PVC Fittings

Features and Drawbacks

BY LARRY WORKMAN

TENS OF THOUSANDS OF IRRIGATION systems that have been designed and built with PVC pipe and fittings perform satisfactorily, while a very small percentage run into problems. Most of these problems arise from three basic causes, all of which can be avoided if you realize that PVC is different from other, more traditional piping materials. Therefore, PVC must be handled differently in designing, installing and repairing systems.

This is not new in the history of civilization. For many, many centuries, bridges were built of wood. Then steel came along. Bridge spans could be built longer than before and they were much stronger. However, they had a drawback, according to some people who had grown up in the wooden bridge building trade; they could not be built with hammers and nails!

Differences between materials

Many times, we face similar problems in plastic irrigation systems. Before I touch on the causes that account for most of the problems in PVC irrigation systems, it might be helpful to compare some of the key properties of PVC when compared to steel. PVC has major advantages in installation: it can be solvent cemented, it has increased chemical resistance and lower weight and friction loss. Steel, on the other hand, obviously scores higher in other properties. The point is not that one material is better than the other, but that they are different—and the different properties require different handling, installation, design, or maintenance when used in irrigation systems.

	PVC	Steel	Unit
Solvent	Join	Yes	No
Weight	814	55.5	lbs/cubic ft
Chemical Resistance	Excellent	Poor	
Flow Coefficient	150	65-110	
Modulus of Elasticity	400,000	29,000,000	psi
Max. Service Temp	140	1,000	°F
Tensile Strength	7,000	60,000	psi
Max. Design Stress	2,000	20,000	psi
Relative Impact Resistance	1	6	
Coefficient of Expansion	3x10-6	0 6x10⁻	in/in/°F

The first and most frequent cause of PVC system problems is failure in designing the system to withstand the surges, shocks and other abnormalities that will and do occur in all piping systems. The easy answer is to make sure that the system is designed so that its normal operating pressure is two-thirds of the working pressure for the "weakest component" in the system. This will reduce the chance of failure due to hydraulic shock or pressure surges.

There are many reasons behind that "easy answer" and it is important to understand those reasons. The PVC piping industry, through the American Society for Testing and Materials (ASTM) and the Plastic Piping Institute (PPI) have developed two pressure-rating systems for PVC pipe. One is the Standard Dimension Ratio (SDR) or Class system. The other is the Schedule system (i.e., Schedule 40 and Schedule 80).

The SDR is a ratio of the minimum wall thickness to the outside diameter of the pipe, and is based on an established stress or pressure level. These piping components are commonly referred to as Class pipe. In this way, a system made of Class 200, Class 315, or Class 160, has a pressure rating of 200psi, 315psi or 160psi respectively.

Standard Dimension Ratio

Pressure	Rating	(psi)
32.5	(Class 125)	125
26	(Class 160)	160
21	(Class 200)	200
17	(Class 250)	250
13.5	(Class 315)	315

Schedule 40 and Schedule 80 pipe have specific pressure ratings for each pipe size. These ratings vary from 850psi for a ½" Schedule 80 pipe and drop to 130psi for 8"

Schedule 40. In these systems, the operating pressure is most commonly limited by the largest diameter pipe.

	Pressure Rating	
	Schedule 40 (psi)	Schedule 80 (psi)
½	600	850
¾	480	690
1	450	630
1¼	370	520
1½	330	470
2	280	400
2½	300	420
3	260	370
4	220	320
6	180	280
8	160	250
10	140	230
12	130	230

Not everything is as simple as it seems. Schedule 40 and Schedule 80 fittings—unlike PVC pipe—do not have pressure ratings. Because of their various shape, thickness, irregularities and configurations, standardized pressure ratings have been impossible to develop.

The fitting must have a wall thickness at least 25% greater than its equivalent schedule and diameter pipe. Many years of field experience and billions of fittings later, this concept appears to validate that the fitting will accommodate the pipe pressures. Furthermore, manufacturers test a new design or configuration to the pipe test criteria as a matter of product qualification. This way, the PVC fitting does not become the weak link in the piping system.

A unique component in the PVC piping system is the nipple. Nipples should only be made from Schedule 80 pipe stock or molded with equivalent wall thickness. Nipples and all threaded fittings must have a wall thickness in the threaded portion equal to the minimum wall thickness of a Schedule 80 threaded pipe. In addition, the Plastic Pipe Institute Technical Report (PPI-TR16-August 1973) states in paragraph 3.7, "threaded pipe has a pressure rating which is exactly one-half that of Schedule 80 pipe." This is due to the cut or notch that the threads make in the wall thickness. Studies have shown that molded threads (nipples and fittings) are substantially stronger in the threaded portion than those with machined or cut threads. This is due to the natural flow of molten material around the thread profile during the molding process. This is similar to metallic fasteners, which are stronger if they have rolled threads rather than machined threads.

Cyclic fatigue

Let me turn to the two other aspects of PVC piping systems that are frequent causes of failures and result in problems about which you need to be aware. One arises from the nature of PVC and the other arises from the nature of irrigation piping systems. Again, there are no easy answers.

Replacement of a fatigue-failed fitting will "solve" the leaking problem for the moment. However, this does not solve the underlying problem that can lead to additional failures a few days, weeks or months later. Chances are, more basic steps are required.

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

These long-term failures will usually be found in the most highly stressed areas of a fitting. In typical PVC tees and elbows, this area is the crotch or the intersection of the connection ports.

Sometimes the failure of a female threaded part seems to contradict this scenario. Here, failure is usually found to originate and follow along the knitline, bondline, or sometimes called the weldline. Simply stated, the knitline can be the weakest link in the chain and with the high wedging loads induced by over-tightening tapered pipe threads, the knitline may fail. In these cases, the crack starts on the inside diameter or threads and propagates through the fitting wall quickly, usually without the stretch marks.

Pressure surges and water hammer

PVC piping systems have both benefits and drawbacks relative to the water hammer phenomenon. Because of the elastic or non-rigid nature of PVC, the pressure wave or surge travels through a plastic pipe much slower than in metal, and the peak surge is greatly reduced. This is partly because some of the energy is dissipated by causing the PVC pipe and fittings to swell or grow slightly as the pressure wave is travelling through the system.

An often overlooked very common cause of water hammer is the air slug, which is nothing more than a bubble or air pocket within the system. When this bubble is travelling through the piping at the velocity of the water, there is no

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real problem. Nevertheless, when that air slug gets to the sprinkler, the air escapes through the sprinkler nozzle roughly five times faster than water, so the upstream water velocity suddenly increases. When the air slug is gone, the system velocity is suddenly reduced to the original value. For example, if the normal velocity is only three feet per second, the system can increase to 15 feet per second during the air escape, and can be instantly reduced by 12 feet per second to the original speed. The 12-foot-per-second change in velocity will create an additional pressure spike of more than 200psi in a two-inch system. The surge of 200psi in addition to a working pressure of 100psi exceeds the 280psi rating of a Schedule 40 pipe.

The 200psi surge will only last about one-third of a second, a short time, only enough to cause the gauge to flicker. Most gauges and pressure recorders will only reflect or show about one-half of the maximum pressure, because their mechanisms cannot react quickly enough. Many times an oil-filled gauge will be installed to provide a steady needle for easy reading; however, the dampening of the needle movement will hide the surges and damage that is being done to the system. Since PVC is a visco-elastic material and sudden changes cannot be tolerated effectively, the surges may result in broken piping and components.

Two-inch Schedule 40 System

	Wave Velocity (fps)	Surge Pressure (psi)	Critical Close time (sec)
PVC	1402	94	0.14
Steel	4367	294	0.05
Copper	4191	282	0.05

You can see that the maximum surge pressure generated in a two-inch Schedule 40 system flowing five feet per second is about one-third of the surge spike generated in a steel or copper system. The axiom that says "Nothing is free," holds true with PVC. Although the peak surge in PVC is small compared to steel, the wave velocity is also very slow, by the same 3:1 ratio. This means that the same valve, which does not cause water hammer in a metal system, can cause a pressure spike in a PVC system. Therefore, in order to prevent damaging pressure spikes, the valve closing times in a plastic system must be much longer than the closing times in a metal system.

Most solenoid-controlled dia-

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phragm valves will close or open more rapidly the greater the difference between the upstream and the downstream pressure. This means that most of the flow (gallons per minute) is closed off in the last 25% of the valve operation. Conversely, the bulk of the flow comes on during the first 25% of opening. These sudden, quick and repeated changes in flow during system operation generate repeated cyclic pressure fluctuations. These are the fatigue-causing culprits that can weaken and ultimately destroy any irrigation system.

Pressure fluctuations within a system should never exceed 1.5 times the lowest-rated component in the system. In addition, if there is a pressure increase or decrease of 50% (i.e. 80psi to 40psi, or 50psi to 100psi) in a short period and it is often repeated, the fitting will fail. Although all systems have some degree of pressure fluctuation and not all pressure variations can be removed, an effort must be made to stabilize the pressures.

Although PVC piping systems appear to be the ideal material to use, nothing—including steel—is perfect for all applications.

There are many methods of reducing severe pressure fluctuations. The first and most essential step is to find out what is happening within your system. That may call for a pressure recorder. Depending on the complexity of the system and its size, recorders may be installed either for a short-term check or for permanent monitoring; they can vary, too, from a unit with a hand-wound clock motor up to solid-state computerized models. Pressure recorders may be available for short-term rental in some areas, and we have heard of municipal water purveyors lending them to their customers.

By recording the system pressure and comparing it to the irrigation schedule, a good analysis can be

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made as to what must be done to reduce the quantity or magnitude of the surges. Many times, surges or pressure variations are worse during the night hours, when no one is available to observe what the recorder can capture.

Once the source of the surges is located, the solution may be as simple as adjusting the high/low pressure limits of the pump station, revising some valve grouping, or lowering the overall system pressure.

Although these steps may remedy the cause of failures, they will not necessarily eliminate future breaks. Once a component has been "bruised," it may only be a matter of time until a fracture happens. However, making pressure corrections may significantly extend the system's operating life.

To sum up, the best method to prevent a catastrophe is to be aware of what is actually happening in the system, not simply what was designed. Installing pressure recorders at various locations in a system, including the extremities, can be beneficial in preventing failures. This in turn, will result in an irrigation system which will last and perform as expected and specified. Remember, smooth out the pressure fluctuations to have a smooth running system.

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Although PVC piping systems appear to be the ideal material to use, nothing—including steel—is perfect for all applications. Each material has its own set of characteristics and drawbacks. It is these attributes that must be constantly reviewed by the user or designer before proceeding with designing, installing or repairing a piping system. Along with these considerations, the proper tools, education and techniques must be used to create a project that will fit its materials and purpose.

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