	140	70	212		C	C	C	C	B	B	B		B	B	A	B	
Bleach (Sodium Hypochlorite)	12% Cl	73	185	120	140		73																				
Blood									200	70	C	70	70		B		B		C	C			B		A	A	
Borax $Na_3B_4O_7 \cdot {}_{10}H_2O$	Sat'd.	160	180	212	140		140			300	B to 200	B to 200	200		A	A	A	A	A	A	B	A	A	A	A	A	
Boric Acid H_3BO_3	Sat'd.	160	180	212	140	B to 212	140			B to 300	B to 200	B to 200	185	A	B	B	B	B	C	C	B		C	B	A	B	
Brine	Sat'd.		180	140	140		140		400	B	B	B	B		A	A	A		C	C	C	B	C	B	A	B	
Bromic Acid $HBrO_3$			180	C	140	B to 212	C			200	C	C	200		C	C	C	C									C
Bromine Br_2	Liquid	73	C	C	C	B to 248	C		300	C	C	C	B to 350	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Bromine Br_2	Gas, 25%		180	C	140		C		200	C	C	C	B to 180	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Bromine Water	Sat'd.		180	C	140	B to 176	C		300	C	C	C	B to 210	C	C	C	C	C	C	C	C		C				C
Butadiene $H_2C{=}CHHC{=}CH_2$	50%		180	C	140		73		C	C	C	C	70		A	A	A	A	A	A	A	A	A	A	A	A	A
Butane C_4H_{10}	50%		180	140	140		140	73	350	C	B to 250	B to 200	B to 400		A	A	A	A	A	A	A	A	A	A	A	A	A
Butyl Acetate $CH_3COOCH_2CH_2CH_2CH_3$		C	C	C	C	C	C		175	C	C	C	C		B	B	B	B	B	B	B		B	A	A	A	
Butyl Alcohol $CH_3(CH_2)_2CH_2OH$			C	180	140		140		300	B to 250	B to 190	140	B to 390	A	B	B	B			B			A	A	A	A	B
Butyl Cellosolve			C		73				200	B to 300	C	C	C	A	A	A	A	A	A	A			A	A	A	A	
n-Butyl Chloride C_4H_9Cl		C	C						400	C	C	C	70		B	B	B	B	B	B	B		B	B	B	B	
Butylene © $CH_3CH{=}CHCH_3$	Liquid			C	140		120		400	C	250	C	B to 400		A	A	A	A			A			A	A	A	
Butyl Phthalate $C_{16}H_{22}O_4$			C	180		B 140				250	C	C	C														
Butyl Stearate					73				250	C	C	C	B to 400		A	A	A	A	B	B			B	A	A	A	
Butyric Acid $CH_3CH_2CH_2COOH$		C	C	180	73		73		300	C	C	C	C		A	A	A	A	C	C	C	C	C	B	A	A	
Calcium Bisulfide $Ca(HS)_2 \cdot {}_6H_2O$			73		C		140		200	200	B to 140	140	140												A		

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)					METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Calcium Bisulfite $Ca(HSO_3)_2$			180	180	140		C		350	C	B to 200	B to 200	B to 400		C	C	C	C	C	C	C		C	B	A		
Calcium Carbonate $CaCO_3$			180	180	140	B to 248	140		350	B to 210	B	140	248		C	C	C	C	B	B	B		B	A	A	A	A
Calcium Chlorate $Ca(ClO_3)_2{\cdot}2H_2O$			180	180	140	B to 248	140		350	B to 200	B to 200	B to 200	B to 190	140	B	B	B	B	B	B	B	B	B	B	A		C
Calcium Chloride $CaCl_2$		120	180	180	140	B to 248	B to 176		350	B to 212	B to 200	B to 200	300	A	B	B	B	B	A	A	C		C	B	A	B	B
Calcium Hydroxide $Ca(OH)_2$		160	180	180	140		140		250	210	B to 200	B to 220	212		C	C	C	C	C	C	C		C	A	A	A	C
Calcium Hypochlorite $Ca(OCl)_2$	30%	160	180	140	140		140		200	B to 310	C	C	B to 400	90	C	C	C	C	C	C	C		C	B	B	B	C
Calcium Nitrate $Ca(NO_3)_2$			180	180	140		140		200	B to 300	B to 200	B to 200	B to 390	C	B	B	B	B	B	B			B		A		B
Calcium Oxide CaO			180		140		140			B	B to 200	B to 200	140						A	A	B				A	A	
Calcium Sulfate $CaSO_4$		100	180	180	140	B to 212	140		200	B to 300	B to 176	B to 70	B to 212	A	A	B	B	B	A	A	B	A	A	A	A	A	A
Camphor $C_{10}H_{16}O$		C		73	73		73		350	C	100	C	70		B	B	B	B	B	B	B		B	A	A	A	
Cane Sugar $C_{12}H_{22}O_{11}$			180	180	140		140		400						A	A	A	A	A	A	A	A	A	A	A	A	
Caprylic Acid $CH_3(CH_2)COOH$									350		C		B to 140						A	A	B		A		A		
Carbitol			C		73				200	B to 80	B to 80	C	C		B	B	B	B	B	B	B		B		B		
Carbon Dioxide CO_2	Dry, 100%	160	180	140	140	B to 212	140		400	B to 250	200	B to 200	212	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Carbon Dioxide CO_2	Wet	160	180	140	140		140		400	B to 250	140	C	212	A	A	A	A	A	B	B	B	B	B	A	A	A	A
Carbon Disulfide CS_2		C	C	C	C		B to 68		200	C	C	C	B to 400	A	B	B	B	B	A	A	A		A	A	A		C
Carbon Monoxide CO	Gas		180	180	140	B to 140	140		400	B to 300	160	140	B to 400	A	A	A	A	A	A	A	B		A	A	A	A	
Carbon Tetrachloride CCl_4		C	C	C	73	C	C	B to 73	350	C	C	C	B to 350	A	A	A	A	A	C	C	A		C	A	A	A	B
Carbonic Acid H_2CO_3	Sat'd.	185	180	140	140		140		350	B to 300	70	200	B to 400	A	C	C	C	C	B	B	B	B	B	A	A	A	
Castor Oil			C	140	140		73		350		212	200	B to 400	550	A	A	A	A	A	A	A	A	A	A	A	A	A
Caustic Potash (Potassium Hydroxide) KOH	50%	160	180	180	140		140			200	B to 150	B to 70	B to 140														

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Caustic Soda (Sodium Hydroxide) Na0H	40%	160	180	180	140		140			B to 200	212	B to 200	80														
Cellosolve			C	73	73		C		200		C		C	A	A	A	A	A	A	A	A		A		A		
Cellosolve Acetate $CH_3COOCH_2CH_2OC_2H_5$			C	73	73				300	C	C	C	C		B		B			B					B		
Chloral Hydrate $CCl_3CH(OH)_2$			180	C	140		120			B to 70	C	70	C														
Chloramine NH_2Cl	Dilute		C	73	73		73			70		B to 80	70		B	B	B	B	C	C	C				B		
Chloric Acid $HClO_3 \bullet _7H_2O$	10%		180	73	140		73		140	212	C	B to 120	B to 120		C	C	C	C	C	C	C	C	C	C	B	C	
Chloric Acid $HClO_3 \bullet _7H_2O$	20%		185	73	140		73		140	212	C	70	C		C	C	C	C	C	C	C	C	C	C	C	C	
Chlorine Gas (Moisture Content < 150 ppm)									400	C	C	C	B	A	C	C	C	C	B	A*	A*	B	B	B	A		C
Chlorine Gas (Moisture Content > 150 ppm)		C	C	C	C		C		400	C	C	C	C		C	C	C	C	C	C	C	C	C	C	C	C	C
Chlorine	Liquid	C	C	C	C		C			C	C	C	B		B	B		B	C	C	C		C	C	C	C	
Chlorinated Water (< 3500 ppm)									400					73	B	B	C	C			C		C	B	A	A	C
Chlorinated Water (> 3500 ppm)									400					73	C	C	C	C			C			C	A	B	C
Chloroacetic Acid $CH_2ClCOOH$	50%	C	180	C	140		120		200	B to 175	C	C	C		C	C	C	C	C	C	C		C	C	C	C	C
Chlorobenzene C_6H_5Cl	Dry	C	C	73	C		C	C	200	C	C	C	B to 400	A	A	A	A	A	C	C	B		C	A	A	A	
Chloroform $CHCl_3$	Dry	C	C	C	C		C	C	200	C	C	C	B to 400	A	A	A	A	A	C	C	C		C	A	A	A	
Chlorosulfonic Acid $ClSO_2OH$			73	C	73		C		200	C	C	C	C		C	C	C	C	B	B	C	C	B	C	C	C	C
Chromic Acid H_2CrO_4	10%	73	180	140	140	B to 212	73		350	70	C	C	B to 400	C	C	C	C	C	C	C	C	C	C	B to 212	A to 70		C
Chromic Acid H_2CrO_4	30%	C	180	73	140	B to 212	73		350	70	C	C	B to 400	C	C	C	C	C	C	C	C	C	C	B to 212	B to 70		C
Chromic Acid H_2CrO_4	50%	C	C	73	C	B to 212	73		200	C	C	C	B to 400	C	C	C	C	C	C	C	C	C		C	B to 70		C
Citric Acid $C_6H_8O_7$	Sat'd.	160	180	140	140	B to 248	140		200					A	C	C	C	C	C	C	C		C	B	A	A	C
Coconut Oil			C	73	140	B to 248	73		400	C	250	C	B to 390		B	B	B	B	C	C	B		C	B	A		
Coffee			180	140	140		140			B to 140	140	140	B to 200		A	A	A	A	C	C	C			A	A	A	A
Coke Oven Gas				73	140		140		400	C	C	C	B to 390		B	B	B	B	A	A	A	A	A	A	A	A	

FABCO PLASTICS

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Copper Acetate $Cu(C_2H_3O_2)_2{\cdot}H_2O$	Sat'd.		73	73	73				350	B to 300	C	C	C		C	C	C	C	C	C	C		C	B	A		
Copper Carbonate $CuCO_3$	Sat'd.		180		140		140		350	B to 210	C	70	B to 190											B	A		
Copper Chloride $CuCl_2$	Sat'd.	73	180	140	140		140		350	B to 212	176	B to 210	B to 400	A	C	C	C	C	C	C	C	C	C	B	A		C
Copper Cyanide CuCN			180		140	B to 212	140		350	B to 300			B to 390		C	C	C	C	C	C	C	A	C	B	A		C
Copper Fluoride $CuF_2{\cdot}2H_2O$	2%		180	73	140		140			B to 250	80	140	B to 190	A													
Copper Nitrate $Cu(NO_3)_2{\cdot}3H_2O$	30%		180	140	140					B to 210	B to 230	B to 200	212	A	C	C	C	C	C	C	C		C	B	A		C
Copper Sulfate $CuSO_4{\cdot}5H_2O$	Sat'd.	120	180	120	140	B to 212	140			B to 300	B to 212	200	B to 212	A	C	C	C	C	C	C	C		C	A	A	A	C
Corn Oil			C	73	140		120		400	C	250	C	B to 400		B	B	B	B	B	B	B	B	B	A	A	A	A
Corn Syrup			185	140	140		140			200	200	C	212														
Cottonseed Oil		120	C	140	140		B to 140		400	B to 70	200	C	B to 400		B	B	B	B	B	B	B		B	A	A	A	
Creosote			C	73	C		140		350	C	B to 220	C	B to 400		B	B	B	B	A	A	A	A	A	A	A	A	B
Cresol $CH_3C_6H_4OH$	90%	C	C	B to 73	C	B to 68	73		200		C	C	B												B		
Cresylic Acid	50%		180		140		C		200	C	C	C	140		A	A	A	A	A	A	B	A	A	A	A	A	A
Crude Oil			C	140	140	B to 212	C		400	C	B to 250	C	B to 300		C	C	C	C	C	C	B			A	A	A	C
CuprIc Sulfate $CuSO_4{\cdot}5H_2O$	Sat'd.	100	180	73	140				250					A													
Cuprous Chloride CuCl	Sat'd.	70	180		140		140		350					A	C			C									C
Cyclohexane C_6H_{12}		73	C	C	C	B to 248	C		300	C	250	C	B to 400		A	A	A	A	B	B	A		B	A	A	A	
Cyclohexanol $C_6H_{11}OH$		C	C	140	C	B to 104	73		250	C	B to 70	B to 70	B to 400						A	A			A	A	A	A	
Cyclohexanone $C_6H_{10}O$	Liquid	C	C	73	C	C	C	C	200	C	C	C	C		B	B	B	B	B	B	B		B	B	A		
Detergents (Heavy Duty)			C	180	140		B to 140								A	A	A	A	A	A	A	A	A	A	A	A	A
Dextrin (Starch Gum)	Sat'd.		180	140	140		140		200	176	B to 180	B to 200	212		A	A	A	A	B	B	B				A		A
Dextrose $C_6H_{12}O_6$			180	140	140		140		400	200	200	200	B to 400		A	A			A						A		
Diacetone Alcohol $CH_3COCH_2C(CH_3)_2OH$			C	120	C				350	B to 300	C	C	C		A	A	A	A	A	A	A	A	A	A	A	A	A

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F) ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	SEAL MATERIALS MAX TEMPERATURE (°F) PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLOROPRENE	FKM	GRAPHITE	METAL BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Dibutoxyethyl Phthalate $C_{20}H_{30}O_6$			C		C										A	A	A	A	A	A	A		A		A		
Dibutyl Phthalate $C_6H_4(COOC_4H_9)_2$		C	C	73	C		73		350	B to 250	C	C	C		A	A	A	A	A	A	A				A		
Dibutyl Sebacate $C_4H_9OCO(CH_2)_8OCOC_4H_9$				73	73		73		350	C	C	C	C														
Dichlorobenzene $C_6H_4Cl_2$		C	C	C	C		C			C	C	C	B						A	A			A		A		
Dichloroethylene $C_2H_4Cl_2$			C	C	C		C		350	C	C	C	200				B			B					B		
Diesel Fuels			C	140	140	B to 212	73		350	C	B	C	C		A	A	A	A	A	A	A	A	A	A	A	A	A
Diethylamine $C_4H_{10}NH$		C	C		C	C	C		200	70	C	70	C	A	C	C	C	C	A	A	C			A	A	A	C
Diethyl Cellosolve $C_6H_{14}O_2$																			A	A			A		A		
Diethyl Ether $C_4H_{10}O$		C	C	73	73		C	B to 73		C	C	C	C	A													
Diglycolic Acid $O(CH_2COOH)_2$	Sat'd.		180	140	140		140		250	B to 300	200	B to 200	C														
Dimethylamine $(CH_3)_2NH$				73	140	C	73			B to 140	C	C	C						C						A		
Dimethyl Formamide $HCON(CH_3)_2$		C	C	180	C		120	C	250	B to 122	C	C	C		B	B	B	B	B	B	B				A		
Dioctyl Phthalate $C_6H_4(COOC_8H_{17})_2$		C	C	C	C		73		200	C	C	C	C		A	A	A	A	C	C	C						
Dioxane $C_4H_8O_2$			C	C	C		140			B to 160	C	C	C	A	A	A	A	A	A	A	A					A	
Diphenyl Oxide $(C_6H_5)_2O$	Sat'd.						73			C	C	C	B to 310		A	A	A	A	A								
Disodium Phosphate Na_2HPO_4			180	140	140		140		400	B to 210	70	80	90	A	B	B	B	B	B	B					A		
Dow Therm A $C_{12}H_{10}•C_{12}H_{10}O$					C				212	C	C	C	B to 350	A	A	A	A	A	B	A	A		A	A	A	A	
Ether ROR		C	C	C	C		73			C	C	C	C		A	A	A		B	B	B	A	A	A	A	A	A
Ethyl Acetate $CH_3COOCH_2CH_3$		C	C	C	C		73	C	200	B to 158	C	C	C		A	A	B		A	A	A			A	A	A	
Ethyl Acrylate $CH_2=CHCOOC_2H_5$			C		C				350	C	C	C	C		A	A			A	A	A		A	A	A	A	
Ethyl Alcohol (Ethanol) C_2H_5OH			C	140	140		140	73	300	200	B to 200	158	C	A	A	A	A	A	A	A	A	A	A	A	A	A	
Ethyl Benzene $C_6H_5C_2H_5$				C	C				350	C	C	C	70		B	B			B	B	B		B		A		
Ethyl Chloride C_2H_5Cl	Dry		C	C	C		C		350	140	200	C	B to 400	A	A	A	B		A	A	A	A	A	A	A	A	

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)					METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Ethylene Bromide $BrCH_2CH_2Br$	Dry		C		C				350						A					A	A				A		
Ethylene Chloride (Vinyl Chloride) CH_2CHCl	Dry	C	C	C	C		C		350	C	C	C	200												A		
Ethylene Chlorohydrin $ClCH_2CH_2OH$			C	73	C				200	C	C	C	70	A								A					
Ethylene Diamine $NH_2CH_2CH_2NH_2$		C		73	C		140			B to 300	80	B to 90	C		A	C		A	A	B				A		A	A
Ethylene Dichloride $C_2H_4Cl_2$	Dry	C	C	C	C		C		350	C	C	C	B to 400	A	A	A			A	A	A		A		A	A	
Ethylene Glycol $OHCH_2CH_2OH$		73	C	212	140	B to 212		B to 220	400	250	250	250	B to 250	A	A	A	A	A	A	A	A		A	A	A	A	A
Ethylene Oxide CH_2CH_2O			C	C	C		73		400	C	C	C	C		A	A			B	A	A		A		A		
Ethyl Formate										C	C	C	B to 400		A	A			A	A			A		A		
Fatty Acids R-COOH		160	73	120	140		120		400	C	B to 250	C	250	A	C	C	C	C	C	C	C		C		A		
Ferric Chloride (Aqueous) $FeCl_3$	Sat'd.	120	180	140	140	B to 212	140		400	B to 300	B to 200	160	176	A	C	C	C	C	C	C	C	C		C	C	C	C
Ferric Hydroxide $Fe(OH)_3$	Sat'd.	160	180	140	140		140		400	B to 210	B to 176	B to 200	B to 200						C	C			C		A		C
Ferric Nitrate $Fe(NO_3)_3 \bullet {}_9H_2O$	Sat'd.	160	180	140	140	B to 212	140		400	B to 300	B to 176	B to 200	B to 400	A	C	C	C	C	C	C	C		C	B	A	A	C
Ferric Sulfate $Fe_2(SO_4)_3$		160	180	140	140	B to 212	140		200	B to 280	B to 200	B to 200	176	A	C	C	C	C	C	C	C		C	B	A	A	C
Ferrous Chloride $FeCl_2$	Sat'd.	160	180	140	140	B to 212	140		400	210	B to 200	200	185	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Ferrous Hydroxide $Fe(OH)_2$	Sat'd.	160	180	140	140		140		400	B to 200	B to 176	B to 200	212						C						A		
Ferrous Nitrate $Fe(NO_3)_2$		160	180	140	140		140		400	B to 210	B to 200	B to 200	212	A											A	A	
Ferrous Sulfate $FeSO_4$		160	180	140	140	B to 212	140		400	B to 200	B to 200	B to 200	B to 200	A	C	C	B		C	C	C	C	C	A	A	A	B
Fish Oil			180	180	140		140		300	C	250	B to 70	B to 400		A	A	C		B	A	A		A	A	A	A	A
Flue Gas															A	A			A	A	A		A	A	A	A	
Fluoroboric Acid HBF_4		73	73	140	140		140		350	70	C	70	140		B	B			C	C			C		A		C
Fluorine Gas F_2	Dry, 100%		73	C	73		C		C		C		C	B to 300	B	B			C	C	A				A	A	
Fluorine Gas F_2	Wet	C	73	C	73		C		C		C		C	C	C	C			C	C	C				A	A	

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Fluorosilicic Acid (Hydrofluosilicic Acid) H_2SiF_6	50%		73	73	140	B to 212			300	B to 300	160	158	185							C	C		C	B	B	B	C
Formaldehyde HCHO	Dilute	160	73	140	140	B to 176			300	212	140	150	C	A	A	A	B		C	C	B			A	A	A	
Formaldehyde HCHO	35%	160	C	140	140	B to 212	140	100	300	212	140	150	C	A	A	A	B		C		B			A	A	A	
Formaldehyde HCHO	50%		C		140		140		300	B to 140	C	B to 70	C	A	B	B	B		C		B			B	A	A	
Formic Acid HCOOH		C	C	140	73	B	140		300	210	C	B	B	A	C	C	B		C	C	C	B	C	A	A	A	
Freon 11 CCl_3F	100%	C	73	C	140		73		300	C	B to 250	C	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Freon 12 CCl_2F_2	100%		73	73	140		73		C	B	B	B	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Freon 21 $CHCl_2F$	100%			C	C		C		300	C	C	C	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Freon 22 $CHClF_2$	100%		73	73	C		C		C	140	C	250	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Freon 113 $C_2Cl_3F_3$	100%			C	140		73		300	C	B	B	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Freon 114 $C_2Cl_2F_4$	100%			C	140		73		300	B	B	B	C	A	A	A	A	A	B	B	B		B	A	A	A	A
Fructose $C_6H_{12}O_6$	Sat'd.	73	180	180	140		140		300										A	A			A	A	A	A	
Furfural C_4H_3OCHO		C	C	C	C		C		300	B to 160	C	C	C		A	A	A	A	A	A	A		A	A	A	A	A
Gallic Acid $C_6H_2(OH)_3CO_2H \cdot H_2O$			73		140		73		300	C	C	C	B to 400		B	B	C		C	C	C		C	A	A	A	
Gasoline (Leaded)		C	C	C	B		73		200	C	190	C	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasoline (Unleaded)		C	C	C	B		73		200	C		C	190	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasohol		C	C	C	B		73		200					A	A	A	A	A	A	A	A	A	A	A	A	A	A
Gasoline (Sour)		C	C	C	B		C		200	C	250	C	B to 250	A	B	B			A	A	A		A	B	A	A	
Gelatin			180	180	140		140		300	200	200	200	212		C	C	B		C	C	C		C	C	C	A	
Glauber's Salt									200	B to 200	C	B to 200	B to 400		A	A		A	A	A			A	A	A	A	
Glucose $C_6H_{12}O_6 \cdot H_2O$		120	180	212	140		140		400	B to 212	200	200	B to 400		A	A	A	A	A	A	A	A	A	A	A	A	A
Glue				140	140		140		400	B	B	B	B		A	A	A	A	A	A	A	A	A	A	A	A	A
Glycerin $C_3H_5(OH)_3$		140	180	212	140		140	B to 320	400	B to 200	250	B to 180	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Glycol Amine															C	C	C		A	A	A		A		A		
Glycolic Acid $OHCH_2COOH$	Sat'd.		180	73	140		140		200	140	B	140	C		B	B			C	C	C		C		A		

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Glyoxal OCHCHO							140								B	B	B		C	C	C		C		A	A	
Grease										C	100	C	140		C	C	C	C	A	A	A		A		A	A	
Green Liquor		160	180		140					B to 300	B to 200	B to 160	B to 400		C	C	C		A	A		A	A		A	A	
Gypsum	Slurry								350						A	A	B	B	A	A	B	A	A	A	A	A	A
Heptane C_7H_{16}		73	180	C	140		73		300	C	250	B to 200	200		A	A	A		A	A	A	A	A	A	A	A	
n-Hexane C_6H_{14}		C	73	73	73				300	C	250	B to 140	B to 250		A	A	A		A	A	A	A	A	A	A	A	
Hexanol $CH_3(CH_2)_4CH_2OH$			180		140		140		300	C	140	C	212		A	A	A		A	A	A		A	A	A	A	
Hydraulic Oil (Petroleum)					73		73		300	C	250	C	70	A	A	A	B		A	A	A		A	A	A		
Hydrazine H_2NNH_2			C	73	C				250		C	C	C	A	C	C	C	C	C	C	C		C		A		
Hydrobromic Acid HBr	20%	73	73	140	140	B to 212	140		250	B to 300	C	C	200	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Hydrobromic Acid HBr	50%	C		120		B to 140	140		250	200	C	C	200	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Hydrochloric Acid HCl	10%	C	180	140	140	B to 212		73	250	176	B to 150	140	230	A	C	C	C	C	C	C	C	C	C	C	B	C	C
Hydrochloric Acid HCl	30%	C	180	140	140	B to 212			250	B to 130	B to 70	B to 100	160		C	C	C	C	C	C	C	C	C	C	B	C	C
Hydrocyanic Acid HCN	10%	160	180	73	140	B to 248	140		250	B to 300	B to 200	C	B to 400		C	C	C	C	C	C	C	C	C	C	A	B	C
Hydrofluoric Acid HF	Dilute	73	73	180	73	B to 212	140		300	212	B to 70	B to 185	212	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Hydrofluoric Acid HF	30%	C	73	140	73		140		300	B to 140	C		212	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Hydrofluoric Acid HF	50%	C	C	73	73	B to 212	120		300	B to 140	C	C	70	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Hydrofluosilicic Acid	50%								300	140	B to 220	C	B to 400	C	B	B			C	C	C		C	B	B	B	C
Hydrogen H_2	Gas		73	140	140	B to 248	140		300	200	B to 220	200	210		A	A	A	A	A	A	A	A	A	A	A	A	A
Hydrogen Peroxide H_2O_2	50%		180	73	140	B to 212	140	B to 73	300	B to 100	C	C	70	A	C	C	C	C	C	C	B	C	C	A	A	A	C
Hydrogen Peroxide H_2O_2	90%		180	C	140		73		30	B to 70	C	C	C	C	C	C	C	C	C	C	B	C	C	A	A	A	C
Hydrogen Sulfide H_2S	Dry		180	150	140	B to 248	140			250	140	140	C	A	B				B		B				A	B	
Hydrogen Sulfide H_2S	Wet		180		140		140			130	C	70	C	A	C	C	C	C	C	C	C		C	C	A	C	C

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Hydrogen Sulfite H_2SO_3															C	C	C	C	C	C	C		C	C	A		C
Hypochlorous Acid HOCl	10%	73	180	73	140	B to 212	140		300	104	C	C	120														C
Inks				140			140		300	B	B	B	70		A	A	A		C	C	C		C		A		
Iodine I_2	10%	C	73	73	C	B to 176	C		200	B to 160	80	B to 80	190	B to 70	C	C	C	C	C	C	C		C	C	C	C	C
Iron Phosphate														A	C	C	C	C					B	A	A	A	C
Isobutane									140	C	250	C	250		A	A	A	A	A	A	A	A	A	A	A	A	A
Isobutyl Alcohol $(CH_3)_2CHCH_2OH$		C	C	73			140		300	B to 300	C	160	B to 400												A		
Isooctane $(CH_3)_3CCH_2CH(CH_3)_2$				C			73	73	300	C	250	C	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Isopropyl Acetate $CH_3COOCH(CH_3)_2$		C	C				73		200	B to 160	C	C	C	A	A				A	A	A		A	A	A	A	A
Isopropyl Alcohol $(CH_3)_2CHOH$			C	212	140	C	140	B to 130	300	160	70	B to 120	170	550	A	A	A	A	A	A	A	A	A	A	A	A	A
Isopropyl Ether $(CH_3)_2CHOCH(CH_3)_2$			C	C	C		73		140	C	C	C	C		A	A		A	A	A	A	A	A	A	A	A	
JP-3 Fuel									200	C	70	C	140		A	A	A	A	A	A	A	A	A	A	A	A	A
JP-4 Fuel			C	C	B		73		300	C	250	C	B to 400		A	A	A	A	A	A	A	A	A	A	A	A	A
JP-5 Fuel			C	C	B		73		300	C	250	C	B to 400		A	A	A	A	A	A	A	A	A	A	A	A	A
JP-6 Fuel									200	C	B to 120	C	70		A	A	A	A	A	A	A	A	A	A	A	A	A
Kelp Slurry															B	B	B	B	B	B	B		B	A	A	A	
Kerosene		73	B	C	B		C		250	C	250	C	B to 400	A	A	A	A	A	A	A	A	A	A		A	A	A
Ketchup					73				250	210	200	70	200		C	C	C		C	C	C		C	B	A	A	
Ketones		C	C	C	C		73		200	200	200	C	C	A	A	A	A		A	A	A		A	A	A	A	
Kraft Liquors		73	180		140		120		250						C	C	C	C	C	C	C		C		A		
Lactic Acid $CH_3CHOHCOOH$	25%	73	180	212	140		140		300	212	80	70	B to 400	A	C	C	C	C	C	B	C		B	A	A	A	
Lactic Acid $CH_3CHOHCOOH$	80%	C	C	140	73		140		300	176	80	70	B to 400	A	C	C	C	C	C	B	C		B	A	A	A	
Lard Oil			C		140		C		300						C	C	C	C	B	B	B		B		A		C
Latex				140			140		200	B to 200	200	160	160		A	A			A	A			A		A		
Lauric Acid $CH_3(CH_2)_{10}COOH$			180	140	140		120		300	C	70	70	70						C	C			C		A		
Lauryl Chloride $CH_3(CH_2)_{10}CH_2Cl$			73		140	B to 248	120		300										C	C			C		A		

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Lead Acetate $Pb(CH_3COO)_2 \cdot {}_3H_2O$	Sat'd.		180	180	140	B to 212	140		300	200	B to 140	B to 140	C		C	C			C	C	C		C		A		
Lead Chloride $PbCl_2$			180	140	140		120		300	176	140	C	212	A													
Lead Nitrate $Pb(NO_3)_2$	Sat'd.		180	140	140		120		300	B to 300	B to 220	200	212	A							A				A		
Lead Sulfate $PbSO_4$			180	140	140		120		300	B to 210	120	B to 180	212	A	B	B			C	C	C		C		B		
Lemon Oil			C	C				B to 73	300	C	70	C	70						C	C			C	B	A	A	
Lime Sulfur			73	73	73		120			B to 300	B to 220	B to 180	B to 420		C	C	C	C	A	A	A		A		A		
Linoleic Acid			180	180	140				300	C	C	C	C		C	C	C	C	C	C	C		C	C	B	B	C
Linseed Oil		73	C	140	140	B to 248	B to 73		300	C	200	B to 180	250		A	A	A	A	A	A	A	A	A	A	A	A	A
Lithium Bromide LiBr				140	140		140	B to 212	300					A													
Lithium Chloride LiCl				140	140		120			160	160	160	160	A	B	B	B		B	B	C		B		A		
Lithium Hydroxide LiOH				140			120			160	C	70	C		C	C	C	C	A	A			A		A		
Lubricating Oil (ASTM #1)			180	C	140	B to 248	73		350	C	180	150	70		A	A	A	A	A	A	A	A	A	A	A	A	A
Lubricating Oil (ASTM #$_2$)			180	C	140		73		350	C	B to 180	C	70-300		A	A	A	A	A	A	A	A	A	A	A	A	A
Lubricating Oil (ASTM #$_3$)			180	C	140		73		350	C	180	C	350		A	A	A	A	A	A	A	A	A	A	A	A	A
Ludox															C	C	C	C	A	A	A		A		A		
Magnesium Carbonate $MgCO_3$		120	180	212	140	B to 212	140		225	B to 300	140	B to 180	212		B	B			B	B	B		B	A	A	A	
Magnesium Chloride $MgCl_2$	Sat'd.	120	180	140	140	B to 140	140		400	230	176	B to 200	185	A	A	A	B	B	C	C	C		C	C	C	C	A
Magnesium Citrate $MgHC_6H_5O_7 \cdot {}_5H_2O$			180		140		140		300	176	140		212														
Magnesium Oxide MgO		160													A	A				A			A				
Magnesium Sulfate $MgSO_4 \cdot {}_7H_2O$		160	180	212	140	B to 212	140		300	194	B to 230	B to 200	B to 390	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Maleic Acid HOOCCH=CHCOOH	Sat'd.	160	180	140	140	B to 140	140		250		C	C	140	A	C	C	B	C	C	C	C		C	B	A	B	B
Manganese Sulfate $MnSO_4 \cdot {}_4H_2O$			180	180	140		140		300	176	B to 200	B to 200	212	A	A	A	A		C	C	B		C		A		
Mercuric Chloride $HgCl_2$			180	180	140		140		300	B to 210	B to 200	160	B to 300	A	C	C	C	C	C	C	C	C	C	C	C	C	C

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL											
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Mercuric Cyanide $Hg(CN)_2$	Sat'd.		180	140	140	B to 212	140		300	B to 210	B to 160	B to 70	C		C	C	C	C	C	C	C		C		A		C
Mercuric Sulfate $HgSO_4$	Sat'd.		180	140	140		140		300	70	70	B to 70	C	A	C	C	C	C									C
Mercurous Nitrate $HgNO_3 \bullet {}_2H_2O$	Sat'd.		180	140	140		140		300	100	B to 90	90	C	A	C	C	C	C	C	C	C		C	A	A	A	C
Mercury Hg			180	140	140	B to 248	140		300	210	140	140	185	A	C	C	C	C	A	A	A		A	A	A	A	C
Methane CH_4		C	73	73	140		140		300	C	B	B to 140	B		A	A	A	A	A	A	A	A	A	A	A	A	A
Methanol (Methyl Alcohol) CH_3OH			C	180	140		B to 140		300	B to 176	B to 160	160	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Methyl Acetate $CH_3CO_2CH_3$		C	C	140	C		C		300	160	C	C	C		B	B			B	B	B		B	B	A		
Methyl Acetone														C	A	A	A	A	A	A	A	A	A	A	A	A	A
Methyl Amine CH_3NH_2			C	C	C				300						C	C			A	A	B		A		A		
Methyl Bromide CH_3Br			C	C	C		C		300	C	C	C	185		C	C	B		C	C	B				B		
Methyl Cellosolve $HOCH_2CH_{20}CH_3$			C	73	C		C			C	C	C	C		A	A	B		B	B	B			A	A	A	
Methyl Chloride CH_3Cl	Dry	C	C	C	C		C		250	C	C	C	C		A	A	C	C	A	A	A	A	A	A	A	A	
Methyl Chloroform CH_3CCl_3		C	C	C	C		C		200	C	C	C	C						A	A			A		A		
Methyl Ethyl Ketone (MEK) $CH_3COC_2H_5$		C	C	73	C			C	200	B to 200	C	C	C	A	A	A	A	A	A	A	A		A	A	A	A	A
Methyl Formate										B to 120	C	C	C		A	A	A		A	A	C		A	A	A	A	
Methyl Isobutyl Ketone $(CH_3)_2CHCH_2COCH_3$		C	C	73	C		73		200	B to 130	C	C	C	A					A						A	A	
Methyl Isopropyl Ketone $CH_3COCH(CH_3)_2$			C		C		73		150	C	C	C	C														
Methyl Methacrylate $CH_2{=}C(CH_3)COOCH_3$			C		73		140		150	C	C	C	C								C						
Methylene Bromide CH_2Br_2			C	C	C		C		250	C	C	C	C														
Methylene Chloride CH_2Cl_2			C	C	C	C	C	C	250	C	C	C	C		B	B	B		B	B	B				A	A	
Methylene Chlorobromide CH_2ClBr			C		C														A	A					A		
Methylene Iodine CH_2I_2			C	C	C		C		200			C	70														
Methylsulfuric Acid CH_3HSO_4			180	140	140					70	C	70	C														
Milk		160	180	212	140	B to 212	140		400	250	250	250	250		B	B	B	B	C	C	C		C	C	A	A	A

FABCO PLASTICS

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Mineral Oil		73	180	C	140	B to 212		B to 73	300	C	250	B to 200	B to 400		A	A	A	A	A	A	A	A	A	A	A	A	A
Molasses			180	140	140		140		300	B to 212	200	200	212		A	A	A	A	A	A	A		A	A	A	A	A
Monochloroacetic Acid $CH_2ClCOOH$	50%			140	140		140		200		C	70	C	A	C	C	C	C	C	C	C		C	C	C	C	C
Monochlorobenzene C_6H_5Cl			C	73	C		C		200	C	C	C	C	A	A	A			A	A	A	A	A	A	A	A	
Monoethanolamine $HOCH_2CH_2NH_2$					C				100	120	C	C	C	A			C		B	B	B		B		A		
Morpholine C_4H_8ONH				140			140		200	C	C	C	B to 70		B	B			B	B	B		B	B	B	B	
Motor Oil			180	C	140		B to 140		350	C	190	B to 70	190	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Muriatic Acid	37%								250						C	C	C	C	C	C	C	C	C	C	B	C	C
Naphtha			73	73	140	B to 122			200	C	B to 250	C	B to 400		A	A	B		A	A	A	A	A	A	A	A	
Naphthalene $C_{10}H_8$			C	73	C		73		250	C	C	C	176		A	A	B		A	A	A	A		A	A	A	
Natural Gas		73		73	140		140		300	C	250	140	250		A	A	A	A	A	A	A	A		A	A	A	A
Nickel Ammonium Sulfate									250	70	70	70	B to 70		C	C	C	C	C	C	C				A		
Nickel Chloride $NiCl_2$	Sat'd.	160	180	180	140	B to 212	140		406	176	176	B to 200	B to 400	A	C	C	B		C	C	C				A		
Nickel Nitrate $Ni(NO_3)_2 \cdot 6H_2O$	Sat'd.	160	180	180	140	B to 248	140		400	212	B to 200	B to 200	248	A	C	C			C	C	C			A	A	A	
Nickel Sulfate $NiSO_4$	Sat'd.	160	180	180	140	B to 212	140		400	176	176	160	B to 400	A	C	C	B		C	C	C						A
Nicotine $C_{10}H_{14}N_2$			180		140		140				C	C	C											B	A		
Nicotinic Acid C_5H_4NCOOH			180		140	B to 212	140			B to 140	70	B to 200			B	B			C	C	C			B	B	B	A
Nitric Acid HNO_3	<10%	C	180	180	140	B to 212			250	B to 104	C	C	B to 185	A	C	C	C	C	C	C	C	C		B	A	A	C
Nitric Acid HNO_3	30%	C	B to 130	140	140	B to 212			250		C	C	B to 185	C	C	C	C	C	C	C	C		B	A		A	C
Nitric Acid HNO_3	40%	C	B to 120	73	140				250	C	C	C	70	C	C	C	C	C	C	C	C		B	A		A	C
Nitric Acid HNO_3	50%	C	110	C	100				250	C	C	C	70	C	C	C	C	C	C	C	C	C		B	A		C
Nitric Acid HNO_3	70%	C	100	C	73				250	C	C	C	C	C	C	C	C	C	C	C	C	C		C	A		C
Nitric Acid	Fuming								70	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A		C
Nitrobenzene $C_6H_5NO_2$		C	C	C	C	B to 122	C		400	C	C	C	C	A	B	B			A	A	A				A		

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Nitrogen N_2	Gas								300	B to 350	B to 230	300	B to 400	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Nitroglycerin $CH_2NO_3CHNO_3CH_2NO_3$					C		73	B to 73	70	70	C	70	C		B	B				B	B				A		
Nitrous Acid HNO_2	10%		180	C	140		73		400	100	C	100	C		C	C	C	C	C	C	C			B	B	B	C
Nitrous Oxide N_2O			73	73	73		73	73	400	140	70	B to 80	C	A	B	B			C	B	B				A		
n-Octane C_8H_{18}			C					B to 250	400	C	B to 200	C	B to 400	550	A	A	A	A	A	A	A	A		A	A	A	A
Oleic Acid		160	180	73	140	B to 248	C		250	C	B to 225	C	B to 212	A	B	B	A		B	B	C			B	A	A	A
Oleum (Sulfuric Acid) $xH_2SO_4 \cdot ySO_3$	Fuming	C	C	C	C	C	C			C	C	C	C														
Olive Oil		160	C	73	140	B to 248	B to 68		350	C	250	C	250		A	A	A	A	A	A	A	A	A		A	A	A
Oxalic Acid $HOOCCOOH \cdot 2H_2O$	50%	160	180	140	140	B to 122	140		300	300	C	C	B to 400	A	C	C	C		C	C	C	C	C	B	A	A	
Oxygen O_2	Gas	160	180	C	140	B to 212	140		406		C		B to 190	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Ozone O_3			180	C	140		C		300	B	C	C	B	C	A	A	A	A	A	A	A	A	A	A	A	A	A
Palm Oil				73			140		200	C	250	C	250		C	C			C	C	C		C		A		
Palmitic Acid $CH_3(CH_2)_{14}COOH$	10%	73	73	180	140		120		300	C	220	C	400		B	B	B	A	B	B	B		B	B	A	A	A
Palmitic Acid $CH_3(CH_2)_{14}COOH$	70%		73	180	73		120		300	C	220	C	400		B	B	B	A	B	B	B		B	B	A	A	
Parafin $C_{36}H_{74}$		73	180	140	140	B to 212	C		250	C	250	C	400		A	A	A		B	A	A	B	B	A	A	A	A
Peanut Oil			C	140		B to 248			250	C	250	C	400		A	A			A	A			A		A		
n-Pentane $CH_3(CH_2)_3CH_3$		C	C	C	C		C		100	C	250	70	200		A	A	A	A	A	A	A	A	A	A	A	A	A
Peracetic Acid CH_3COOOH	40%	C		73	73			B to 73		C	C	70	C														
Perchloric Acid $HClO_4$	10%					B to 212			250	B to 140	C	140	400	A					C						A		
Perchloric Acid $HClO_4$	70%	73	180	C	73	B to 212	73			B to 140	C	70	400	C					C						B		
Perchloroethylene (Tetrachloroethylene) $Cl_2C=CCl_2$		C	C	C	C	C	C	C	200	C	C	C	400		B	B			B	B	B		B	A	A	A	
Perphosphate			73	140	73				250																		
Phenol C_6H_5OH		C	73	73	73		140	B to 140		C	C	C	B to 210	A	A	A	C		C	C	C		C	A	A	A	

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Phenylhydrazine $C_6H_5NHNH_2$			C	C	C	B to 104	C		B to 70	C	C	C	C														
Phosphate Esters										250	C	C			C	C			C	C			C		A		
Phosphoric Acid H_3PO_4	10%		180	212	140		140		300	B to 300	104	B to 206	B to 400	A	C	C	C	C	C	C	C	C	C	B	A	A	C
Phosphoric Acid H_3PO_4	50%	73	180	212	140	B to 212	140		300	176	B to 104	171	212	A	C	C	C	C	C	C	C	C	C	B	A	A	C
Phosphoric Acid H_3PO_4	85%		180	212	140		73		300	176	C	122	B to 185	A	C	C	C	C	C	C	C	C	C	B	A	B	C
Phosphoric Anhydride P_2O_5			73	73	73					200	B	B	B								C				A		
Phosphorus Pentoxide P_2O_5			73	73	73		140										C				B				A		
Phosphorus Trichloride PCl_3			C	73	C	C	120		300	70	C	C	70	A											A		
Photographic Solutions			180	140	140		140			B to 104	B to 70	B to 140	185							C					A		
Phthalic Acid $C_6H_4(COOH)_2$				140	C		140			B to 100	C	B to 100	C	A	A	A			B	B	C		B		A	A	A
Picric Acid $C_6H_2(NO_2)_3OH$	10%	C	C	73	C	B to 212	73			200	B to 200	70	400		C	C	C	C	C	C	C	C	C	B	A		C
Pine Oil			C	140			B to 73			C	70	C	70		C	C	B		B	B	B		B	A	A	A	
Plating Solutions (Brass)			180	140	140		140		300	70	B	140	140														
Plating Solutions (Cadmium)			180	140	140		140		300	300	B to 180	B to 200	190														
Plating Solutions (Chrome)			180	140	140		140		300	210	C	C	B to 400												A		
Plating Solutions (Copper)			180	140	140		140		300	B to 300	B to 190	B to 160	185														
Plating Solutions (Gold)			180	140	140		140		300	B	B	B	B														
Plating Solutions (Lead)			180	140	140		140		300	B to 300	B to 190	140	185														
Plating Solutions (Nickel)			180	140	140		140		300	B to 300	B	B to 200	185	A		C		C							A		C
Plating Solutions (Rhodium)			180	140	140		140		300	120	B to 200	80	B to 190														
Plating Solutions (Silver)			180	140	140		140		300	B to 300	B to 180	B to 200	B to 190												A		
Plating Solutions (Tin)			180	140	140		140		300	210	B to 180	140	140														
Plating Solutions (Zinc)			180	140	140		140		300	B to 300	B to 180	B	B to 190								B						

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Polysulfide Liquor									300						C	C	C	C	B	B			B		B		C
Polyvinyl Acetate									350	B to 280	80	C	C		B	B	B		A	A	C		A	B	B	B	
Potassium Alum			180		140		140		400	176	B to 180	B to 200	212														
Potassium Aluminum Sulphate			180		140		140		400	176	B to 180	B to 200	212			B		C			C			B	A		B
Potassium Bicarbonate $KHCO_3$	Sat'd.		180	140	140	B to 212	140		400	200	200	200	212								A				A		
Potassium Bichromate $K_2Cr_2O_7$	Sat'd.		180	140	140	B to 212			400	140	140	104	212	A		A		B			B			B	A		
Potassium Bisulfate $KHSO_4$			180	212	140	B to 212	140		400	B	140	70	212	A	B	B	B		C	C	C	C	C		A		
Potassium Bromate $KBrO_3$			180	212	140	B to 212	140		400	212	B to 70	B to 140	212						C	A	A		A		A		
Potassium Bromide KBr			180	212	140	B to 248	140		400	212	200	200	B to 212	A	B	B	B		C	C	C				A		
Potassium Carbonate (Potash) K_2CO_3		73	180	180	140	C	140		400	B	200	200	B to 212	A	B	B	B	B	A	A	A	A	A	A	A	A	B
Potassium Chlorate (Aqueous) $KClO_3$		160	180	212	140	C	140		400	B to 200	70	B to 200	B	C	B	B			A	A	A	A		A	A	A	B
Potassium Chloride KCl		160	180	212	140	B to 212	140		400	B	200	200	212			B	A	A	B	B	B	B	C	B	B	B	A
Potassium Chromate K_2CrO_4			180	212	140		140		400	176	B to 140	140	B to 212	C	A	A	B		B	B	B		B		A	A	
Potassium Cyanide KCN			180	180	140	B to 212	140		400	B	200	200	200		C	C	C	C	B	B	B	B		A	A	A	C
Potassium Dichromate $K_2Cr_2O_7$	Sat'd.		180	180	140		140		400	212	140	120	212	C	B	B	C		B	B	C			A	A	A	
Potassium Ferricyanide $K_3Fe(CN)_6$			180	180	140	B to 248	140		400	70	C	70	B to 212		C	C			B	B	C				A		
Potassium Ferrocyanide $K_4Fe(CN)_6{\cdot}3H_2O$			180	180	140	B to 248	140		400	140	C	70	140		B	B	C	C	C	C	C			B	A		C
Potassium Fluoride KF			180	180	140	B to 212	140		400	200	B to 180	70	212	A											A		
Potassium Hydroxide KOH	25%	160	180	212	140		B to 140	248	300	320	B to 80	B to 212	80	A	C	C	C		B	B	B	B		A	A	A	
Potassium Hypochlorite KClO		160	180		140		120		400	70	C	B to 70	C		C	C					C				A		
Potassium Iodide KI			180	73	73	B to 212	140		400	70		70	B	A	B	B					B	B			A		
Potassium Nitrate KNO_3		160	180	140	140		140		400	B	B to 200	B to 200	212	C	A	A	B	B	B	B	B	B		A	A	A	A

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Potassium Perborate KBO_3			180	140	140		140		400	70	B to 70	70	B to 70	A													
Potassium Perchlorate $KClO_4$			180	140	140		140		200	140	C	70	190														
Potassium Permanganate $KMnO_4$	10%		180	73	140		140		400	210	C	140	B to 212		B	B			A	A	A			A	A	A	
Potassium Permanganate $KMnO_4$	25%		180	73	73	B to 212	140		400	200	C	140	B to 212		B	B			A	A	A			A	A	A	
Potassium Persulfate $K_2S_2O_8$			180	140	140	B to 176	140		400	180	C	B	210														
Potassium Sulfate K_2SO_4		160	180	180	140	B to 212	140		200	176	B to 200	B to 200	212	A	A	A	B	B	A	A	A	A	B	A	A	A	A
Potassium Sulfide K_2S			180	140		68	140		300	70		70	210		C	C	C	C	C	C	C	B		B	B	B	C
Potassium Sulfite $K_2SO_3 \bullet 2H_2O$			180	140			140		300	200	B to 150	B to 150	210		B	B	B		C	C	C				A		
Potassium Tetraborate									400					A						A	A		A		A		
Potassium Tripolyphosphate									300					A			B		A		A	A			A		
Propane C_3H_8			73	73	140	B to 248	140		300	C	250	140	250	A	A	A	A	A	A	A	A	A		A	A	A	A
Propargyl Alcohol			C	140	140		140			140	70	70	140														
Propionic Acid $CH_3CH_2CO_2H$		C	C	140		B to 140	140			200		C	C												A		A
Propyl Acetate									140	C	C	C	C					A			A			A	A	A	
Propyl Alcohol $CH_3CH_2CH_2OH$		73	C	140	140	B to 122	B to 140		350	B to 225	180	B to 176	B to 300		A	A	A	A	A	A	A	A		A	A	A	A
n-Propyl Bromide									300						B	B	B		B	B	B				A		
Propylene Glycol	<25%							180	300	200	180	70	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Propylene Glycol	>25%							B to 180	300	200	180	70	250	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Propylene Oxide CH_3CHCH_2O			C	73	C		140		150	C	C	C	C								A				A		
n-Propyl Nitrate									200	C	C	C	C						A	A			A		A		
Pyridine $N(CH)_4CH$			C	C	C	B to 68	73			C	C	C	C		B	B			B	B	B		B	C	B		
Pyrogallic Acid $C_6H_3(OH)_3$					73				150	C	B to 100	C	140		A	A			A	A	A		A	A	A	A	
Pyrrole										C	C	C	C		B	B			B	B	B		B		B		
Quinone $C_6H_4O_2$				140			140			C	C	C	C						A	A			A		A		
Rosin									200	C	B to 200	200	B		C	C			C	C	C		C	A	A	A	

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLOROPRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Salicylic Acid $C_6H_4(OH)(COOH)$				140	140	B to 212	140		300	300	C		300		B	B			C	C	C		C		A		
Selenic Acid H_2SeO_4			180		140		140			70	C	70	C														
Silicic Acid $SiO_2 \cdot nH_2O$			180	140	140	B to 212	140		400	176	176	70	212														
Silicone Oil			180	212	73		73		350	140	212	212	400	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Silver Chloride AgCl		160	180	140	140					70	C	70	90	A	C	C	C	C	C	C	C		C	C	C	C	C
Silver Cyanide AgCN			180	180	140	B to 212	140		350	70	C	70	140		C	C	C	C	C	C	C		C		A to 100		C
Silver Nitrate $AgNO_3$		160	180	180	140		B to 140		350	300	C	B to 200	185	A	C	C	C	C	C	C	C		C	B	A		C
Silver Sulfate Ag_2SO_4		160	180	140	140		140		350	176	140	70	212	A													
Soaps		73	180	140	140		B to 140		400						B	B	A		B	B	B		B	A	A	A	
Sodium Acetate CH_3COONa	Sat'd.		180	212	140	B to 212	140		400	212	C	C	B		A	A	B		B	B	C		B	B	A		
Sodium Aluminate $Na_2Al_2O_4$	Sat'd.				140				300	B to 200	B to 180	140	B to 200		C	C	B		B	B	A		B		A		
Sodium Benzoate C_6H_5COONa			180	140	140		140		300	140	B to 140	B to 70	B to 140														
Sodium Bicarbonate $NaHCO_3$		73	180	212	140	B to 212	140		400	212	B to 200	B to 200	212		A	A	B	B	A	A	C		A	A	A	A	A
Sodium Bichromate	Sat'd.								400	176	140	B to 70	B to 212	C	C	C								A	A	A	
Sodium Bisulfate $NaHSO_4$		73	180	140	140		140			B to 200	B to 200	B to 200	212		C	C	C	C	C	C	C		C	B	A		C
Sodium Bisulfite $NaHSO_3$			180	140	140		140		400	176	160	B to 200	212		B	B			C	C	C		C		A		
Sodium Borate (Borax) $Na_2B_4O_7 \cdot {}_{10}H_2O$	Sat'd.	160	180	180	140		140		300	B to 300	B to 220	B to 200	210	A	A	A			B	B			B	A	A	A	
Sodium Bromide NaBr	Sat'd.	120	180	140	140		140		300	140	C	70	B to 180	A	B	B			C	C	C		C		A		
Sodium Carbonate Na_2CO_3		73	180	212	140	C	140	B to 73	400	176	B to 200	B to 200	212		A	A	B	B	A	A	A	A	A		A	A	C
Sodium Chlorate $NaClO_3$	Sat'd.		180	140	73	C	140		350	B to 200	B to 200	B to 200	B to 200		A	A	C		B	B	B		B	B	A	A	
Sodium Chloride NaCl		120	180	212	140		140		350	B to 212	160	120	212		B	A	A	A	B	B	B	B	C	A	B	B	A
Sodium Chlorite $NaClO_2$	25%		180	73	C		140		200	70	C		B to 140	C													

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Sodium Chromate $Na_2CrO_4{\cdot}4H_2O$		120	180	140		B to 176	140			140	140	70	140	C	A	A			B	B	B		B	A	A	A	
Sodium Cyanide $NaCN$			180	180	140	B to 212	140		350	176	B to 230	140	176	200	275	C	C	C	C	A	A	A	A		A	A	C
Sodium Dichromate $Na_2Cr_2O_7{\cdot}2H_2O$	20%		180	180	140		140		300	176	140	C	B to 212	C	C	C	C		B	B	B				A		
Sodium Ferricyanide $Na_3Fe(CN)_6{\cdot}2H_2O$	Sat'd.		180	140	140		140		350	300	70	70	140		C	C			C	C					A		
Sodium Ferrocyanide $Na_3Fe(CN)_6{\cdot}10H_2O$	Sat'd.		180	140	140		140		350	140	80	70	140												A		
Sodium Fluoride NaF		120	180	180	140	B to 212	140		350	140	100	140	140	A	A	A	B		C	C	C				A		
Sodium Hydroxide $NaOH$	< 5%					B to 68																					
Sodium Hydroxide $NaOH$	<10%								400	B to 200	212	B to 200	B to 140	A	A		A			A	A		B	A	A	A	
Sodium Hydroxide $NaOH$	30%	120	180	212	140	C	B to 140		350	B to 130	212	B to 200	80	A	A		B			B	B		B	A	A	A	
Sodium Hydroxide $NaOH$	50%	120	180	212	140		B to 140	194	350	B to 130	212	B to 200	B to 70	A	B	C	C	C	B	B	B	B	B	A	A	A	B
Sodium Hydroxide $NaOH$	70%	120	180	212	140		B to 140		350	B to 130	B to 70	B to 200	B to 70	A	C	C	C	C	B	B	B	B	B	A	A	A	B
Sodium Hypochlorite $NaOCl{\cdot}5H_2O$		120	180	73	73		140	B to 190	350	C	C	C	70		C	C	C	C	C	C	C	C	C	C	C	C	C
Sodium Metaphosphate $(NaPO_3)n$			180	120	140					300	220	150	B to 400	A	C	C	C		C	C	C				A		
Sodium Nitrate $NaNO_3$	Sat'd.	160	180	180	140	B to 212	140		400	200	B to 171	B to 200	212	A	A	A	B	B	A	A	A	A	A	A	A	A	B
Sodium Nitrite $NaNO_2$		160	180	73	140	B to 212	140		400	176	171	B to 140	212		A	A			B	B	B				A		
Sodium Perborate $NaBO_3{\cdot}4H_2O$		120	180	73	140		73		350	140	C	B	140	A	C	C			B	B	B			A	A	A	
Sodium Perchlorate $NaClO_4$			180	212	140		140		350	70	C	70	C														
Sodium Peroxide Na_2O_2	10%		180		140		140		250	300	C	C	400	C	C	C	C	C	C	C	C			A	A	A	B
Sodium Phosphate NaH_2PO_4	Acid	120	180	212	140	B to 140	140		400					A	B	B	B	B	B	B	B	A	B	A	A	A	B
Sodium Phosphate NaH_2PO_4	Alkaline		120	180	212		140		400					A	B	B	B	B	B	B	B	A	B	A	A	A	B
Sodium Phosphate NaH_2PO_4	Neutral		120	180	212				400					A	B	B	B	B	B	B	B	A	B	A	A	A	B
Sodium Silicate			180	140	140		140			B to 200	140	B to 200	212		C	C	B		A	A	A		A	A	A	A	

CHEMICAL RESISTANCE CHART

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Sodium Sulfate Na_2SO_4	Sat'd.	160	180	212	140				400	B to 200	200	B to 200	212	A	A	A	B	B	A	A	A	A	A	A	A	A	A
Sodium Sulfide Na_2S	Sat'd.	160	180	212	140		140		350	200	B to 200	B to 200	176		C	C	C	C	B	B	C	B	B	A	A	A	C
Sodium Sulfite Na_2SO_3	Sat'd.	160	180	212	140	B to 212	140	B to 73	350	200	B to 200	B to 200	140		A	A	C		B	B	B		B	B	A	A	
Sodium Thiosulfate $Na_2S_2O_3•_5H_2O$			180	180	140		140		350	140		160	140		B	B	C		C	C	C		C		A		
Sour Crude Oil				140	140					C	C	C			C				A	A	A		B	A	A	A	
Soybean Oil				73			140		400	C	250	250	B to 400		A	A	B		A	A	B	A	A	A	A	A	
Stannic Chloride $SnCl_4$	Sat'd.		180	140	140		140		350	300	220	C	B to 400	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Stannous Chloride $SnCl_2$	15%	120	180	140	140		140		350	B to 210	B to 150	B to 140	B to 185	A	C	C	C	C	C	C	C	C	C		A		
Starch			180	140	140		140		300	176	B to 176	212	212		B	B	B	B	B	B	B		B	A	A	A	
Steam (Low Pressure)									400					A	A	A	A	A	A	A	A	A	A	A	A	A	A
Steam (Medium Pressure)									400						A	A	A	A	A	A	A	A	A	A	A	A	A
Steam (High Pressure)									C						C	C	C	C	C	B	A	C	B	A	A	A	C
Stearic Acid $CH_3(CH_2)_{16}COOH$			180	73	140		120		350	C	B to 70	C	140	A	A	A	C	B	C	C	C	B	C	A	A	A	A
Stoddard's Solvent			C		C		73			C	250	C	250		A	A			A	A	A		A		A	A	
Styrene $C_6H_5CH=CH_2$				73			C		350	C	C	C	C		B	B	B		B	B	B		B		A		
Succinic Acid $COOH(CH_2)_2COOH$			180	140	140		140		200	140	70	B to 70	B to 176		A	A			A	A	A		A	A	A	A	
Sugar $C_6H_{12}O_6$			180		140		140		350						C	C				B	C		B	A	A	A	
Sulfamic Acid HSO_3NH_2	20%		C	180	C					70	C	B to 150	C		B	B	B		C	C	C		C		A		A
Sulfate Liquors (Oil)	6%		180	140	140				200	B to 250	B to 150	B to 150	170		C	C	C	C	B	A			A		A		C
Sulfite Liquors	6%	73	180		140				350	B	C	B to 70	140								C	B			A		
Sulfur S			180	212	140				350	250	C	70	266	A	C	C	C	C	B	B	C	B	B	B	A		C
Sulfur Chloride S_2Cl_2				C					350	C	C	C	140	A	C	C	C	C	C	C	C	C	C	C	C	C	C
Sulfur Dioxide SO_2	Gas (Dry)	C	73	140	140		140		350	160	C	C	B to 250	A	A	B	A	A	A	A	A		A	A	A	A	A
Sulfur Dioxide SO_2	Gas (Wet)	C	C	140	73		120			140	C	C	B to 140	A	C	B	B	C						C	A	C	C

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)						METAL												
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Sulfur Trioxide SO_3	Gas		C		73		C			B to 120	C	C	B	C	C			C						C	B	B	C
Sulfuric Acid H_2SO_4	<30%	120	180	180	140	B to 248	B to 140	B to 73	250	212	B	158	248	A	C	C	C	C	C	C	C	C	C	C	A	B	C
Sulfuric Acid H_2SO_4	50%	73	180	140	140	B to 212	B to 140	212	250	212	C	158	212	A	C	C	C	C	C	C	C	C	C	C	A	C	C
Sulfuric Acid H_2SO_4	70%	C	180	73	140				200	140	C	C	180	212	C	C	C	C	C	C	C	C	C	C	B	C	C
Sulfuric Acid H_2SO_4	90%	C	150	73	73	B to 212			200	70	C	C	158	212	C	C	C	C	C	C	C	C	C	C	C	C	C
Sulfuric Acid H_2SO_4	100%	C	C	C	C				200	C	C	C	158	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Sulfurous Acid H_2SO_3	Sat'd.		180	140	140	B to 212	140		350	C	C	C	C	A	C	C	C	C	C	C	C	C	C	B	A	A	C
Tall Oil			C	180	140		120		250	C	200	C	200		B	B	B		B	B	B		B	A	A	A	
Tannic Acid $C_{76}H_{52}O_{46}$	10%	C	180	73	140	B to 212	140		250	200	200	B to 200	200		A	A			B	B	C	B	B	B	A	A	
Tanning Liquors		160	180	73	140		120			200	B to 200	70	200		A	A			B						A		
Tar			C		C				250	C	C	C	B		A	A	A	A	A	A	A	A	A	A	A	A	A
Tartaric Acid $HOOC(CHOH)_2COOH$		160	180	140	140	B to 248	140		250	C	200	158	B to 200	A	A	A	C	C	C	C	C	C	C	A	A	A	B
Tetrachloroethane $CHCl_2CHCl_2$				C	C		C	C	400	C	C	C	200												A		
Tetrachloroethylene $Cl_2C{=}CCl_2$		C	C	C	C		C		350	C	C	C	212														
Tetraethyl Lead $Pb(C_2H_5)_4$			73	73	73				350	C	C	C	120		A	A				B	B		A				
Tetrahydrofuran C_4H_8O		C	C	C	C		C	C		C	C	C	C														
Thionyl Chloride $SOCl_2$			C	C	C	C	C	C		C	C	C	C	A													
Thread Cutting Oils			73	73	73			73	350						A				A	A	A			A	A	A	
Titanium Tetrachloride $TiCl_4$				140	C		120			C	C	C	160	A	C	C					C				B		
Toluene (Toluol) $CH_3C_6H_5$		C	C	C	C		C	C	200	C	C	C	B to 200		A	A	A	A	A	A	A	A		A	A	A	A
Tomato Juice			180	212	140		140		350	70	140	140	140		B				C	C	B				A	A	
Transformer Oil			180	73	140		C		300	C	B	C	300	A	A					A	A				A	A	
Transformer Oil DTE/30			180		140		B to 120		300					A	A					A	A				A	A	
Tributyl Phosphate $(C_4H_9)_3PO_4$			C	C	C		73		300	250	C	C	C		B	B	B		A	A	A			B	A		
Trichloroacetic Acid CCl_3COOH	50%			140	140	B to 104	140		200	C	C	C	C	A	B	C			C	C	C			C	B		

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F)							SEAL MATERIALS MAX TEMPERATURE (°F)					METAL													
		ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLOROPRENE	FKM	GRAPHITE	BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Trichloroethylene $CHCl=CCl_2$		C	C	C	C	B to 176	C	C	200	C	C	C	200	A	A	A	A	A	B	B	B			A	A	A	A
Triethanolamine $(HOCH_2CH_2)_3N$		C	73	140	73	C	73	B to 190		B	C	B	C		C	C			C	C	C	C		C	A		
Triethylamine $(C_2H_5)_3N$				C	140		73	B to 73		160	140	B to 70	C			A	A										
Trimethylpropane $(CH_2OH)_3C_3H_5$				140	73		C			C	C	C	70														
Trisodium Phosphate $Na_3PO_4 \cdot 12H_2O$		73	180	140	140		140		350	212	C	C	B to 300	A	C	C			B	B		A			A	A	
Tung Oil										C	250	B to 120	250		B	B	B		B	B	B			B	A	A	
Turpentine		C	C	C	140		C			C	250	C	B to 200		A	A	A	A	A	A	A	A		A	A	A	A
Urea $CO(NH_2)_2$			180	180	140		140									B	B			C	C	C				A	C
Urine		160	180	180	140		140		400	140	140	C	140						C	C	C			A	A	A	
Varnish									350	C	C	C	B to 400		A	A	B	B	C	C	C			B	A	A	A
Vaseline (Petroleum Jelly)			C	140	C		120		300	C	140	140	140						A	A	A			A	A	A	
Vegetable Oil			C	140	140	B to 248	B to 140		300	C	200	C	200		A	A				A	A			A	A	A	
Vinegar		73	150	140	140		140		300	B to 210	C	C	200		C	C	C	C	C	C	C			A	A	A	B
Vinyl Acetate $CH_3COOCH=CH_2$			C	73	C	C	140		350	C	C	C	C		B	B		B	B	B				A		A	
Water (Acid Mine) H_2O		160	180	140	140		140		400	200	B to 210	C	B to 190	A	C	C	C	C	C	C	C	C	C	A	A	A	C
Water (Deionized) H_2O		160	180	140	140		140		400	B to 140	B to 200	B to 150	B to 200	A	B	B	C	C	C	C	C		C	B	A	A	A
Water (Distilled) H_2O		160	180	212	140	B to 248	140		400	140	B to 210		250	A	A	A	B	B	C	C	C	B	C	A	A	A	A
Water (Potable) H_2O		160	180	212	140	B to 248	140		400					A	A	A	A	A	B	B	B	A	B	A	A	A	A
Water (Salt) H_2O		160	180	212	140		140		400	B to 250	B to 210	140	B to 200	A	B	B	B	C	C	C	C	B	C	B	A	A	B
Water (Sea) H_2O		160	180	212	140	B to 248	140		400	B to 250	B to 210	B to 140	212	A	B	B	B	C	C	C	C	B	C	B	B	A	B
Water (Soft) H_2O		160	180	212	140		140		400					A	A	A	A	B	C	C	B	B	C	A	A	A	A
Water (Waste) H_2O		73	180	212	140		140		400					A	B	B	B	B	B	B	B	B	B	B	A		B

CHEMICALS AND FORMULA	CONCENTRATION	PLASTICS MAX TEMPERATURE (°F): ABS	CPVC	PP	PVC	PVDF	PEX	PPSU	SEAL MATERIALS MAX TEMPERATURE (°F): PTFE	EPDM	NITRILE (BUNA-N)	POLYCHLORO-PRENE	FKM	GRAPHITE	METAL: BRONZE (85% CU)	SILICON BRONZE	ALUMINUM BRONZE	BRASS	GRAY IRON	DUCTILE IRON	CARBON STEEL	3% NI / IRON	NI PLATED DUCTILE	400 SERIES SS	316 SS	630 SS	COPPER
Whiskey			180	140	140	B to 212	140		350	200	200	140	B		C	C	B		C	C	C		C	B	A		A
White Liquor		73	180		140					300	104	140	190		C	C	C		C	C	C		C		A		
Wine		73	180	140	140	B to 248	140		350	200	200	140	200		C	C			C	C	C		C	B	A		
Xylene (Xylol) $C_6H_4(CH_3)_2$		C	C	C	C	C	C	C	350	C	C	C	B to 200	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zinc Acetate $Zn(CH_3COO)_2{\cdot}2H_2O$			180							140	C	C	C		C	C	C	C	C	C	C		C		A		
Zinc Carbonate $ZnCO_3$			180	140		B to 212	140			70	70	70	70		B	B									B		
Zinc Chloride $ZnCl_2$		120	180	180	140		140		400	210	B to 200	194	212	A	C	C	C		C	C	C		C	C	B	B	
Zinc Nitrate $Zn(NO_3)_2{\cdot}6H_2O$		160	180	180	140		140			180	140	100	190	A											A	A	
Zinc Sulfate $ZnSO_4{\cdot}7H_2O$		160	180	212	140		140		400	B to 300	B to 220	171	B	A	C	C	B		C	C	C	B	C	A	A	A	A

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Glossary of Terms

Adhesive – a substance capable of holding materials together by surface attachment.

Adhesive solvent – an adhesive having a volatile organic liquid as a vehicle. See Solvent Cement.

Aging – (1) The effect on materials of exposure to an environment for an interval of time. (2) The process of exposing materials to an environment for an interval of time.

Antioxidant – a compounding ingredient added to a plastic composition to retard possible degradation from contact with oxygen (air), particularly in processing or exposure to high temperatures.

Artificial weathering – the exposure of plastics to cystic laboratory conditions involving changes in temperature, relative humidity, and ultraviolet radiant energy, with or without direct water spray, in an attempt to produce changes in the materials similar to those observed after long-term continuous outdoor exposure. Note: The laboratory exposure conditions are usually intensified beyond those encountered in actual outdoor exposure in an attempt to achieve an accelerated effect. This definition does not involve exposure to special conditions such as ozone, salt spray, industrial gases, etc.

Bell end – the enlarged portion of a pipe that resembles the socket portion of a fitting and that is intended to be used to make a joint by inserting a piece of pipe into it. Joining may be accomplished by solvent cements, adhesives, or mechanical techniques.

Beam loading – the application of a load to a pipe between two points of support, usually expressed in pounds and the distance between the centers of the supports.

Burst strength – the internal pressure required to break a pipe or fitting. This pressure will vary with the rate of build-up of the pressure and the time during which the pressure is held.

Cement – see adhesive and solvent, cement.

Chemical resistance – (1) The effect of specific chemicals on the properties of plastic piping with respect to concentrations, temperature and time of exposure. (2) The ability of a specific plastic pipe to render service for a useful period in the transport of a specific chemical at a specified concentration and temperature.

Cleaner – medium strength organic solvent such as methyl ethyl katone to remove foreign matter from pipe and fitting joint surfaces.

Compound – the intimate admixture of a polymer or polymers with other ingredients such as fillers, softeners, plasticizers, catalysts, pigments, dyes, curing agents, stabilizers, antioxidants, etc.

Copolymer – see Polymer.

Creep – the time-dependent part of strain resulting from stress, that is, the dimensional change caused by the application of load over and above the elastic formation and with respect to time.

Deflection Temperature – the temperature at which a specimen will deflect a given distance at a given load under a prescribed conditions of test. See ASTM D648. Formerly called heat distortion.

Deterioration – a permanent change in the physical properties of a plastic evidenced by impairment of these properties. Note a. – Burst strength, fiber stress, hoop stress, hydrostatic design stress, long-term hydrostataic strength, hydrostatic strength (quick), long-term burst, ISO equation, pressure, pressure rating, quick burst, service factor, strength, stress and sustained pressure test are related terms.

Elasticity – that property of plastics materials by virtue of which they tend to recover their original size and shape after deformation. Note – if the strain is proportional to the applied stress, the material is said to exhibit Hookean or ideal elasticity.

Elastomer – a material which at room temperature can be stretched repeatedly to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length.

Elevated temperature testing – tests on plastic pipe above 23° (73°F).

Environmental stress cracking – cracks that develop when the material is subjected to stress in the presence of specific chemicals.

Extrusion – a method whereby heated or unheated plastic forced through a shaping orifice becomes one continuously formed piece. Note – this method is commonly used to manufacture thermoplastic pipe.

Failure, adhesive – rupture of an adhesive bond, such that the plane of separation appears to be at the adhesive-adherend interface.

Fiber stress – the unit stress, usually in pounds per square inch (psi), in a piece of material that is subjected to an external load.

Filler – a relatively inert material added to a plastic to modify its strength, permeance, working properties, or other qualities, or to lower costs.

Fungi resistances – the ability of plastic pipe to withstand fungi growth and/or their metabolic products under normal conditions of service or laboratory tests simulating such conditions.

Heat joining – making a pipe joint by heating the edges of the parts to be joined so that they fuse and become essentially one pipe with or without the addition of additional material.

Hoop stress – the tensile stress, usually in pounds per square inch (psi), in the circumferential orientation in the wall of the pipe when the pipe contains a gas or liquid under pressure.

Hydrostatic design stress – the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

Hydrostatic strength (quick) – the hoop stress calculated by means of the ISO equation at which the pipe breaks due to an internal pressure build-up, usually within 60 to 90 seconds.

Long-term burst – the internal pressure at which a pipe or fitting will break due to a constant internal pressure held for 100,000 hours (11.43 years).

Impact, Izod – a specific type of impact test made with a pendulum type machine. The specimens are molded or extruded with machined notch in the center. See ASTM D256.

ISO equation – an equation showing the inter-relations between stress, pressure and dimensions in pipe, namely:

$$S = \frac{P(ID + t)}{2t} \text{ or } S = \frac{P(OD - t)}{2t}$$

Where: S = stress
P = pressure
ID = average inside diameter
OD = average outside diameter
t = minimum wall thickness (Note a)

Reference: ISO R161–1960 Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part I, Metric Series.

Joint – the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by an adhesive, a solvent-cement or a mechanical device such as threads or a ring seal.

Long-term hydrostatic strength – the estimated tensile stress in the wall of the pipe in the circumferential orientation (hoop stress) that when applied continuously will cause failure of the pipe at 100,000 hours (11.43 years). These strengths are usually obtained by extrapolation of log-log regression equations or plots.

Molding, injection – a method of forming plastic objects from a granular or powdered plastics by the fusing of plastic in a chamber with heat and pressure and the forcing part of mass into a cooler chamber where it solidifies. Note: this method is commonly used to manufacture thermoplastic fittings.

Outdoor exposure – plastic pipe placed in service or stored so that it is not protected from the elements of normal weather conditions, i.e., the sun's rays, rain, air and wind. Exposure to industrial and waste gases, chemicals, engine exhausts, etc. are not considered normal "outdoor exposure."

Permanence – the property of a plastic which describes its resistance to appreciable changes in characteristics with time and environment.

Plastic – a material that contains as an essential ingredient an organic substance 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.

Plastics pipe – a hollow-cylinder of 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. See plastics tubing.

Plastics tubing – a particular size of plastics pipe in which the outside diameter is essentially the same as that of copper tubing. See plastics pipe.

Polypropylene plastics – plastics based on polymers made with propylene as essentially the sole monomer.

Poly (vinyl chloride) – a resin prepared by the polymerization of vinyl chloride with or without the addition of small amounts of other monomers.

Poly (vinyl chloride) plastics – plastics made by combining poly (vinyl chloride) with colorants, fillers, plasticizers, stabilizers, lubricants, other polymers, and other compounding ingredients. Not all of these modifiers are used in pipe compounds.

Pressure – when expressed with reference to pipe the force per unit area exerted by the medium in the pipe.

Pressure rating – the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

Primer – strong organic solvent, preferably tetrahydrofuran, used to dissolve and soften the joint surfaces in preparation for and prior to the application of solvent cement. Primer is usually tinted purple.

Quick burst – the internal pressure required to burst a pipe or fitting due to an internal pressure build-up, usually within 60 to 90 seconds.

Schedule – a pipe size system (outside diameters and wall thicknesses) originated by the iron pipe industry.

Self-extinguishing – the ability of a plastic to resist burning when the source of heat or flame that ignited it is removed.

Service factor – a factor which is used to reduce a strength value to obtain an engineering design stress. The factory may vary depending on the service conditions, the hazard, the length of service desired, and the properties of the pipe.

Solvent cement – in the plastic piping field, a solvent adhesive that contains a solvent that dissolves or softens the surfaces being bonded so that the bonded assembly becomes essentially one piece of the same type of plastic.

Solvent cementing–making a pipe joint with a solvent cement. See Solvent Cement.

Stress – when expressed with reference to pipe the force per unit area in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure.

Sustained pressure test – a constant internal pressure test for 100 hours.

Thermoplastic – a plastic which is thermoplastic in behavior. Capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

Vinyl Chloride Plastics – plastics based on resins made by the polymerization of vinyl chloride or copolymerization of vinyl chloride with other unsaturated compounds, the vinyl chloride being in greatest amount by weight.

Weld-orKnit-line – a mark on a molded plastic formed by the union of two or more streams of plastic flowing together.

ABBREVIATIONS

ASA – American Standards Association
ASTM – American Society for Testing and Materials
CPVC – Chlorinated Poly (Vinyl Chloride) plastic or resin.
IAPMO – International Association of Plumbing and Technical Officials
ISO – International Standards Organization
NSF – National Sanitation Foundation
PP – Polyproylene plastic or resin
PPI – Plastic Pipe Institute
PS – Product Standard when references to a specification for plastic pipe and fittings. These specifications are promulgated by the U.S. Department of Commerce and were formerly known as Commercial Standards.
PSI – pounds per square inch
PVC – Poly (Vinyl Chloride) plastic or resin
SPI – The Society of the Plastics Industry, Inc.

HDPE General Specifications & Material Standards

REFERENCE SPECIFICATIONS

- ASTM F714: Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR). Based on outside diameter.
- CSA B137.1: Polyethylene Pipe, Tubing and Fittings for Cold Water Pressure Services.
- ASTM D3350: Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
- AWWA C901: Polyethylene (PE) Pressure Pipe and Tubing, 1/2 in. Through 3 in. for Water Service.
- ASTM D3035: Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR). Based on Controlled Outside Diameter
- ISO 9001:2000: Model for Quality Assurance in Production and Installation.
- AWWA C906: Standard for Polyethylene (PE) Pressure Pipe and Fittings 4 in. Through 63 in., for Water Distribution.
- NSF 14, 61
- API 15LE

MATERIAL

The pipe shall be made from polyethylene resin compound with a minimum cell classification of PE 345464C for PE 3408 materials in accordance with ASTM D3350. This material shall have a Long Term Hydrostatic Strength of 1600 psi when tested and analyzed by ASTM D2837, and shall be a Plastic Pipe Institute (PPI) TR4 listed compound.

The raw material shall contain a minimum of 2%, well dispersed, carbon black. Additives, which can be conclusively proven not to be detrimental to the pipe may also be used, provided that the pipe produced meets the requirements of this standard.

The pipe shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specification and from the same raw material supplier.

Compliance with the requirements of this paragraph shall be certified in writing by the pipe supplier, upon request. Manufacture's Quality System shall be certified by an appropriate independent body to meet the requirements of the ISO 9001:2000 Quality Management Program.

PIPE DESIGN

The pipe shall be designed in accordance with the relationships of the ISO-modified formula (see ASTM F714).

$$P = \frac{2S}{(D°/t) - 1}$$

S = Hydrostatic Design Stress (psi)
P = Design Pressure Rating (psi)
D° = ODavg for IPS Pipe
ODmin for ISO Pipe
t = Minimum Wall Thickness
D°/t = Dimension Ratio

The design pressure rating P shall be derived using the formula, expressed in pounds per square inch.

The Hydrostatic Design Basis for PE 3408 materials is 1600 psi.

The pipe dimensions shall be as specified in manufacturer's literature.

MARKING

The following shall be continuously indent printed on the pipe or spaced at intervals not exceeding 5 feet:

- Name and/or trademark of the pipe manufacturer.
- Nominal pipe size.
- Dimension ratio.
- The letters PE followed by the polyethylene grade per ASTM D3350, followed by the Hydrostatic Design basis in 100's of psi e.g. PE 3408.
- Manufacturing Standard Reference e.g. ASTM F 714
- A production code from which the date and place of manufacture can be determined.

JOINING METHODS

Whenever possible, polyethylene pipe should be joined by the method of thermal butt fusion as outlined in ASTM D2657, Heat Joining Polyolefin Pipe and Fittings. Butt fusion joining of pipe and fittings shall be performed in accordance with the procedures recommeneded by the manufacturer. The temperature of the heater plate should be between 400°F and 450°F. Follow the recommendations of ASTM D2657 regarding interfacial pressures for pipe wall thickness less than or equal to 1.5". Follow the manufacturer's recommendations regarding interfacial pressures for pipe walls thicker than 1.5".

Polyethylene pipe may be connected to fittings or other piping systems by means of a flanged assembly consisting of a polyethylene flange adaptor or stub end, and a metal backup ring that has a bolting pattern meeting the dimensional requirements of Class 150, ANSI B16.1/B16.5 in sizes up through 24", and meeting Class 150 Series A, ANSI B16.47 or AWWA C207 Class B for larger sizes. Follow the manufacturer's recommendations regarding bolting techniques and the use of gaskets. Pipe or fittings may be joined by butt fusion only by technicians who have been trained and qualified in the use of the equipment.

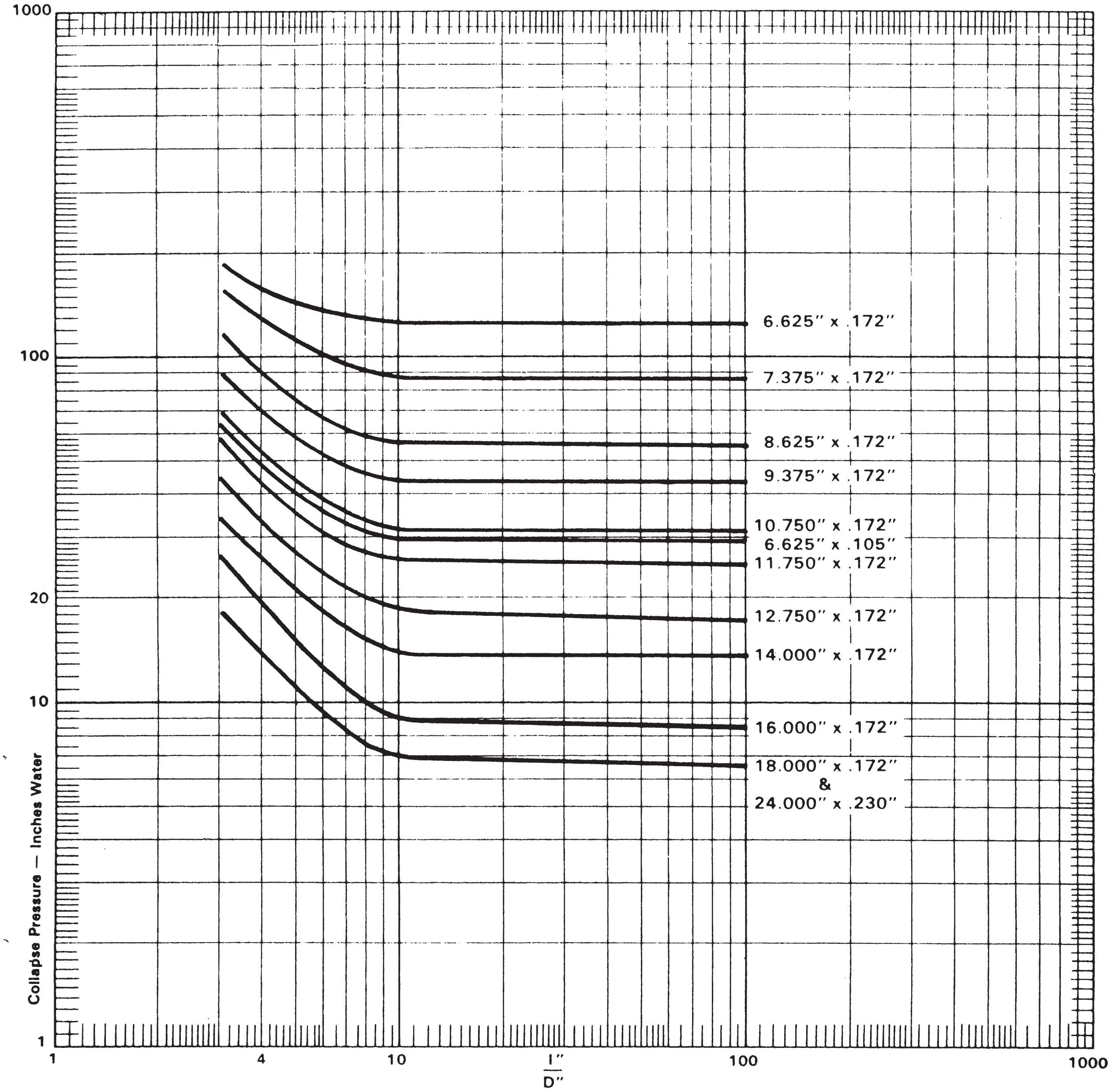
GENERAL REQUIREMENTS

The pipe manufacturer shall provide, upon request, an outline of quality control procedures performed on polyethylene system components.

FABCO PRODUCTS FABCO PLASTICS

Collapse Pressure - PVC Duct

Graph I: Calculated Collapse Pressures with Safety Factor of 5, FABCO Type I Grade I PVC Seamless Duct (minimum wall) @ 70-75° F vs Length of Span/Nominal O.D.



The Sheet Metal & Air Conditioning Contractors' National Association (SMACNA) sponsored a physical testing program on both rectangular and round Type I Grade I PVC fabricated duct, as well as a theoretical analysis of the test work. Equations were developed for collapse pressures of varying I/D ratios (I = distance between reinforced stiffeners (inches) and D = OD (inches)) as well as for collapse of a very long tube. Round duct sizes ranged from 18″ O.D. to 48″ O.D. with wall thicknesses of .137″ to .282″. Test values correlated within a 10% range.

Fabco ran actual collapse tests on 4 sizes of extruded seamless duct from 6″ through 12″ with I/D ratios exceeding 10 which confirmed the values calculated from the very long tube equation. (Note: Collapse values for all sizes with ratios exceeding 10 approach values for a very long tube).

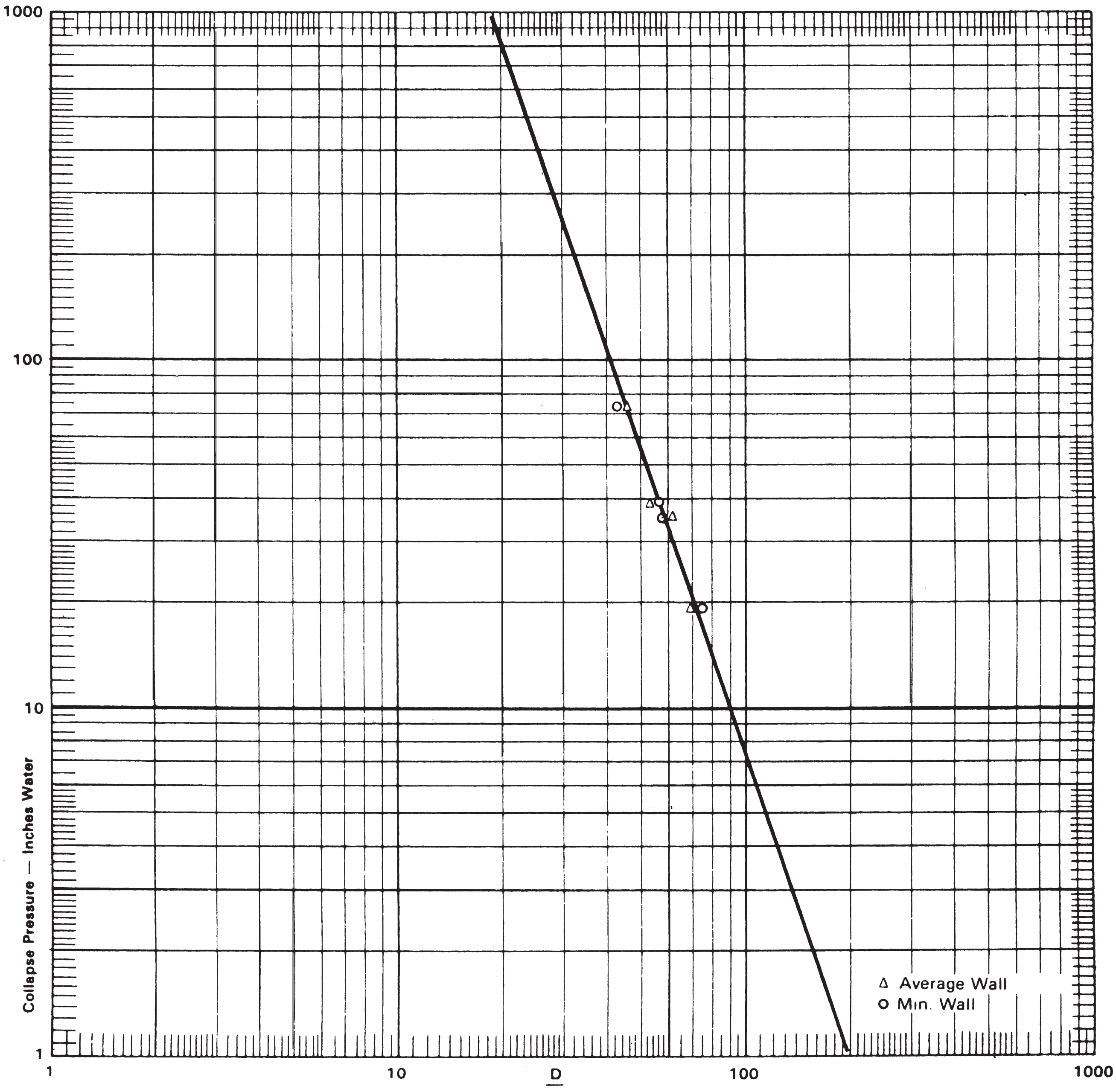
This graph can be utilized to determine reinforcement spacing distance for higher negative pressures than shown in the SMACNA publication(1) for the sizes and minimum wall thicknesses shown.

Example: 16″ duct at 20″ water I/D = 4

I = 16 x 4 = 64″ between reinforcing stiffeners.

(1) Thermoplastic Duct (PVC) Construction Manual, SMACNA

Graph II: Calculated Collapse Pressure with Safety Factory of 5, FABCO Type I Grade I PVC Seamless Duct @ 70–75°F vs Nominal O.D./Wall



This calculated collapse pressure graph with a safety factor of 5 for Type I Grade PVC duct has been experimentally confirmed for D/I ratios from 44-170. The 5-1 safety factor is believed to be sufficient for reasonable out of roundness due to storage and handling. Use of this graph for lower D/I ratios of Type I Grade I PVC pressure pipe should provide collapse pressures of greater than a 5-1 safety factor, since out of roundness will be appreciably less due to heavier walls of pipe produced under ASTM standards 1785 and 2241.

Use of minimum wall thicknesses as shown in Fabco's Specification for Duct and the ASTM Standards mentioned above are recommended when utilizing this graph for operating temperatures of 70° – 75° and below.Values of collapse pressures above 407" of water exceed a complete vacuum and should be considered as external collapse pressure. Conversion to PSI collapse pressure can be obtained by multiplying the inches of water by .0361; inches of water to inches of mercury by .07369.

Pump Data

I. STANDARDS FOR MEASURING HEADS AND CAPACITY.

Head is measured in feet, pounds per square inch (PSI), or in inches of mercury. However, so that a common means of head measurement is understood, it is recommended that all heads be expressed in feet of water. Measurement of liquid should be expressed in U.S. gallons.

II. ATMOSPHERIC PRESSURE.

At sea level it is 14.7 PSI. This will maintain a column of mercury 29.9 inches or a column of water 33.9 ft. high. This is the theoretical height of which water may be lifted by suction. The practical limit for cold water (60 F) is 25 feet.

III. SUCTION AND DISCHARGE HEAD.

Static Suction Lift – Is the vertical distance from the center line of the pump's suction inlet to the constant level of the water. This is added to discharge head to obtain total dynamic head.

Positive Suction Head – Is the vertical distance above the center line of the pump's suction to the constant level of the water. This is subtracted from the discharge head to obtain total dynamic head.

Dynamic Suction Head – Is the suction lift (or head) plus suction line friction loss. May be positive or negative.

Static Discharge Elevation – Is the vertical distance from the pump's discharge to the highest point in the discharge line.

TDH (Total Dynamic Head) – Is the total head and is the total of static suction lift (head), friction loss in suction line, static discharge elevation, friction loss in discharge line and fittings, plus discharge pressure, if any. To be hydraulically correct, we should not include "Static Head" in total dynamic head. Dynamic means "moving" and "Dynamic Head" only includes velocity head and friction loss. However, most pump people use TDH interchangeably with TH (Total Head).

Friction Head – Is the heat loss experienced by the movement of the liquid through the suction and discharge lines. Charts are available showing loss in feet of head at various flows through various pipe or hose sizes. Charts also show velocity in feet/sec, which is particularly important when pumping liquids with solids in suspension. Fittings, valves, etc. must be considered.

IV. NPSH.

Net Positive Suction Head is defined as head that causes liquid to flow through the suction line and enter the impeller eye. This head comes from either atmospheric pressure or from a static suction head plus atmospheric pressure. Two types of NPSH will be considered.

Required NPSH – Is a function of pump design. It varies between different makes, between different models, and with capacity of any one pump. This value is supplied by the manufacturer, if available. Refer to pump curves or contact the factory.

Available NPSH – Is a function of the system in which pumps operate. Can be calculated for any installation. For a pump to operate properly, available NPSH should be greater than the required NPSH, plus 2 feet for safety factor, at a desired head and capacity. In simple terms, available NPSH is calculated by deducting from barometric pressure, in feet, the static suction head (+ or -), friction loss, and the vapor pressure (ft.) of liquid being pumped. Velocity heads should also be deducted.

NPSH does not indicate the priming capabilities of self-priming centrifugal pumps. This capability is shown, generally on engine driven pumps, by respective "break-off" lines representing 10, 15, 20, 25' static suction lifts.

V. USEFUL FACTORS OR FORMULAS.

a) Feet head x .433 = PSI (pounds per square inch).

b) PSI (water) x 2.31 = Ft. Head

c) Specific gravity of water (sp.gr.) = 1.0.

d) PSI (water) x 2.31/sp.gr. = Ft. Head

e) Weight of one U.S. gallon of water = 8.33 pounds

f) One cubit foot (cu.ft.) of water contains 7.48 gallons.

g) GPM = Gallons Per Minute.

h) Imperial gallon x 1.2 = U.S. gallon; U.S. GPM x .833 = Imp. GPM.

i) TDH = Total Head or total dynamic head.

j) WHP = Water Horsepower.

k) BHP = Brake Horsepower.

I) EFF = Pump Efficiency.

m) WHP = Ft .Head x GPM/3960

n) BHP = WHP/EFF or BHP = Ft. Head x GPM/3960 x EFF (Pump)

o) EFF = WHP/BHP x 100

p) For liquids having different specific gravity other than 1.0.

WHP = Ft. Head x GPM x sp.gr./3960

BPH = Ft. Head x GPM x sp.gr./3960 x EFF

BHP (for liquids other than water)

= BHP (for water) x sp.gr.

VI. EFFECT ON CENTRIFUGAL PUMPS ON CHANGE OF SPEED OR CHANGE OF IMPELLER DIAMETER.

Three rules govern the operation of centrifugal pumps:

a) Capacity varies directly with changes of speed or of the impeller diameter.

GPM1/GPM2 = RPM1/RPM2

or GPM1/GPM2 = Dia.1/Dia.2

GPM2 = GPM1/RPM1xRPM2

and GPM2 = GPM1/Dia.1xDia.2

b) Head varies as the square of the speed or the impeller diameter.

Head1/Head2= RPM12/RPM22
or Head1/Head2 = Dia.12/Dia.22
Hd2 = Hd1/RPM12/RPM22
and Hd2 = Hd1/Dia.12 /Dia.2

c) Power (BHP) varies as the cube of the speed or impeller diameter

BHP1/BHP2 = RPM13/RPM13
or BHP1 = Dia13/Dia23
BHP2 = BHP13/RPM13xRPM23
and BPH2= BHP13/Dia.13xDia23

VII. EFFECT OF ALTITUDE ON PUMPS

At elevations above sea level, suction lift should be reduced accordingly to insure that the same amount of water can get into the pump as would occur at an equivalent sea level lift. Lower atmospheric pressure reduces horsepower output of gas engines, thus causing a drop in speed which reduces pump performance. Enginepower will decrease 3.5% for each 1000 ft. above sea level and 1% for each 10°F above standard temperature at 60°F.

ATMOSPHERIC PRESSURE CONDITIONS ELEVATIONS ABOVE SEA LEVEL				
Altitude Above Sea Level	Atmospheric Pressure Pounds/ sq.in.	Barometer Reading Ins. of Mercury	Equivalent Head or Water, Ft.	Reduction to Max. Practical Dyn.Suction Lift
0	14.7	29.929	33.95	0 ft.
1000	14.2	28.8	32.7	1.2″
2000	13.6	27.7	31.6	2.3″
3000	13.1	26.7	30.2	3.7″
4000	12.6	25.7	29.1	4.8″
5000	12.1	24.7	27.9	6″
6000	11.7	23.8	27.0	6.9″
7000	11.2	22.9	25.9	8″
8000	10.8	22.1	24.9	9″

VIII. GUIDELINES FOR PUMPING WARM WATER

MAXIMUM PRACTICAL DYNAMIC SUCTION LIFTAND VAPOR PRESSURE

WATER CHARACTERISTICS				
Altitude Above Sea Level	Atmospheric Pressure Pounds/ sq.in.	Barometer Reading Ins. of Mercury	Equivalent Head or Water, Ft.	Reduction to Max. Practical Dyn.Suction Lift
0	14.7	29.929	33.95	0 ft.
1000	14.2	28.8	32.7	1.2″
2000	13.6	27.7	31.6	2.3″
3000	13.1	26.7	30.2	3.7″
4000	12.6	25.7	29.1	4.8″
5000	12.1	24.7	27.9	6″
6000	11.7	23.8	27.0	6.9″
7000	11.2	22.9	25.9	8″
8000	10.8	22.1	24.9	9″

IX. EFFECT OF SPECIFIC GRAVITY

The specific gravity of a substance is the ratio of the weight of a given volume to the weight of an equal volume of water at standard conditions.

1. A centrifugal pump will always develop the same head in feet no matter what the specific gravity of the liquid pumped; however, the pressure (in pounds per square inch) will be increased or decreased in direct proportion to the specific gravity.
2. The brake horsepower (BHP) of a pump varies directly with specific gravity. If the liquid has a specific gravity other than water (1.0), multiply the BHP for water by the sp.gr. of liquid handled.

X. VISCOSITY

The viscosity of a fluid is the internal friction or resistance to motion of its particles. The coefficient of viscosity of a fluid is the measure of its resistance to flow. Fluids having a high viscosity are sluggish in flow, for example: heavy oil or molasses. Liquids such as water or gasoline have relatively low viscosity and flow readily. Viscosity is a fluid property independent of specific gravity. Viscosities vary with temperature; as temperature increases, viscosity decreases. Pressure changes have negligible influence on viscosity. There are many types of viscometers and expressed in many terms. Commonly used is SSU (Seconds Saybolt Universal). This is actually the time in seconds required for a given quantity of fluid to pass through a standard orifice under standard conditions. Viscous liquids tend to reduce the capacity, head, and efficiency, and increase the BHP.

Kinematic Viscosity (in Centistokes)
= Absolute Viscosity (in centipoise)/Specific Gravity
Centistrokes = SSU/4.64

This is an approximation for Viscosities greater than 250 S.S.U.The approximated performance for pumping fluids more viscous than water is determined from the following formula:

BHPvis = Qvis X Hvis X S.G./3960/Evis

HOW CENTRIFUGAL PUMPS WORK

Liquid is supplied to the inlet at the center of the pump head. Since centrifugal pumps are not self-priming, liquid must be supplied by gravity feed or the pump must be primed. The spinning impeller propels the liquid outward by centrifugal force, providing the motive force required to move the liquid. The specially shaped volute receives the liquid and converts the radial motion to a smooth pulseless flow. Easily adjust the flow rate by restricting the flow at the outlet.

CENTRIFUGAL PUMP TERMS

IMPELLER – A rotating vaned disck that provides the pumping force.

VOLUTE – The body of the pump that is shaped to receive liquid from the inlet and direct it through the outlet.

Liquid Pump Terminology

HEAD – The ability of a pump to push a column of water vertically in a pipe. As the column lengthens, the flow rate decreases until the column's weight just balances the pump's force and there is no flow. This height is the total head (usually expressed as feet of head).

FLOW RATE – Usually expressed in gallons per minute (GPM) for large-volume pumps; in gallons per hour (GPH) for small-volume pumps.

DYNAMIC SEAL – Seal located at the shaft end of the pump drive.

HECK VALVE – Allows liquid to flow in one direction only. Generally used in discharge line to prevent reverse flow.

DEAD HEAD – Ability of a pump to continue running without damage when discharge is closed off. Only recommended with centrifugal pumps.

DENSITY (specific weight of a fluid) – Weight per unit volume, often expressed as pounds per cubic foot or grams per cubic centimeter.

FLOODED SUCTION – Liquid flows to pump inlet from an elevated source by means of gravity. Recommended for centrifugal pump installations.

FLOW – A measure of the liquid volume capacity of a pump. Given in gallons per hour (GPH), gallons per minute (GPM), liters per minute (I/min), or milliliters per minute (ml/min).

FLUIDS – Include liquids, gases, and mixtures of liquids, solids, and gases. For the purposes of this catalog, the terms fluid and liquid are both used to mean a pure liquid or a liquid mixed with gases or solids that acts essentially like a liquid in pumping applications.

FOOT VALVE – A type of check valve with a built-in strainer. Used at point of liquid intake to retain liquid in system, preventing loss of prime when liquid source is lower than pump.

HEAD – A measure of pressure, expressed in feet of head for centrifugal pumps. Indicates the height of a column of water being moved by the pump, assuming negligible friction losses.

PRESSURE – The force exerted on the walls of a container (tank,,pipe etc.) by a liquid. Normally measured in pounds per square inch (psi) for positive displacement and metering pumps.

PRIME – A charge of liquid required to begin pumping action when liquid source is lower than pump. May be held in pump by a foot valve on the intake line, or by a valve or chamber within the pump.

SEAL – A device mounted in the pump housing and/or on the pump

shaft, to prevent leakage of liquid from the pump. There are three types:

1. LIP – A flexible ring (usually rubber or similar material) with the inner edge held closely against the rotating shaft by a spring.
2. MECHANICAL – Has a rotating part and a stationary part with highly polished touching surfaces. Has excellent sealing capability and long life, but can be damaged by dirt or grit in the liquid.
3. PACKED – Multiple flexible rings mounted around the pump shaft and packed together by tightening gland nuts; some leaking is essential for lubrication.

RELIEF VALVE – Usually used at the discharge of a positive displacement pump. An adjustable, spring-loaded valve opens when a preset pressure is reached. Used to prevent excessive pressure buildup that could damage the pump or motor.

SEALLESS (MAGNETIC DRIVE) – No seal is used; power is transmitted from motor to pump impeller by magnetic force.

SELF-PRIMING – Refers to pumps that draw liquid up from below pump inlet (suction lift), as opposed to pumps requiring flooded suction.

SPECIFIC GRAVITY – The ratio of the weight of a given volume of liquid to the same volume of pure water. Pumping heavier liquids (specific gravity greater than 1.0) will require more drive horsepower.

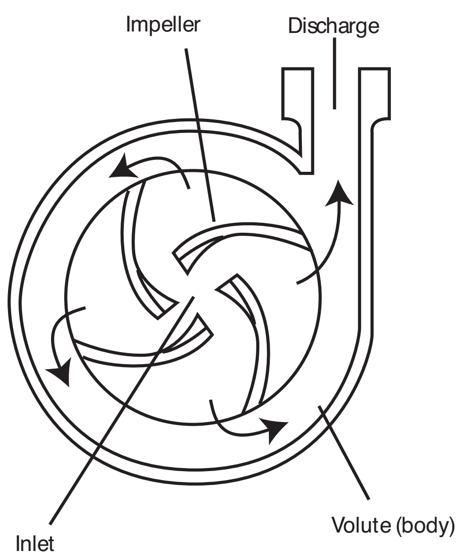
STATIC DISCHARGE HEAD – Maximum vertical distance (in feet) from pump to point of discharge with no flow.

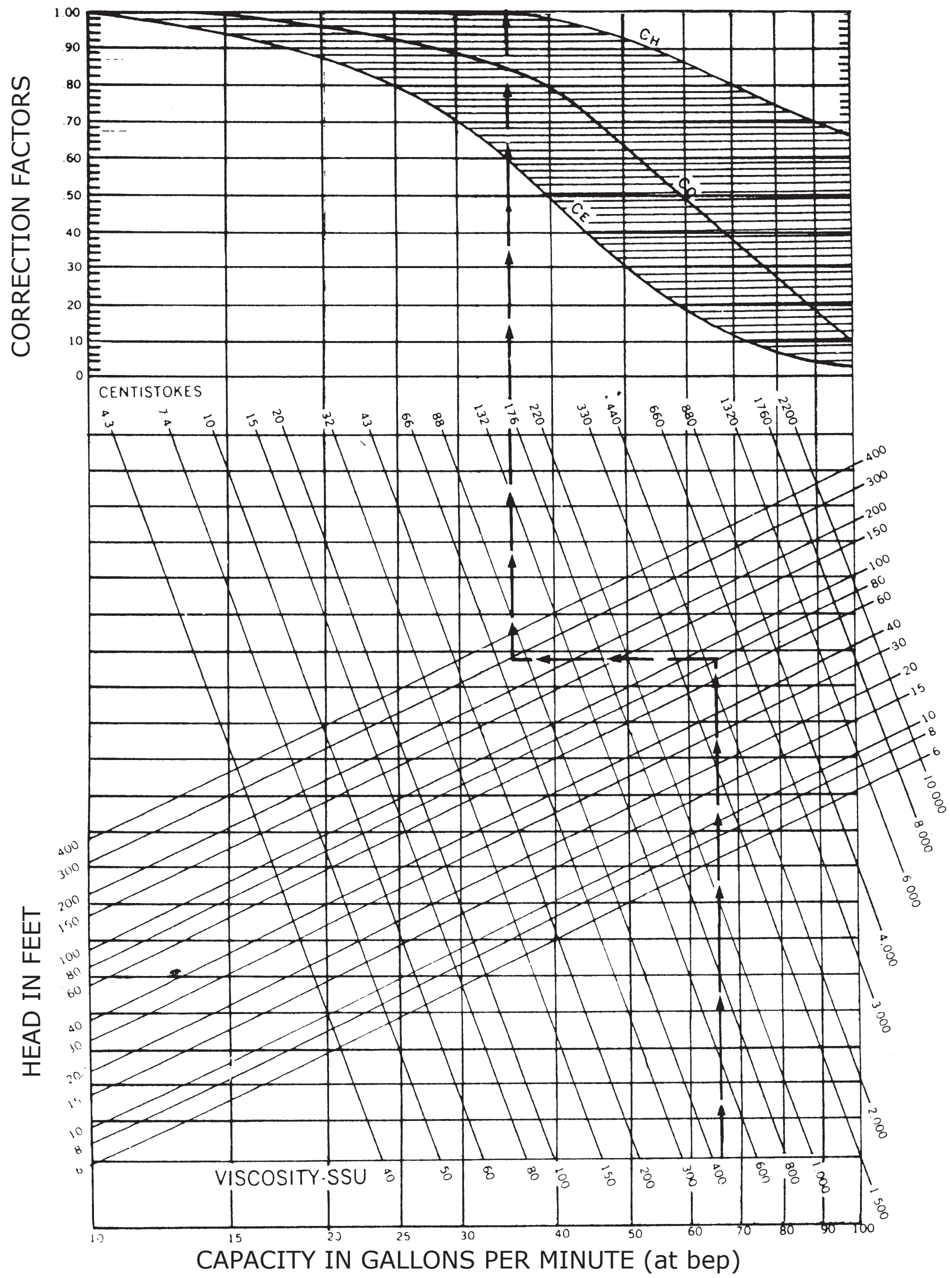
STRAINER – A device installed in the inlet of a pump to prevent foreign particles from damaging the internal parts.

SUMP – A well or pit in which liquids collect below floor level sometimes refers to an oil or water reservoir.

TOTAL HEAD – Sum of discharge head, suction lift, and friction loss.

VISCOSITY – The "thickness" of a liquid, or its ability to flow. Most liquids decrease in viscosity and flow more easily as they get warmer.





VISCOSITY CORRECTION CHART

Example - Viscosity

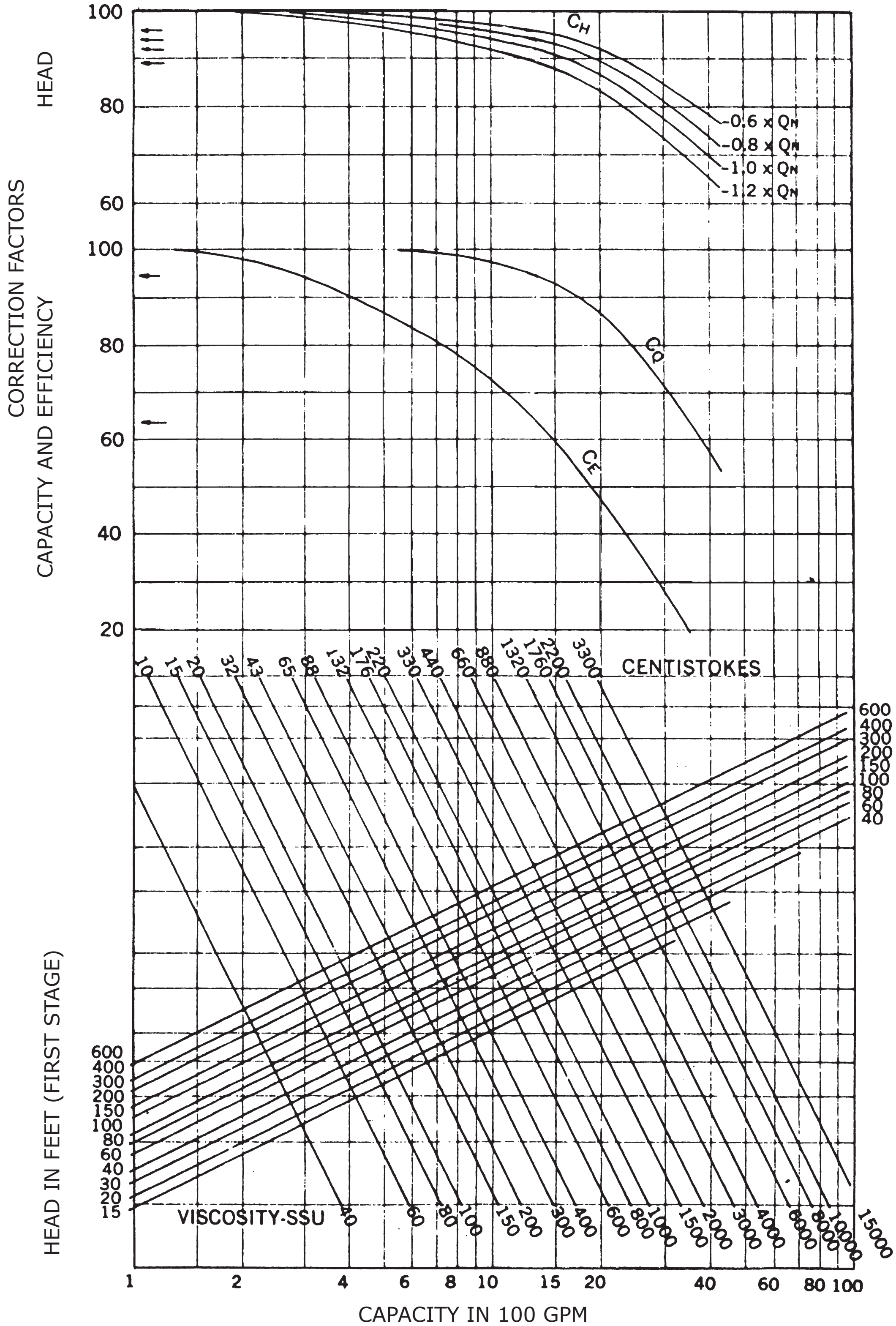
Determine BHPvis when pumping 66 usgpm at 80 ft. of 50% NaOH with a pump at 48% Eff. with water.

*S.G. = 1.53 *Given from other tables
*Visc = 78cSt = 120 CP/1.53
Qw = 66 usgpm
H.W. = 80 ft.
E.W. = 48% = .48
Cq = .84)
Ch = 1.00) From above chart
Ce = .58
Qw x Cq = 66 x .84 = 55.44
Hw x Ch = 80 x 1.00 = 80.0
Ew x Ce = .48 x .58 = .2784
BHPvis = 55.44 x 80.0 x 1.53/3960/0.2784 = 6.16 H.P.

WHERE

BHPvis = Viscous brake horsepower
S.G. = Specific Gravity
3960 = Constant
Qw = Capacity pumping water (USGPM)
Cq = Capacity correction factor (Fig 1)
Qvis = Viscous Capacity (USGPM) = Cq X Qw
Hw = Head pumping water (ft.)
CH = Head correction factor (Fig 1)
Hvis = Viscous head (ft) = Ch X Hw
Ew = Efficiency pumping Water
Ce = Efficiency correction factor (Fig 1)
Evis = Viscous Efficiency = Ce X Ew
BHPvis = (cq X Qs) X (Hw X Ch) X S.G./3960/Ce/Evis

PERFORMANCE CORRECTION CHART



Conversion Factors

- PHYSICAL DIMENSIONS - VOLUME

U.S. CUSTOMARY UNITS					S.I. UNIT	OTHER METRIC UNIT
cubic Inch (in.^{3})	US gallon (US gal)	Imp.gallon (Imp gal)	cubic foot (ft.^{3})	barrel* (bbl)	cubic meter (m^3)	liter (l)
1	0.00433	0.00360	0.000579	0.000103	0.00001639	0.01639
231	1	0.8327	0.1337	0.0238	0.003785	3.785
277.42	1.2009	1	0.1606	0.0286	0.004546	4.546
1728	7.481	6.229	1	0.1780	0.02832	28.32
9702	42	34.97	5.615	1	0.15897	158.97
61.024	264.17	220	35.31	6.2898	1	1000
61.024	0.2642	0.2198	0.0353	0.00630	0.001	1

*By trade custom, one barrel petroleum oil is equal to 42 US gal.

CONVERSION TABLE - CAPACITY

U. S. CUSTOMARY UNITS					S.I. UNIT	OTHER METRIC UNITS	
Millions of US gallons per day (MGD)	US gallons per min (gpm)	Imp. gallons per min (lgpm)	cubic feet per sec (cfs)	*barrels per hr (bph)	cubic meters per sec (m3/s)	liters per min (l/min)	cubic meters per hr (m3/hr)
1	694.4	578	1.547	992	0.0438	2628	157.72
0.00144	1	0.8327	0.002228	1.4286	63.08×10^{-6}	3.785	0.2271
0.00173	1.2009	1	0.00268	1.7156	75.77×10^{-6}	4.5454	0.2728
0.64636	448.86	373.8	1	641.23	2.832×10^{-2}	1699	101.952
0.00100	0.7000	0.5829	0.00156	1	44.166×10^{-4}	2.6495	0.1590
22.824	15.852	13.188	35.316	22.643	1	60.000	3.600
0.000380	0.2642	0.2198	0.000586	0.3774	16.67×10^{-6}	1	0.0600
0.00634	4.4028	3.666	0.00981	6.2898	2.777×10^{-4}	16.667	1

*By trade custom, one barrel petroleum oil is equal to 42 US gal.

gpm = $\frac{0.1247}{w}$ x lb/hr when w = density, lb/cu ft

CONVERSION TABLE-MASS, WEIGHT AND FORCE

Definitions:

1. Mass is absolute, the pound (lb) and kilogram (kg) are most commonly used units, the kilogram is the SI unit.

U.S. CUSTOMARY UNITS (avoirdupois)					S.I. UNIT	OTHER METRIC UNITS	
grain (gr)	ounce (oz)	pound (lb)	short ton	long ton	kilogram (kg)	gram (g)	metric ton
1	0.002286	-	-	-	-	0.0648	-
437.5	1	0.0625	-	-	0.02835	28.35	-
7 000	16	1	-	-	0.4536	453.6	-
-	-	2 000	1	.8929	907.2	-	0.9072
-	-	2 240	1.12	1	1016	-	1.016
15 432	35.27	2.205	-	-	1	1 000	0.001
15.432	0.03527	0.002205	-	-	0.001	1	-
-	-	2205	1.102	0.9842	1000	1 000 000	1

CONVERSION TABLE-POWER

U.S. CUSTOMARY UNITS			S.I. UNIT	OTHER METRIC UNITS	
foot-pounds per sec. (ft-lb/sec)	horsepower (hp)	British thermal units per sec (Btu/sec)	watts (W)	kilowatts (kW)	metric horsepower
1	0.00182	0.001285	1.356	0.001356	0.00184
550	1	0.7068	7.457×10^2	0.7457	1.014
778.2	1.415	1	1.055×10^3	1.055	1.434
0.7376	1.341×10^{-3}	9.478×10^{-4}	1	0.001	0.00136
737.6	1.341	0.9478	1000	1	1.360
542.5	0.9863	0.6971	7.355×10^2	0.7355	1

CONVERSION TABLE-PRESSURE

Units and symbols:

pounds per square inch (psi)
pascal (Pa) = 1 N/m (SI unit)
kilograms per square centimeter (kg/cm)
bar

1 psi = 0.0703 kg/cm^2 = 6894.76 N/m^2 = 6.894 kPa
1 kg/cm^2 = 14.22 psi = 9.80665×10^4 N/m^2 = 98.0665 kPa
1 atmosphere = 14.7 psi = 1.0332 kg/m^2 = 10.13×10^4 = 101.3 kPa
1 metric atmosphere = 98.0665 kPa
1 pascal = 1.45×10^4 psi = 1.02×10^5 kg/cm^3
1 bar = 10^5 Pa = 100 kPa