PVC PIPING SYSTEMS

Helpful Tips for Avoiding Problems

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Preface

The information in this book is the culmination and cooperation of manufacturer representatives who unselfishly work to improve their products for greater user experience with PVC piping. As the author, I was able to combine information the PVC pipe and fitting industry has assembled, gained and developed over the past decades. Many of the topics included have been shared, sometimes preached, by those who have preceded this document. Some topics may be new enough that this may be first time you have read about them.

I wish to express my thanks to the Plastic Pipe and Fittings Association, Terry McPherson, Jack Roach, IPS Corp., and LASCO Fittings for their assistance and indulgence during the development of this book.

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Failures

When things go wrong it is important to fix the failure, but it is even more important to find the cause. The cause most times is not simply a defective part, but more often the effect of another problem. Good design practice is to incorporate piping and fittings with a reasonable service factor for system reliability. As an example, pipe with a pressure rating of 200 psi, should not be used in a system with a 175 psi working pressure. System pressure needs to include both static and expected surge pressure.

When systems have repeated failures it may take some extensive investigative analysis of the entire installation to find the cause. Many times the closeness of the failures to each other could show the existence of pressure surges, or water hammer. It could be the consequence of the system installation, revision or repair at a different time than the rest of the site. In above ground piping, exposure to the ambient conditions could encroach on the life or service factor of the system.

The recent changes to a system, such as expansion or revision, have many times had a direct connection with system failures. Experience has shown that the increased flow rates, entrapped air from system restart have been the culprit in more than a few installations. These failures like those mentioned above tend to be clustered, but not necessarily in the new part of the system. Often the older piping suffers the damage because of these revisions.

A comprehensive check of the system operational modes, including cycle time, pressure surge frequency and amplitude can provide valuable information in finding the cause of piping failures. The use of most pressure recorders although helpful, cannot provide precise data on the damaging effects of pressure surges, air slugs or water hammer. In these cases the unusually high pressure spike the system experiences is of such short duration, milliseconds, that the recording mechanism cannot react quickly enough to record its peak. The pressure peak travels through a PVC system at roughly 1400 ft/sec. so the recorder only sees it for 0.7 milliseconds. Before and after the pressure spike, the system pressure would be close to normal and only a small “blip” would have been recorded, with the amplitude many times removed from the true value.

A simple but often overlooked piece of evidence in tracking the source of a failure is to go over all the failed components to look for similarities. On more than one occasion a manufacturer has been accused of a defective product only to have a group of components of differing brands or configurations on the same system failing. The common denominator would likely be the system and not the manufacturer.

Any failure that is the result of external stress or loads will reoccur if the stress is not removed. If you need to install extra supports or restraints to remove the external stress, make sure you do it before making repairs. With external failures, a crack or break will progress from the outside of the pipe or fitting toward the interior.

A simple method can help you decide if a failure is external. Try to open the crack or make it wider. This will show where the external loads were applied. It is also important to know that cracks and splits are perpendicular to the producing load. For example when paper is torn, pulling horizontally causes it to tear vertically. Each has a set of characteristics that can be used to help find the source of the problem.

Causes of failures in PVC systems:

- ♦ Short Term (Burst)
  - Hydrostatic (Liquids)
  - Pneumatic (Air/Gas)
- ♦ Long Term Failure
- ♦ Surge (Water Hammer)
  - Air Slugs/Entrapped Air
- ♦ Cyclic (Fatigue)
- ♦ Freeze
- ♦ Mechanical
  - Bending
  - Flange Installation
  - Over tightened threads
- ♦ Solvent Welding

Short Term (Burst) Failure

The failure of a pipe or fitting from exceedingly high pressure over a short period, usually defined as less than a minute, would be classified as a burst or short term failure. The more common evidence for these failures is sharp edged cracks and fragments, similar to glass. If these fragments are not contained or entrapped during the failure they can be dangerous. This is the foremost reason that PVC piping and fittings are NOT to be used to transport or to be tested with compressed air.[i]

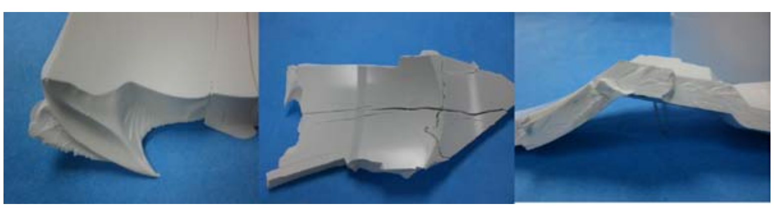


Figure 1: Typical burst or short term failure

A short term or brittle failure shows no visible, to the naked eye, material deformation, stretching, elongation or necking down close to the break.[ii]

Air

Except under very special circumstances, PVC piping is not to be tested or used with compressed air or gases.[iii] The catastrophic failure of a PVC air assembly, with its sharp shrapnel pieces is dangerous, and can be deadly. Water and most liquids are not compressible, but air and gases are. The potential energy stored in a compressed air piping system at about 100-psi has propelled sharp edged fragments hundreds of feet in all directions.

Because a compressed air failure is almost instantaneous, the failure surfaces are reminiscent of brittle and freeze type failures. Cracks or breaks are somewhat straight with tributaries that merge and create sharp edges.

Long Term Failure

A fitting or pipe that has failed from exposure to high pressure over a long time will not generally shatter. The failure will show evidence of stretching or deformation especially at the extremes of any crack or split.

Figure 2: Classic long term failure

Generally, a magnified examination of the failure will show material that has tapered off-shoots, whitened surface or "stretch marks" (a necked down cross section) past the end of the crack. (See figure 2.)

Long term failures are most commonly found in the high stressed areas of a fitting, such as the inside corner or "crotch" of an Elbow or Tee. A long term failure shows material deformation, stretching, elongation or necking down, along the edges of the crack. [iv]

Surge (Water Hammer)

There are many similarities between surge pressure and short term failures. In most instances the part breaks down after repeated exposures to high and short duration pressure applications. The repetitive surges tend to significantly degrade directional fittings considerably more than pipe or couplings. The failures tend to appear first in the high stress areas or crotch of Tees and Elbows. A simple vector analysis shown in Fig. 3 suggests that the stress in the crotch of an elbow (or tee) is 1.4 times that found in the body of the fitting. This simple vector analysis is conservative and does not consider the extra stress of outward bulging that is clear in 3D vector analysis, Finite Element Analysis (FEA) and laboratory testing. Some industry testing has shown that the stress in the crotch area of a 90-degree elbow, or Tee to be about 2.8 times the stress of the rest of the fitting.

Differences in the design, configuration, dimensions or special working conditions of a fitting will lead to deviations in the stresses applied. It is the responsibility of the user to conduct tests to assure suitability of the fitting for each purpose.

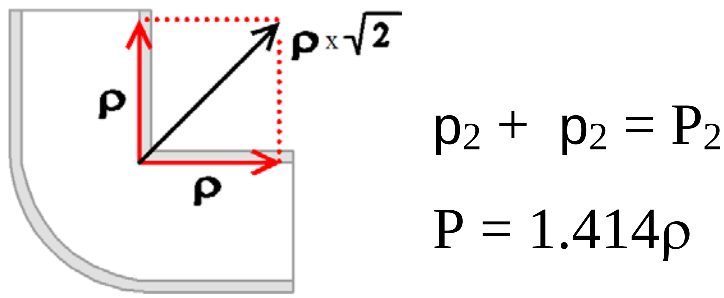


Figure 3: Vector representation of stress in crotch.

So, with the extraordinarily high surge pressure a system experiences, the crotch of a Tee or an Elbow could sense a force that is about 2.8 times greater than the body of the same fitting. Wye fittings have even higher stresses applied in the crotch (estimates upwards of 3.5 times the stress in the body).

A pocket of air within a piping system can create the same shock pressure as water hammer. Air pockets occur from improper design, system filling or undulating terrain.

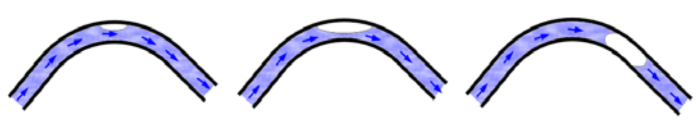


Figure 4: Air pocket in pipe line

As air separates from the liquid, a bubble or air slug slowly builds creating a restriction. This restriction in turn creates an increase in velocity directly underneath the air pocket. Once the air pocket reaches a critical size it is swept downstream leading to high fluid velocities where none existed before. To prevent this scenario the system design needs to accommodate the ability to remove air from high points in a system. Water has a density about 800 times of air. Because of this, and its smaller molecular size (compared to a molecule of water), air can be expelled through an opening, nozzle or spray head several times faster than water. The actual difference in velocity depends on several factors but a rough estimate is 10 times faster. This means that the velocity of water behind a slug of air moving thru a system can be about 10 times faster than just water moving thru a system with no air slugs. When the last of an air pocket or slug of air is expelled thru an orifice the moving water is decreased in velocity by 10 times almost instantaneously as it seeks unsuccessfully to move thru the same orifice. This rapid change in fluid velocity creates a large pressure surge or water hammer condition.

Cyclic Fatigue

Similar to surge, cyclic failures are a result of material fatigue from a high number of repeated pressure cycles. Each time a PVC fitting is pressurized or the system pressure increases the high stressed areas stretch slightly. This causes tensile stress, or stretch, in the crotch of tees and elbows. Piping and fittings are designed to withstand pressure fluctuations if they are limited, both in strength and quantity. But, high amplitude and/or quantity can cause the pipe or fittings

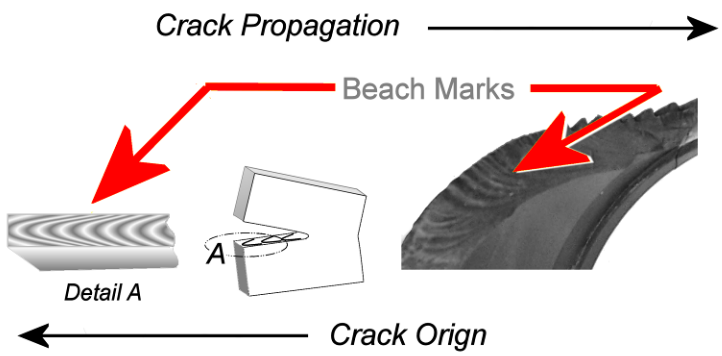


Figure 5: Beach or clamshell marks.

to fail prematurely. The "stretch marks" found along the edge of the break along with "clamshell marks" or "beach marks" on the internal fracture surface are evidence of cyclic failure propagation.[v]

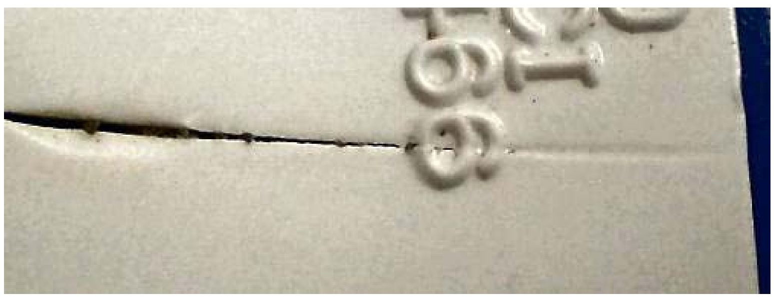


Figure 6: Stretch mark at end of a crack.

Freeze

Water expands when it freezes. PVC, as do most materials, becomes brittle as the temperature is lowered. So, when PVC fails from entrapped frozen water; the break surfaces and cracks are brittle in appearance and give an appearance much like shattered glass.

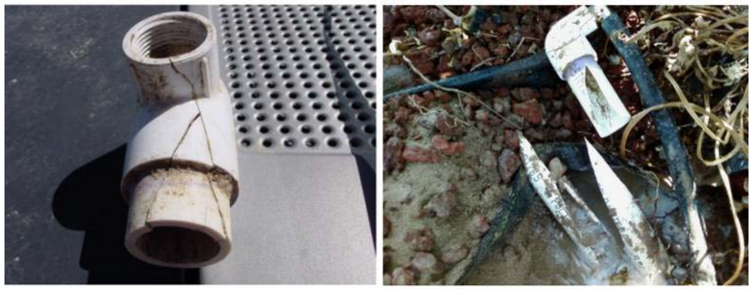


Figure 7: Breaks due to freezing water

Mechanical

There are two common causes of mechanical breakage in PVC piping systems. The bending, or vibration, and the over tightened threaded connection. The bending or vibration failure starts on the outer surface of the part, and progresses inward. This distinguishes it from the other forms.

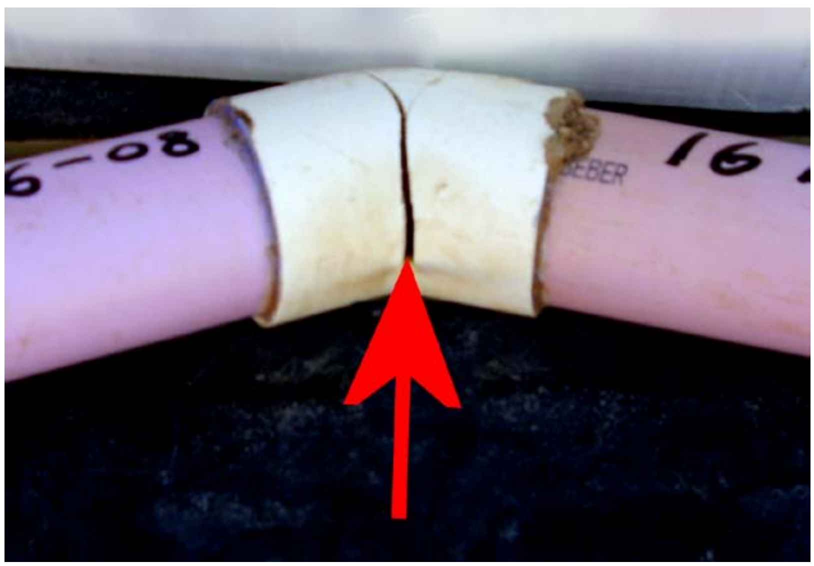


Figure 8: Break due to mechanical load.

In the hands of a plastics failure expert, the fracture surface will have clues not only of the origin site of the failure but will also tell the expert the "how" or "what" caused the failure. Many times it is possible to find the orientation of external load by carefully fitting the pieces together and observing the fit and distortion of the failure area. This should not be attempted by a novice, as surface features unique to the failure may be lost due to the relatively soft surfaces coming together and smearing the fracture surfaces.

Because many of the mechanical failures are caused by vibration, the crack and fracture surface is similar to that of a cyclic fatigue, except its orientation. Cyclic fatigue with a hydraulic source will start on the interior of the pipe or part. The mechanical failure will start on an exterior surface. Male pipe threads, such as found in the male adapter, are the most common examples of a vibration fatigue failure.

Figure 9: Vibration failure of male threads.

Because pipe threads are tapered, the material is the thinnest under the male threaded section at the first thread past the female threads. The trimmed down wall thickness within the thread segment of the PVC male threaded part becomes the focus of all bending loads induced from any system vibration or misalignment.

Split Female Threaded Parts

When tapered threaded parts are assembled and the PVC female threaded part splits, the most likely cause is from over-tightening. The failure of the female part with a crack that is parallel to the axis of the fitting identifies the cause as over tightening.

Figure 10: Over tightened connection caused the female adapter to split.

Many times the crack has progressed through the pipe and other parts, but its origin was in the threads. A crack or split is always oriented perpendicular to the causing load. In these failures the male threads induced stress (stretch) to the female threads. Most materials, including PVC, are more tolerant to compressive, than tensile loads, leading to a split and a leaking joint.

Solvent Welding Failures

The solvent weld joint creates a chemical welding of the components resulting with a leak free connection. The use of correct equipment, procedure and chemicals are mandatory! Solvent weld failures fall into three general categories.

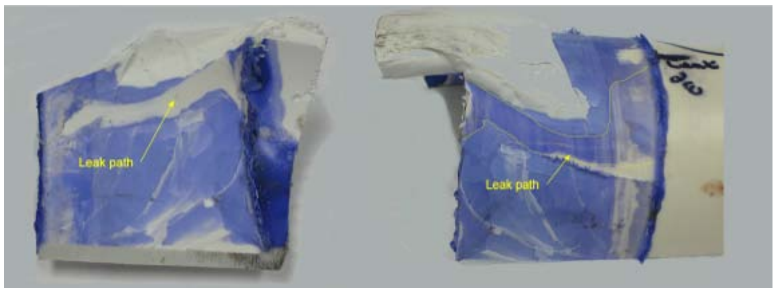


Figure 11: Insufficient cement resulted with a leak path.

The dry joint, is the result of solvent cement that has partly dried, either in the can or during the installation. The lack of sufficient solvent to create the fusion bond will have the consequence of a weak and/or leaking joint.

If a solvent joint is disturbed during the cure period then the fusion bond is broken and a leak is imminent. The cure time depends on the temperature, piping size, humidity and solvent cements used. It is important to follow the manufacturer's recommendations about the time necessary to allow the joint to set long enough for handling.

Figure 12: Assembly was moved during cure time.

Figure 13: Dry Joint, no fusion of pipe and fitting.

Too little solvent cement will produce what is known as a dry joint. The applicable standards from ASTM (American Society for Testing Materials) provide a slight taper in the socket diameter of all fittings. So, when the pipe and fitting are of ideal size the pipe will interfere with the tapered socket at about 1/3 to 2/3's of the socket depth. This provides a chemical fusion bond in the bottom third of the socket from the solvent cement. But the gap between the upper socket and pipe wall must be filled with solvent cement to assure a strong, leak-free joint. The lack of sufficient cement is obvious when a gap appears at the socket entrance around the pipe wall at the socket entrance.

Although there are many other styles of PVC pipe and fitting failures, the above examples show some of the more common that take place. It is always important to ask for assistance from the manufacturers of the piping, fitting, cement and appurtenances that fail. Their experience with their own products can provide the information needed to prevent more problems.

Materials

Is PVC the perfect material for all piping systems? Although the use of PVC piping is universal in many applications it is not to be recommended for all. The designer or installer must check all the circumstances the system is to experience before deciding.

PVC is not capable of withstanding high temperatures like metals, such as iron, copper and steel. Most plastics are recommended for cold water applications and must not be used in elevated temperature situations. PVC is not recommended where the working temperature of the system exceeds 140° F. (60° C). PVC pipe pressure ratings are based on working temperatures of 72° F (22° C). As the pipe temperature increases the pressure ratings of the system must be lowered. CPVC, a derivative of PVC, can safely handle system temperatures approaching boiling water or 210° F (100° C).[vi] The maximum pressure capability of CPVC is also based on temperatures of 73°F. As the CPVC pipe temperature increases the pressure ratings of the system must be lowered. Polyethylene or HDPE piping is more heat sensitive than PVC, generally 130º F (54° C) is its peak service temperature.[vii]

The strength of PVC, although it is about 10-15% that of steel, when compared to its lightweight, corrosion resistance, ease of assembly and lower pressure loss due to friction, make it the ideal choice in many applications. While the effects of many acids and compounds are common knowledge with metal pipes, PVC can handle inorganic concentrated and oxidizing acids superior to steel and HDPE. Organic acid anhydrides are also better handled in PVC piping.

Comparing PVC Pipe with Steel and HDPE			
Characteristic	**PVC**	**Steel**	**HDPE**
Solvent weld	Yes	No	No
Weight	81 lbs/ft^3	455.5 lbs/ft^3	59 lbs/ft^3
Chemical resistance	Excellent	Poor	Good
Flow coefficient	150	65 to 110	150
Modulus of elasticity	400,000 psi	29,000,000 psi	170,000 psi
Maximum service temperature	140° F	1,000° F	140° F
Tensile strength	7,000 psi	60,000 psi	4,600 psi
Maximum design stress	2,000 psi	20,000 psi	800 psi
Relative impact resistance (higher is better)	1	6	3
Coefficient of Thermal Expansion	3 x 10^{-5} in/in/°F	6.7 x 10^{-6} in/in/°F	9.0 x 10^{-5} in/in/°F

Table 1: Physical Properties [ix]

For exposed installations, above ground or within structures, the rigidity of PVC calls for less support brackets or structure than the more flexible HDPE. Along with its stiffness, PVC does not expand or contract as much as HDPE with temperature change. Many open trench installations are installed when the ambient temperatures are about 70° F (21° C); but when buried the normal ground temperature may be 50° F (10° C). This will mean that a 100 foot run of PVC pipe will contract by .72-inches, although the HDPE will shrink 2.20-inches. [viii] This contraction can lead to elevated stress on directional fitting, valves and other appurtenances.

The true test of a piping material is long term serviceability. Do the materials provide for an operational system during estimated life expectancy? Many of the first PVC piping was produced in 1940 and since that time, billions of feet and fittings have been installed worldwide. The successes of those installations, many in operations close to 50 years, have proven that PVC can be used with confidence when the system environment matches its properties. Irrigation, agriculture and turf are a few of the most common applications for PVC pipe and fittings. Also, there are many successful swimming pools, water features, residential irrigation and food processing operations in long term service using PVC.

Prevention and Cures

Cyclic Failures

Cyclic and surge failures are closely related in cause and outcome. When either is found in a system it is important to remove the cause as quickly as possible. Because water is almost not compressible, these pressure surges are sent throughout the pipes and fittings doing damage as they go.

As the surge wave travels down the pipe line there are two chief conditions controlling its strength. The piping material and duration of the velocity change. The more rigid the pipe material, the higher the resultant pressure spike; but softer material requires more time to change the flow velocity. In a 1,000 foot section of Schedule 40 piping, at 150 psi, with a flow velocity of 5 feet per second the critical velocity change time and pressure surge created is shown in the table below.

Material	Critical time	Surge Pressure	Valve Operation
PVC	1.4 sec	94 psi	5.6 sec
HDPE	2.3 sec	60 psi	9.2 sec
Cast Iron	0.5 sec	294 psi	2.0 sec

Table 2: Surge pressure and valve close time.

Note that we use critical velocity change time and not valve closing time. The most commonly used valves do not cut the flow rate evenly as they operate. In these valves most the flow rate is controlled during the last 25% of closing or the first 25% of opening operation. So, a good rule of thumb would be to use one-fourth of the valve operation time as the "Critical Close Time."

With repeat pressure surges, or water hammer, cyclic fatigue is to be expected. It is not just the peak pressure or the frequency, but the combination of both that is the villain. Let's use a paper clip to explain cyclic fatigue. If you make repeated right angle bends, the number of cycles needed to break the wire will be significantly less than if bent just a few degrees. Also, if the wire is bent many times in a short period, it will break much quicker than if bent once a day. These two conditions, frequency and amplitude of the pressure surges, are critical to the life expectancy of a piping system. Frequent high surges will drastically increase cyclic fatigue in the system.

Let's think about the same 2-inch PVC Schedule 40 system with a 150 psi working pressure, much like a typical golf installation. The pressure rating of the pipe is 280 psi. The pressure ratings of pipe have been developed by decreasing the long term design factor of PVC by 50-percent. Although the design factor is intended to reflect all the variables it is without consideration to conditions such as aggressive environments, cyclic stressing, localized stress concentrations, and temperature fluctuations.[ix]

Recommended design practice is to limit the sum of any surge pressure plus the working pressure to 100 percent of system pressure rating.

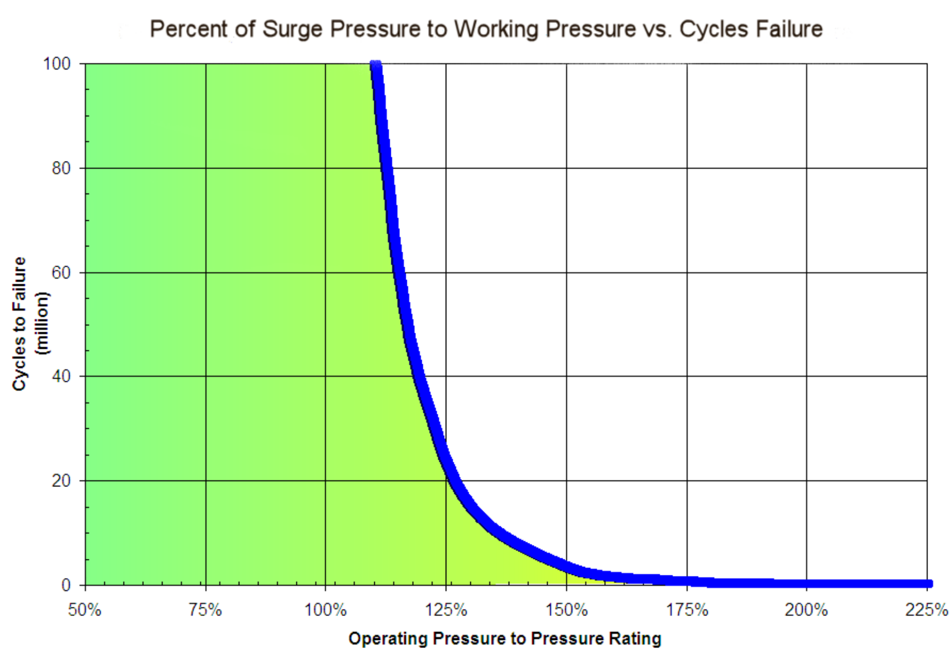
Directional fittings have extra loads induced because of their configurations, and it is imperative that designers and installers be aware of these for system longevity. Proper design of a PVC system is to assure the operating pressure, which is working pressure plus surge pressure, is lower than the pipe rating.[x] If there is a high frequency of pressure surges and/or the peak pressure exceeds the pressure rating of the pipe, higher rated pipe, fittings and appurtenances must be used.

PVC has a unique feature which allows it to handle short-term stress better than long term. Yet, with repeated surges taking the operating pressure above the pipe pressure rating, the cycles to failure must be taken into consideration.[xi] In the mid-80's R. D. Bliesner mentioned a study by H. W. Vinson that developed an empirical method in an effort to work out the cyclic surge life of PVC piping[xii]. However, later studies showed that more than surge pressure and the cycles influence the fatigue life of PVC, as the ultra-conservative Vinson method estimated.[xiii] This Uni-Bell study shows an intertwined relationship between the average system pressure, the peak surge pressure and the cycles to failure. The Uni-Bell study shows that the greater a variance between the average and the surge pressure, the shorter life expectancy of the system. A 50-year design life is expected, if the operating pressure, which is working pressure plus surge pressure, is less than the system pressure rating.

$$\mathbf{P_{(operating)} = p_{(surge)} + p_{(working)}}$$

Note that Schedule 40 and Schedule 80 fittings DO NOT have a pressure rating. These fittings have a wall thickness that is 25-percent heavier than the equal schedule and diameter pipe. For life cycle evaluation use the pressure rating of the same diameter and schedule pipe as the fittings. The Uni-Bell study can be used to estimate the harmful effect that surges and cycles have on PVC pipe and fittings. Figure 14 shows that when the operating pressure exceeded the pressure rating of the piping, the number of cycles before failure decreases rapidly. Surge pressure is added to the working pressure to get the operating pressure, which in turn is used to achieve a piping system service factor.

Figure 14: Predicted surge cycles to failure.



Controlling Cyclic Surges

There are multiple ways available to cut the surge pressure or spikes within a system. Surges and water hammer must be considered during the design of a system. The designer must also think about the potential of the end users operational modes, especially manual operation after repairs, or changes.

All components in a piping system that have been exposed to continual surge activity will be damaged. The first part to fail is the lowest rated part and only shows the tip of the iceberg. The rest of the pipe, fittings and apertures have been "bruised" or can be in position for failure upon replacement of the first to fail. It is important to remove the cause of surges to do away with future failures.

System flow velocity is the easiest and many times the least expensive method to control surges and water hammer effects. Often by increasing the pipe by one size during the design phase and by keeping the flow velocity under 5-feet per second the possibility of surges will be greatly reduced. For example, AWWA recommends surge allowance based on 2-feet per second flow velocity change.[xiv]

Large pressure swings, from pump starts and jockey pumps, have been cut over the recent years, thanks to variable speed pumps. These soft start/soft stop pump units have become a welcome improvement to the elimination of pressure surges.

Air pockets within piping systems need to be continuously watched. During a repair or at "Springtime Startup" recharging of water in the system needs a vigilant operator. Although in practice the admission of air is not without problems, most of the problems are found during the release of air, sometimes leading to pressure even higher than if air valves were not installed.[xv] It is often assumed that because air relief valves are installed into a system, all of the air will be removed. When a slug or bubble of air is traveling in a piping system, it generally travels at the water velocity. Air can escape through an opening or nozzle about 10-times faster than water. When the slug is expelled through a sprinkler nozzle, for example, the water behind it will increase in velocity by a factor of ten. When the air is expelled the velocity of the water is instantly slowed, causing a reflective surge pressure wave back through the system. A 100 foot length of 2-inch SDR-21 pipe has a 1,571 pound column of water and its momentum will create a 16 psi pressure surge for each foot per second of velocity change.

In the past decade most of the solenoid irrigation valves have been redesigned to cut the "slam" effect of their predecessors. Yet it is important for designers and installers to understand that a slower closing valve will not produce the surge wave of a faster valve. The solenoid valve works on a difference of pressure across a diaphragm mechanism to control the flow of water. When the valve is opened, there is a high differential pressure and the passage is opened quickly. But on the close mode, the high differential pressure is at the end of the valve operation. A good "rule of thumb" is to assume that 75-percentage of the flow velocity is removed in the last 25-percentage of the valve close time.

Freeze

PVC piping, like all plastics, becomes stiffer and more brittle with low temperatures. Damage from frozen water within a system is the most common problem associated using PVC for cold temperatures. If the water or liquid does not freeze, expansion does not take place and PVC can be effectively used. But, the expansion of water upon freezing comes during a phase change and the water crystallizes into an open hexagonal form. This hexagonal lattice needs more space than the liquid state. This increases its volume about 9%. The damaging phenomenon is that the water will freeze from the outside toward the middle.

First a frozen shell which contains the remaining water is created. Then microscopic fissures constantly crack, swell and refreeze exerting outward pressure on the container, or piping. When the stress forces developed by the ice go above the strength of PVC, the pipe or fitting will fail.

The winterization process, in climates that experience freeze conditions, includes a step to “blow out” an irrigation system to remove all water. Although, strong safety warnings regarding the use of compressed air in PVC systems must be carefully heated, this operation differs in its method and constraints. The equipment used must provide air at a high volume, but low pressure. With enough air, you only need to have about 50 psi to blow out most systems. The piping system must have a large vent and earlier drained of as much water as possible. *Note: Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety hazards should a system fail for any reason.*

Entrapped Air

The “Springtime Startup” procedure is equally essential. The refilling of a system that has been drained needs the full attention of the operator to prevent air slug and surge failures in the operation. Start by filling the system with the valve one-quarter opened, until all the air within the system has been displaced. Only after all the air has been removed should the valve be opened completely.

All air must be expelled from a piping system to prevent air slugs which cause pressure spikes. This is best done during the filling or refilling of a system. To lower the chance of getting air in a system it is important to fill slowly from the lowest possible elevation. The flow velocity during the filling process should not exceed 2 feet per second. Be sure to allow sufficient air venting at the highest possible elevation. The combination of slow filling and ample venting will keep the amount of entrapped air to a minimum.

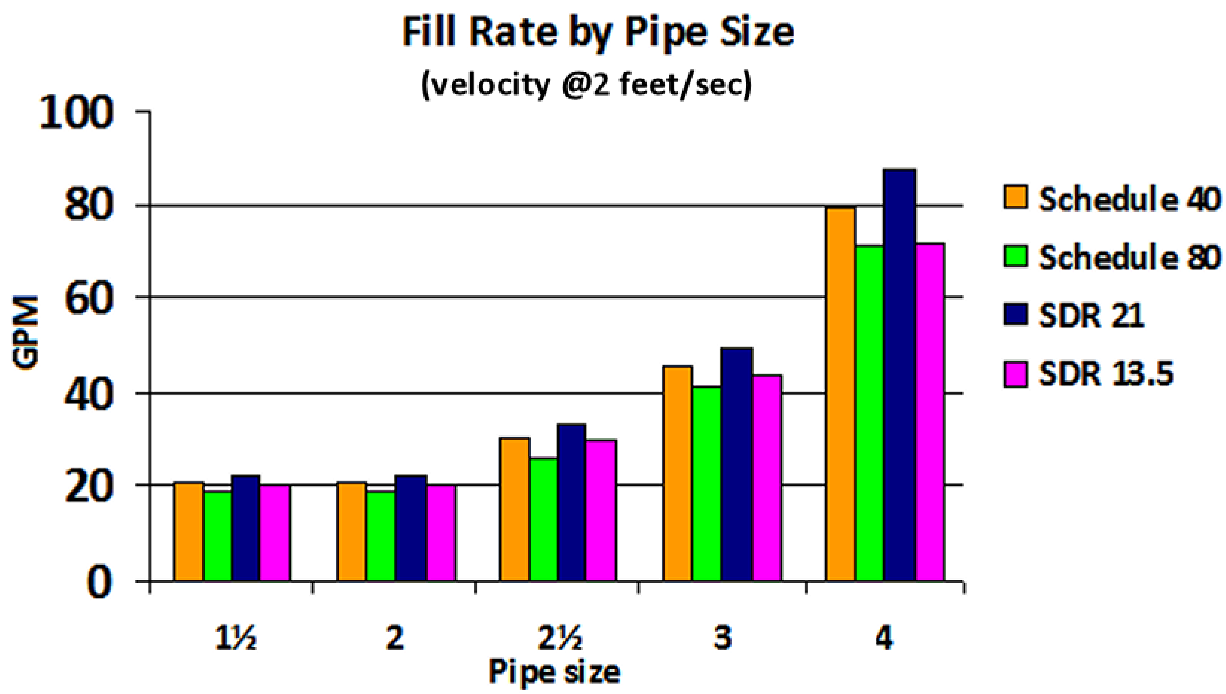


Figure 15: Fill rate by pipe size

Bending and Mechanical Loads

PVC is known for its ability to flex and bend more than metal piping. Although this is a blessing in most situations, it can also be a cause for failures. Thermal expansion and contraction of piping, which is not buried, must be controlled to reduce any mechanical loads on the piping and fittings. The incorporation of expansion loops and offsets in the system layout are generally used.

A flange is most commonly used to connect parts of differing materials within a system. Pump stations, Butterfly valves and tanks are some examples of flange type connections. Usually the flange that mates to PVC is metallic, which is a stronger and stiffer material. PVC flanges and other piping components often suffer from excessive loads during the installation process. The mating of two flanges requires that both sealing surfaces be parallel and aligned.

During the installation and tightening process, most of the loads resulting from misalignment and clamping are moved to the softer PVC. This is the reason that extra attention is needed during the installation of PVC flanges. More than once has there been a flange broken by trying to "pull" the adjoining parts into alignment with the bolts while tightening. When possible the mating flange pieces should be assembled before solvent welding the next downstream part. All bolts in the flange joint must be tightened uniformly using a tightening pattern recommended by the manufacturer. The mating faces must remain parallel within 1/16-inch during the entire tightening process. A torque wrench must be used for the final tightening sequence. Because of slight product variations it is important to use the bolts, nuts, washers, and gasket recommended by the PVC flange manufacturer. Using the recommended tightening sequence and correct torque of the nuts will assure a secure, trouble free joint.

Threads

Although the following information is specific to PVC plastic threads, the idea holds true for other materials as well. The standards for National Pipe Threads (NPT) and those published by the American Society of Testing Materials (ASTM) define the size, tolerance and wall thickness of threaded components. This is clearly done to allow universal interface and compatibility between various materials, manufacturers and components.

Pipe that is Iron Pipe Size (IPS) has a controlled outside diameter, yet the wall thickness will vary with the different Schedules or SDR. For example, a 1" Schedule 40, Schedule 80 and SDR/class pipe will have the identical outside diameter, but the wall thickness will vary depending on the specific schedule or pressure rating. The fittings are separated into two basic groups Schedule 40 for lower pressure and Schedule 80 for the higher pressure applications.

When discussing the prevention of failures in PVC threaded parts we must look at two categories, internal and external threads. PVC threaded fittings follow the conventions, and dimensions of the American National Standard for Taper Thread[xvi], with slight changes of the lead-in thread and minimum wall thickness. Male threaded PVC fittings are recommended for making connections with parts of dissimilar materials. The connection of a PVC system to pumps, valves and filters of other materials are acceptable threaded connections.

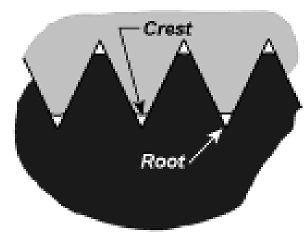


Figure 16: Root and crest of thread profile

All tapered pipe threads have a small spiral leak path between the root and crest of the mating threads. This leak path needs to be sealed during the joint assembly. Recommended good practice is to use a thread sealant (not a thread lubricant) or Teflon tape to assemble the joint to finger tight one plus one and one-half (1½) turns, two turns at the most. When Teflon tape is wrapped around male threads, it can add to the strain and tensile stress of the female parts during assembly. The tendency of many installers is to wrap too many thicknesses of tape around the male threads, increasing strain and stress further. The tape also makes the threads more slippery, increasing the tendency for over tightening. The joint goes together so easily that two turns does not feel tight, and encourages over-tightening. To sum up, it is necessary for the installer to use extra care when using Teflon tape.

PVC threaded joints need a sealing compound that meets plastic fittings criteria. Teflon filled pipe dope, just like Teflon tape, tends to make threaded joints more slippery. Metal to metal threaded joints are more difficult to tighten; because the surfaces tend to gall without the aid of lubricants like Teflon tape or pipe dope. Plastic fittings do not need this lubrication. This does not mean that sealing compounds are to be avoided.

When assembling threaded PVC fittings, a sealing compound that is non-hardening is the best. If you intend to apply a liquid or paste thread sealant, first confirm with the manufacturer of the pipe and fitting that it is compatible, or use teflon tape. Teflon tapes and hardening pastes can permit a leak path to develop when a joint is backed off, mechanically flexed or expanded with rising temperatures. Conversely, a non-hardening compound is forced by the internal fluid pressure into potential points of leakage; by that performing a true sealing role. The sealing compound must be compatible to all materials and media to which the joint will be exposed. Many brands of pipe sealants contain oils, solvents or carriers that can damage PVC. A proper sealant must be approved by the manufacturer to be harmless to the joint materials and not contaminate the fluid in the piping system. Finally, a sealing compound must not lubricate the joint to the point that over-tightening is encouraged.

External Threads

Let's start with the simple act of making a male pipe thread. The NPT threads have a taper of ¾-inch for 12-inch of length or roughly 3½ degrees. This is what creates a sealing or leak-free joint. Because of this taper or conical shape, Schedule 40 and thin wall pipe cannot be threaded or used to make nipples. The lead-in thread is cut deeper, causing the wall thickness to be decreased at the end of the pipe. As an example, the wall thickness of 1-inch Schedule 40 PVC pipe is .133 inches thick; the taper of the threads alone would cut the pipe wall thickness by 45 percent. This means that a 1" Schedule 40 pipe wall would become too thin under the first few lead threads of the pipe. This same relationship would follow through on all sizes of Schedule 40 pipe.

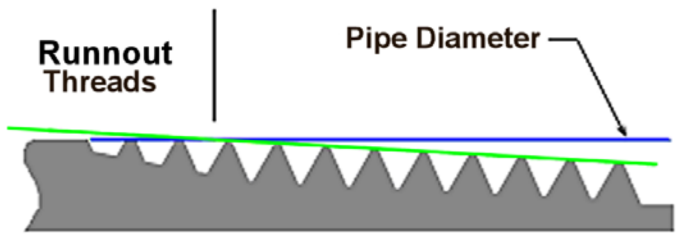


Figure 17: Reduction of wall thickness with taper thread.

The ASTM standards for tapered threads in PVC and other plastic pipe and fittings, control the wall thickness within the threaded part of a fitting or nipple. Two standards govern threads in PVC fittings, ASTM D2466[xvii] for Schedule 40 fittings and ASTM D2464[xviii] for Schedule 80 fittings. The standard for Schedule 40 says: "For any threaded fitting the minimum wall thickness of the threaded part must be at least equal to the thickness of material under the thread root (valley) of threaded Schedule 80 pipe of the same size."

This requires the external or male threaded section of a schedule 40 fitting to have extra material under the threads so the wall thickness is to equal that of a Schedule 80 pipe.

Male PVC threads are either molded or cut into the part, but in either case the internal diameter or waterway segment must not be larger than Schedule 80 pipe bore of the same size.[xix] This requirement means that a Schedule 40 fitting, such as a male adapter, must have a wall thickness in the threaded portion the same as Schedule 80 pipe. So, nipples or other fittings should not be made from Schedule 40 or SDR pipe stock.

The location of the highest stress on a male threaded fitting is the first thread outside the female threaded component.

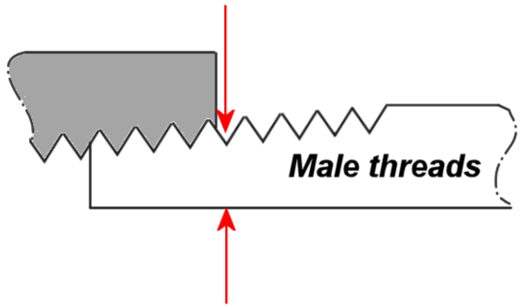


Figure 18: Thinnest wall is at the first exposed thread.

This is where the material is the thinnest and it is the focus of any external loads such as bending and vibration. All bending, misalignment and vibrations loads are easily accommodated by the two-wall combination of the female thread and male threaded part.

Because of the thread taper, the thinnest wall is at the root, or valley of that first exposed male thread. It is common for PVC male adapters to experience a failure at this point. When using this form of joint connection, it is necessary to provide sufficient reinforcement to resist external loads. Yet, the piping in each direction of the joint connection must be made flexible to relieve the loads on the PVC male threads.

Internal Threads

The wall thickness, minimum limit, also holds true for female threads. Often the Schedule 40 coupling or socket fitting will have an outside diameter as large as a threaded fitting. Since a socket fits over the outside of a pipe, a female needs more material added to the socket wall thickness, to achieve the necessary thickness under the threads.

The ASTM standard for Schedule 80 fittings defines a minimum outside diameter for female threaded parts.

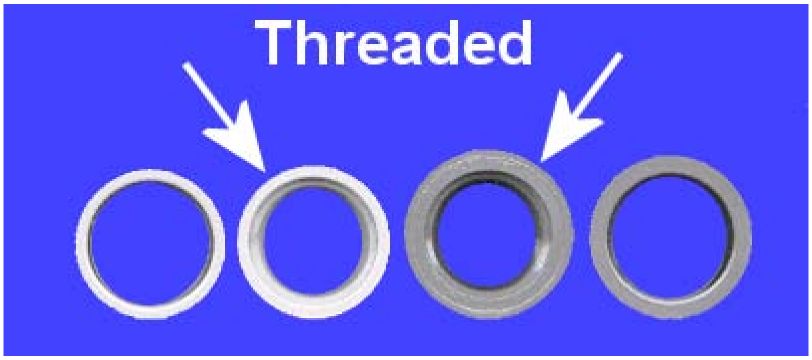


Figure 19: Compare wall thickness of fittings with internal threads.

The ASTM Standards refer to this as the "M" diameter, and it is larger than the outside diameter of a Schedule 80 socket. So, a Schedule 80 female threaded part may have a larger outside dimension than a solvent welded version of the same part. Figure 18 shows a socket and female threaded version of both Schedule 40 and 80 fittings, and difference in outside diameter and wall thicknesses.

Female threaded parts such as Female Adapters, Tee's, Couplings, and Elbows have a history of being one of the most troublesome due to their inherent weaknesses. Let's explain what happens when a tapered pipe thread joint is tightened. Just like an ordinary bolt and nut, until clamping forces are present, tapered threads are "free running", while there is clearance between male and female threads. As the two components are wedged together by additional turns, the internal forces increase.

Size (ips)	Strain/Turn (in./in.)	Stress/turn (psi)	Stress/Hydraulic (psi)	Turns to Fail (approx.)
1/2	.00580	2352	2,000	2.1
3/4	.00461	1844	2,000	2.7
1	.00447	1788	2,000	2.8
1 1/4	.00349	1396	2,000	3.6
1 1/2	.00302	1208	2,000	4.1
2	.00239	956	2,000	5.2
2 1/2	.00287	1148	2,000	4.4
3	.00234	936	2,000	5.3
4	.00180	720	2,000	6.9

NOTES:

1. Strain/turn is calculated at the Pitch diameter
2. Stress/turn is calculated using 400,000 psi modulus for PVC
3. Stress/ Hydraulic is based pressure rating of pipe
4. Turns to fail is based on the 7,000 psi tensile strength of PVC

Table 3: The Stress and Strain levels in a PVC threaded Joint.

Once the male and female threads are engaged (finger tight, not even hand tight), more turns cause the female part to "strain” or undergo stretch. Strain is defined as the ratio of the change in diameter to the original diameter.

"Stress" or tensile stress, is the force exerted by the strain of the male thread multiplied by the resistance of the PVC. The resistance of PVC is 400,000 pounds per square inch (psi). The strain per turn past finger tight for one-inch PVC pipe is .00447-inch, so the stress per turn is 1,788 psi. So, a one-inch threaded PVC joint that is tightened four turns past finger tight will develop a tensile stress of 7,152 psi. The joint is bound to fail since the stress exceeds the 7,000 psi tensile strength of PVC, even without adding the tensile stress caused by the pressure inside the irrigation system (up to a maximum of 2,000 psi).

You can see that four turns past finger tight with one-inch PVC pipe can lead to a split joint failure. But, two turns past finger tight plus the stress of the system pressure is within the tensile strength of one-inch PVC fitting. The amount of strain, for every revolution, decreases as the diameter of the pipe increases.

It is easier to split smaller diameter threaded joints than larger ones since the stress and strain produced is greater. It is also easier to over-torque smaller diameter fittings because their resistance to torque is less.

The recommended best practice is to use a thread sealant (not a thread lubricant) and to assemble the joint to finger tight plus one and one-half turns, two turns at the most. Finger tight can be defined as: tightened using the fingers, no tools, to a torque of about 1.2 to 1.7 foot-pounds (1.7 to 2.3Nm).

Many plastic piping system installers who come across problems with split female threaded fittings assume Schedule 40 fittings are weak. They think that the problem can be resolved by switching to "stronger" Schedule 80 fittings. There are several fallacies in this reasoning. First, all the problems in over-tightening apply as much to Schedule 80 systems as they do to Schedule 40. While the walls of female Schedule 80 threaded fittings may be thicker, wall thickness does not change stress and strain levels. One advantage in using a Schedule 80 threaded joint arises from its greater stiffness produced by its extra wall thickness. The installer senses this stiffness as tightness, so there is less of a tendency to over-tighten the joint; it feels snug with fewer turns than Schedule 40 fittings.

Installers believe Schedule 80 systems are stronger because they have higher pressure ratings than Schedule 40 systems. This is true only when comparing systems with components that have been welded using solvent cement. Introduce even one PVC threaded fitting, pipe or nipple, and the rating of the entire system must be cut by 50 percent.

Bear in mind that thread grooves in a fitting bring about a lessening of the fitting's wall thickness. Besides, most plastics, including PVC, are "notch sensitive.” When the smooth wall of a plastic part is notched, the part loses a significant portion of its original strength, just as a sheet of glass will break along a scribed line on its surface. This is why the presence of even one threaded fitting in a system requires a cut in the system pressure rating.

Maximum Working Pressure of PVC Pipe

Nominal Size	Schedule 40	Schedule 80	Threaded Schedule 80
1/2	600	850	425
3/4	480	690	345
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
5	190	290	140
6	180	280	140
8	160	250	120
10	140	230	120
12	130	230	110

Note:

1. Schedule 40 & Schedule 80 fittings do not have a pressure rating.

Table 4: Pressure rating of Schedule 40 and 80 pipe.

It is also not recommended to assemble male metal threaded nipples into PVC (or plastic) female threaded fittings. Doing so places extra stress on the female threaded fitting. Plastic to plastic threaded connections share the stress load from being tightened. The male thread is in compression and the female thread is in tensile. When a metal male thread is introduced into a female PVC thread the entire stress load is applied to the female fitting. This means that when a male metal thread is tightened 2 turns into PVC fitting the female is experiencing the equivalent of 4 turns.

The problem is further exacerbated when cold water is drawn thru the piping and the PVC fitting tries to contract down around the metal threads but cannot do so because the metal fitting is too stiff to allow any further compression. This in turn adds to the tensile stress of the female PVC fitting.

Solvent Welding

In an assessment of solvent welding procedures for PVC pipe and fittings we must first talk about the chemicals or solvent cements that are to be used. There are many types of solvent cements available from manufacturers. Many formulations available are designed for specific applications or materials. These manufacturers also provide several primers and cleaners. It is the installers' responsibility to use the proper cleaners, primers and solvent cement formulation for the materials being joined. Check with manufacturers for recommendations on product selection and safe use. Also refer to ASTM F402 for safe handling of solvent cements, ASTM

D2855 for PVC instructions, ASTM F493 for CPVC instructions, ASTM D2235 for ABS instructions, or the cement manufacturer's instructions printed on the container label for further information.

Many people have been confused about the difference between cleaners and primers, and have incorrectly used cleaners as a primer. Cleaners, as the name tells, are used to clean grease, and dirt from pipe and fitting surfaces to be joined. Cleaners do not soften the material surfaces to assist with the solvent welding procedure.

Primers, on the other hand, do have the necessary solvents to prepare the material surface of both the pipe and fitting to insure a proper fusion bond. Primers are available as clear or more commonly Blue and or Purple for PVC. The use of a colored primer is to provide an indicator of use and the quality of coverage. The clear primer is generally used where visual aesthetics of the joint is at a premium.

In swimming pool applications it is a common practice to join ABS and PVC with solvent cement. The proper solvent cement for this process is different from what is used when joining PVC to PVC or even PVC to CPVC. Each solvent welded connection must use a product recommended by the solvent cement manufacturer for the proper joining of the materials involved.

The procedure and tools necessary for solvent welding PVC are usually the same as those used in solvent welding most other plastic materials. Many publications talk about the process of cutting the pipe square, deburring, cleaning and priming of the pipe and fitting before applying the solvent cement. Important aspects of proper solvent welding PVC pipe and fittings are:

1. Choosing the correct primers and solvent cements.
2. Choosing and using the correct sized applicator.
3. Using proper procedures for solvent welding PVC.

Primer and cement

First and most important, choose the proper solvent cements and primers. According to the American Society for Testing and Materials (ASTM), a primer must be identified by its role and the designation "F-656" on its label[xx]. This avoids confusion with plastic piping cleaner, which is intended only to clean the surface of the pipe. The label on the solvent cement container will show the pipe size range the manufacturer recommends for each cement. Follow the solvent cement manufacturer's instructions closely; or, joint failure is likely.

Solvent cements designed for smaller-sized piping systems have a lower viscosity, or a more "water-like" consistency. They do not have the higher viscosity (or thicker body) necessary to fill the normal gap or void that exists between larger-diameter fittings and pipe. In some larger sizes (4-inch Schedule 40, for example), the industry-allowable tolerances for pipe and fittings can lead to a gap of about 1/32 inch at the socket entrance. It is necessary for the solvent cement to fill this gap between the pipe and fitting and bond the two pieces.

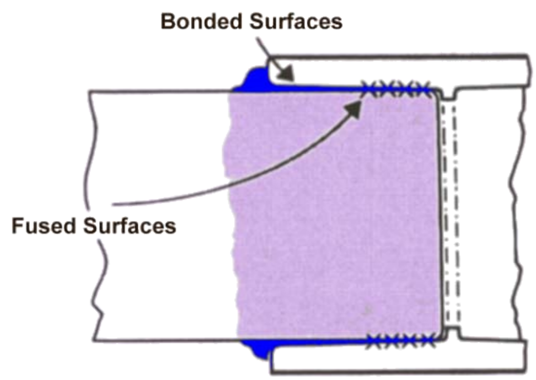


Figure 20: A Solvent Welded Joint

Correct size applicators

Solvent cement consists primarily of solvents (volatiles) that evaporate during curing. When the applicator is too small to apply the cement quickly, the volatiles flash off, leaving inadequate solvent to create a fusion between the pipe and fitting. This leads to a weak joint.

To prevent this, the applicator size needs to be one half of the pipe diameter. For example, a 4-inch pipe needs a 2-inch diameter applicator. Remember! The applicators for both primer and cement need to be ½ the diameter of the pipe being assembled.

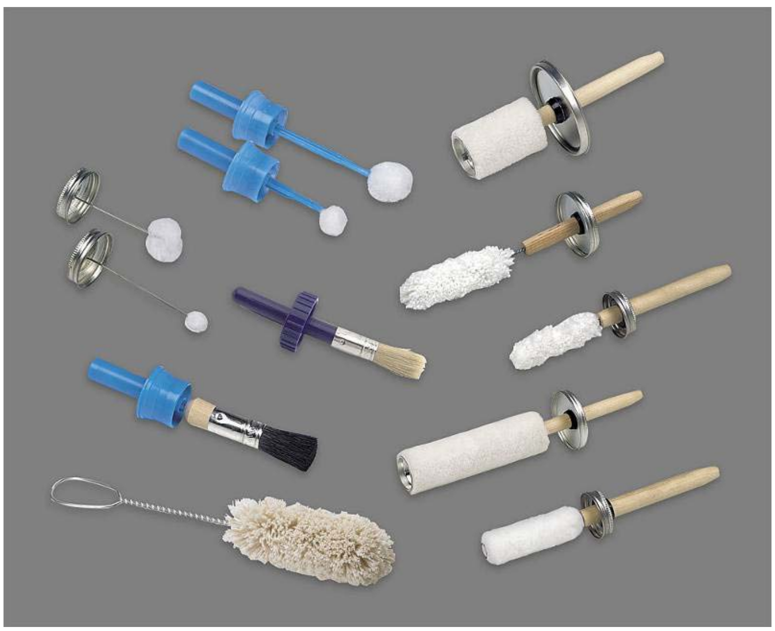


Figure 21: Various types of solvent cement applicators.

Application:

The proper sequence of applying the primer and cement is important when you assemble larger sizes (above 3”) and necessary when you use Schedule 80 fittings.

Follow these steps in order:

1. Shake or stir can of solvent cement before use.
2. Always start with the fitting.
3. Apply primer to the fitting socket. Next apply primer to the end of the pipe to a point ½ inch beyond the depth of the fitting socket.
4. Apply a second coat of primer to the fitting socket. Do not allow puddles of primer nor let primer run down pipe or fitting.
5. With the proper size and type of applicator, and while the primed surfaces are still wet, right away and 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.
6. Next apply a medium layer of cement in the fitting socket.
7. Apply a second full layer of cement to the pipe and immediately push the parts together while rotating one-eighth to one-quarter turn. Do not continue to rotate after the pipe has reached the socket bottom.
8. Hold the joint together for 15 to 30 seconds. (In cold weather installations, increase the hold time to prevent push-off.)

Many joint failures can be attributed to the lack of a second coat of cement on the pipe. As you push the pipe into the fitting, any excess cement on the pipe will be pushed back out of the socket along the pipe, filling the tapered gap between the pipe and fitting at the socket opening. This also cuts the possibility of cement becoming trapped, or puddled, inside the fitting. Any excess cement needs to be wiped off the exterior of the pipe at this point. This is referred to as removing the bead of cement at the entrance of the fitting socket. Avoid puddles of primer or solvent cement inside the fitting.

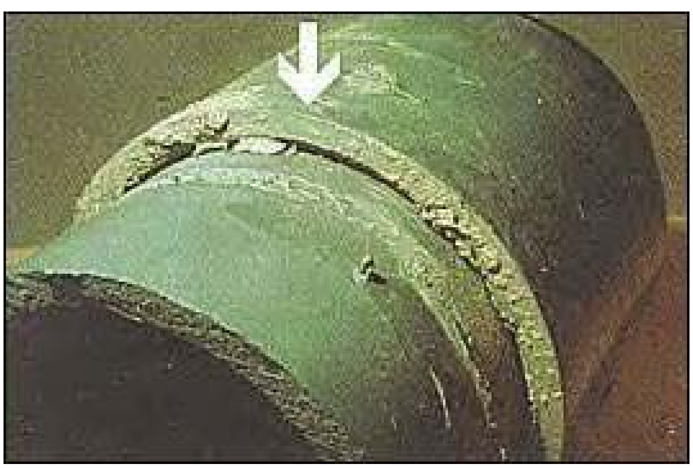


Figure 22: Insufficient Solvent cement was used.

Remember! Put cement on the pipe, then in the socket and a <u>second</u> coat on the pipe before assembling.

Many times field failures portrayed as defective parts have been found by laboratory analysis to be solvent weld failures. Often, improper solvent welding technique and assembly is the cause of the joint failure.

Exposure to Sunlight & Ultraviolet Radiation

Over the years PVC has been used in a multitude of applications above ground while being continuously exposed to the elements including Ultraviolet radiation (UV). For many years there has been concern about the ability of PVC pipe and fittings to resist the degradation influence of this exposure. The PVC compounds used in today's pipe and fittings are much improved over those that were used decades ago. The present day formulations have improved stabilizers and UV inhibitors that resist UV breakdown that many earlier products experienced. Long exposure to UV does lead to some discoloration and chalking of the surface. This is a result of a breakdown of the molecular chain on the outermost surface. This thin surface skin in turn provides a UV shield to the PVC below, like Aluminum Oxide provides protection to the base Aluminum.

To prevent yellowing or discoloration of the pipe and fittings that are exposed to UV light you may wish to coat them with a heavily pigmented, water based exterior latex paint. Do not use a solvent or oil based paint! The color of the paint is of no particular importance, as the paint acts as an ultraviolet screen and prevents sunlight damage. White or other light color is recommended as it helps lower pipe temperature. The latex paint must be thickly applied as an opaque coating on any pipe and fittings that have been well cleaned.

It is recommended to paint Gray or Schedule 80 pipe and fittings a light color to cut the absorption of solar radiation or heat into the system.

Thrust Blocking

The question is occasionally asked, "Do solvent welded systems need to be Thrust Blocked?" To answer this question we must first understand thrust blocking. Then we need to understand the differences in design between solvent welded, and Gasket (O-ring) joining systems.

The force of water within piping can be great enough to cause separation of certain types of joints. Thrust blocking is the procedure of placing a solid backing, such as concrete, behind a directional fitting to hold the assembly together.

In a solvent welded system, the joined parts are fused together into a self-restraining entity. The same happens when a steel pipes and fittings are arc welded together. The American Society for Testing and Materials (ASTM) socket dimensions used in Schedule 40 and Schedule 80 fittings provide more than twice the socket depth necessary to constrain the thrust forces generated by the hydraulic pressure. To sum up, thrust blocking is not required on solvent welded joints**.**

In a Gasket or O-ring joint system the parts are not welded or fused together. They remain separate entities. An O-ring is needed to halt seepage of water from the connection. Because they remain separate unrestrained entities the only restraining forces that are available are O-ring friction and burial load. Yet, neither of these forces is capable of counter balancing the force created by the internal hydraulic pressure of the system. It is for this reason that thrust blocking is required on a Gasket or O-ring joining system**.**

Thrust transmitting joints that are heat fused or solvent welded, are capable of restraining maximum expected thrust forces generated by internal pressure, expansion and contraction.[xxi] Gasket and other non-thrust transmitting joints should be restrained by means of properly engineered external restraints or joint restraint devices. To prevent joint disengagement of piping systems with gasket or O-ring type joints, thrust restraint is necessary at certain points in the system, such as changes in direction, or terminal ends.

Proper construction and placement of thrust blocking is necessary to keep joint integrity[xxii]. The ability of the adjacent soil to resist the thrust forces developed is the first step in working out the size needed. The table shows the estimated bearing load each soil type will accommodate. It is important to determine the soil bearing properties by a qualified person. The amount of thrust

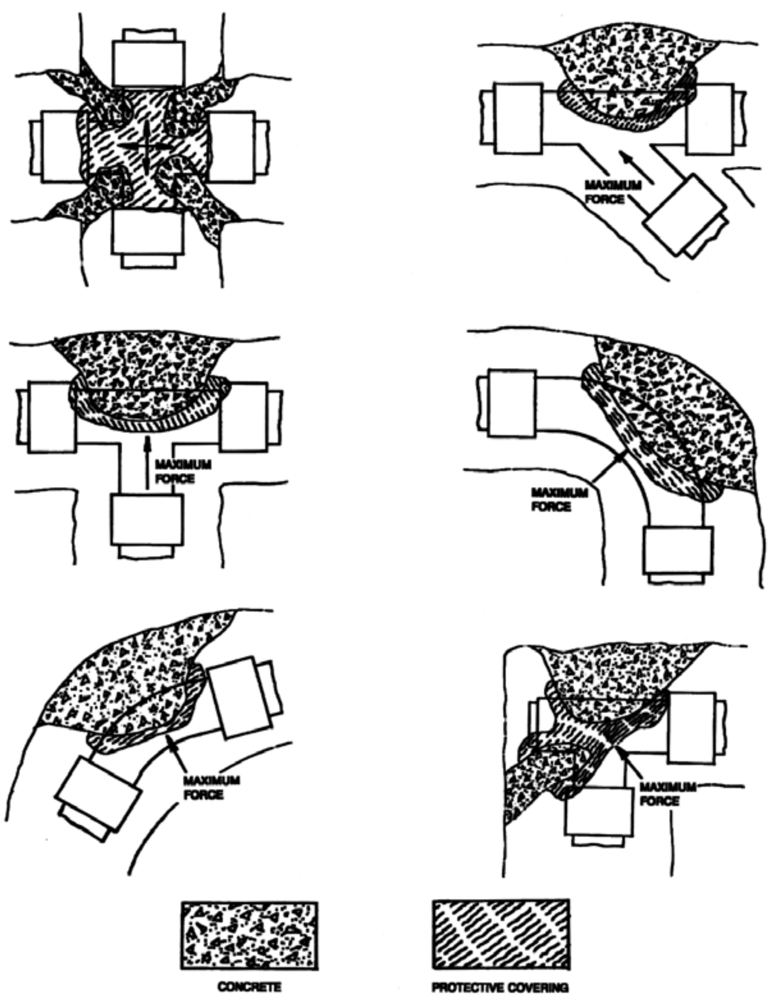


Figure 23: Proper placement of thrust blocks.

force generated depends on both the shape of the fitting and the hydraulic pressure in the system. For the thrust block to properly resist these forces, its bearing surface must be sufficiently large, so that bearing limit of the adjacent soil is not exceeded. This cannot be done with cinder blocks, timbers, bags of ready-mix, or even a blob of concrete.

Soil Type	LBS/ft^2
Muck, Peat, etc.	0
Soft Clay	500
Sand	1,000
Sand & Gravel	1,500
Sand & Gravel with Clay	2,000
Sand & Gravel Cemented Clay	4,000
Hard Pan	5,000

Table 5: The approximate bearing resistance of different soil types.

The thrust block must have uniform loading on the fitting surface and a soil contact surface of the proper square footage for soil, fitting and pressure.

Pipe Size (IPS)	90° Ell (LBS)	45° Ell (LBS)	Tee & End (LBS)
1½	300	200	200
2	500	300	400
3	1,000	600	800
4	1,800	1,100	1,300
6	4,000	2,300	2,900
8	7,200	4,100	5,100

Table 6: Thrust developed for each 100 psi.

From above information, it is possible to compute the proper size thrust blocking to restrain the joint. To work out the total thrust bearing area on the adjacent soil, it is necessary to define the total thrust developed, divided by the bearing capacity of the undisturbed soil.

The following example shows that a thrust block with a thrust bearing surface against the adjacent soil must be 8 square feet. A bearing surface smaller will allow the joint to move and possibly leak or fail.

Example:

Work out the thrust block size needed for a 6-inch 90° elbow, in sandy soil and a maximum test pressure of 200 psi.

Thrust bearing surface area = Total Thrust / Soil Bearing Load

= (4,000 LBS x 2) / 1,000 LBS / ft^2

= 8 ft^2

It is important to note there are commercially available joint clamps and mechanical systems that are effective in cancelling the thrust forces developed in the gasket joining system.

System Repairs

Everyone that has worked with a pipe and fitting system has had to make a repair at one time, or another. There is a multitude of techniques promoted to repair the components of a PVC system. These methods may appear simple, quick or inexpensive but may not regain the full specifications and performance of the original system.

For example, failures due to misalignment or bending need to be reconfigured to remove these harmful loads. Any failure that is the result of external stress or loads will recur if you do not remove these stresses. If you need to install more supports or restraints to remove the external stress, make sure you do it before making necessary repairs. With external failures, a crack or break will develop from the outside of the pipe or fitting toward the interior. A simple method will help you determine if a failure is external. Try bending the part to open the crack to make it wider. This will reveal the directions in which the external loads were applied.

When tackling a situation that needs repair it is of the utmost importance to find the cause of the failure. If the cause is not identified or removed the effort spent making any repairs may be pointless, and the results will be short term. After you find the leak, you must set up the repair method. The surest method for repairing a failed part, fitting or pipe is to replace it (instead of trying to patch it).

If the cause was hydraulic in nature, the operation of the system must be checked to pinpoint the source. The more dirt, mud and water you can clear away from the area around the leak, the easier it is to discover its true location. The crack or failure is always oriented at 90-degrees to the direction of the instigating force. Most cracks or failures, which are in line with the direction of fluid flow, are caused by internal pressure. Those that go around the pipe or fitting, circumferentially normally result from external sources.

You must find the failed part. It is amazing how many times a "leaking part" has been returned to a manufacturer only to discover in their testing that the actual leak was another part or in a different place than where it was assumed to leak. After you find the leak, you must set up the repair method.

Many kits, methods and so-called solutions are available for patching a leaking system, but remember that all materials, including PVC, fail after being exposed to excessive loads, high pressure or poor installation. An external patch will not deal with these problems.

One repair method that is promoted many times is "hot air welding" or "plastic welding". In this process an extruded PVC rod is melted and fed into the area of a crack or failure of a PVC pipe or fitting; much like welding metals. It's important to remember that during the manufacturing process, injected molded fittings are formed from melted PVC under pressure. When a fitting or pipe leaks due to hydraulic, mechanical or solvent weld failure, hot air welding is a temporary fix at best; because the initial integrity of the wall, or solvent welded joint is not recovered. Even assuming the cause for the failure was corrected, the fact that there was a leak means the wall had been penetrated by the fracture or there was a solvent weld failure which means the joint was faulty.

Placing a bead of PVC on the exterior does not fuse, or bond the interior walls at the tear. The internal pressure exerted by the fluids will continue to work from the inside to open the crack, and a leak will return.

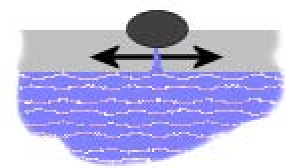


Figure 24: Hot air welding of a cracked fitting.

Transition Fittings and Adapters

When a piping system is mated with components of different materials, care and specific assembly techniques and components must be used. If the two materials can be solvent welded using solvent cement designed for both, then a joining procedure recommended by the solvent cement manufacturer must be followed.

A common method of joining plastic piping to other material systems is by using flanges, unions or threaded connections.

Figure 25: Male and Female adapter

Plastic flanges follow the ASME/ANSI B16.5, for class designation 150.[xxiii] This standard identifies them with a 150 psi pressure rating, dimensions, tolerances, marking, testing, for ½ through 24-inch sizes.

An alternate to using flanges, is to use an adapter or transition fitting. The generally accepted distinction between these fitting types is their construction. An adapter fitting, such as a Male or Female Adapter, is made wholly of a single piece and material. Because of the notch sensitivity of PVC, and most plastics, the threaded segment of adapters is the source of failures when they are installed rather than a transition fitting. Male threads, such as those found on a plastic male adapter, can be used as a transition but only in a cold water system. Thermal expansion and contraction of the piping materials in a system may cause a leak to occur over time when plastic male adapters are used where the water temperatures rise and fall.

When a male adapter is installed, the system pressure must be lowered and mechanical loads and vibrations must be managed. The decreases in wall thickness and the “notch effect” stress risers of the threads lower the strength of the part, and the reliability of the system.

The female adapter will split from over-tightening of a male threaded part because of the high internal stresses that is developed. This extreme stress is from the female adapter being stretched, and quickly exceeds the strength of the plastic. This leads to a failure or crack that runs parallel to the waterway of the fitting.

Transition fittings are available in many configurations and consist of multiple components and materials. They are designed and intended to interconnect components of dissimilar materials. They create a leak-free connection between the different piping materials. Threaded ends may be either male or female threads. Sometimes the plastic part is molded directly to a metal body. The seal between the two materials is achieved with an internally molded O-ring.

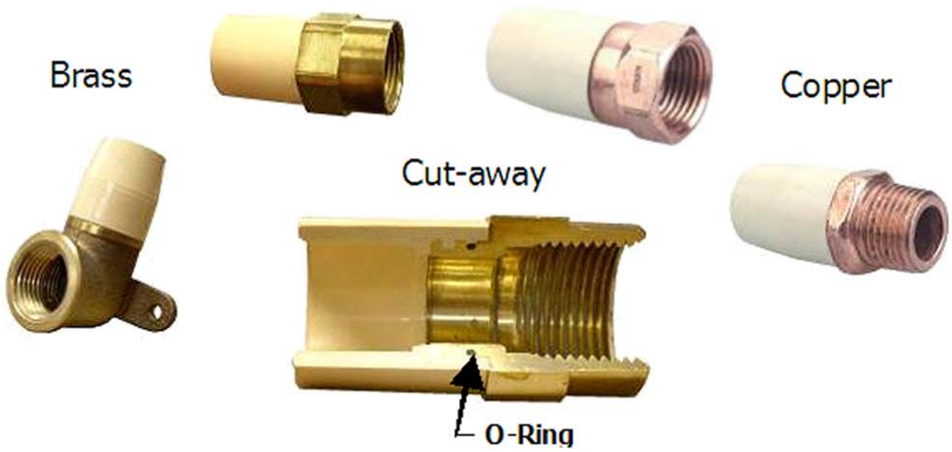


Figure 26: Some styles of transition fittings.

These fittings end the problems associated with threading plastic directly to metal. It is important to remember that the PVC is heat sensitive and the metal part of a transition fitting will easily transfer heat to the plastic quickly.

Figure 27: Transition style unions.

Transition unions are multi-part fittings that have both a plastic and metal end with an elastomeric seal in-between providing a leak-free connection. The plastic end can be either female socket or male spigot. The metal end can be a solder joint socket, threaded, or compression ferrule type fitting. Entirely plastic unions are not to be used as transition unions. Transition unions can be taken apart and put back together again quickly, easily and repeatedly. The plumbing codes and common sense do not allow these fittings to be installed behind walls, or in other un-accessible places. Transition unions should only be installed in easily accessible places.

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