HIGH-PURITY SYSTEM DESIGN

A pure water system comprised of PVDF or polypropylene is similar to most chemical feed systems. The critical factor in a pure system is to design it in a continuous moving loop without dead legs to avoid the possibility of microorganism growth.

Systems should also be sized to have turbulent flow as part of the method of inhibiting bacteria growth. PVDF and PP systems are ideally suited for pure water as they have extremely smooth inner surfaces that reduce particle generation and inhibit sites for bacteria to adhere to and proliferate. In addition, PVDF and PP systems have low extractables, thus not contaminating the water being transported. See the *Purad High Purity Guide* for more data on material purity.

In designing a thermoplastic high-purity water system, the following items need to be considered:

- Materials of Construction
- Operating Parameters
- System Sizing
- Thermal Expansion
- Minimize Dead Legs
- System Monitoring
- Other Considerations
- Hanging
- Welding Methods

Materials of Construction

PVDF is the premier material for high-purity water systems. PVDF has been used in ultra pure water systems for over 15 years because it is superior to materials such as stainless steel or PVC. PVDF combines excellent surface finish with low extractables to provide the highest quality piping material for the application. In addition to its purity attributes, PVDF is also available in a variety of components and welding methods that are well suited for UPW applications. PVDF is a crystalline material that can withstand high pressures. However, the nature of PVDF requires special planning and handling during the installation. These types of requirements are now commonplace on the market and are accepted as standard operating methods. For the strictest applications, requiring low bacteria counts and virtually undetectable levels of metal ions, PVDF is recommended for this service.

For applications less stringent in water quality level, polypropylene is an excellent alternative. PP offers excellent surface smoothness, as well as low extractable levels as compared to stainless steel. Polypropylene systems are thermally fused together, eliminating the use of glues, which will continue to leach into a water system for extended periods of time. PP is an extremely weldable material, making fusion joints simple and reliable. For more information on PP, consult Section B.

The third alternative is E-CTFE. This material, also known as Halar®, provides superior surface even compared to PVDF. Its extraction levels are also similar to that of PVDF. Halar is a very ductile material, making its use and welding methods extremely reliable. E-CTFE is normally available only in certain sizes and does have some pressure limitations at higher pressure. Halar has become the preferred material for tank lining applications.

Operating Parameters

Because thermoplastic systems have varying ratings at different temperatures, it is important to design a system around all the parameters to which it will be subjected. As a first pass, verify the following operating parameters:

- Continuous operating temperature
- Continuous operating pressure
- Media and concentration

By knowing the above parameters, thermal plastic pipe systems can be selected. Compare the actual conditions to the allowable ratings of the material being selected for the job. It is important to predict elevated temperatures, as thermoplastics have reduced pressure ratings at higher temperatures. Valves should be verified in terms of temperature and pressure separately from a piping system, as certain styles and brands of valves have lower ratings than the pipe system. Finally, if the media is not water, a chemical compatibility check should be conducted with the manufacturer. See Section E, *Chemical Resistance.*

After verifying the standard operating conditions, it is necessary to examine other operations that might affect the piping. The following is a sample of items to investigate prior to specifying a material.

- Will there be spikes in temperature or pressure?
- Is there a cleaning operation that the piping will be exposed to?
- If yes, what is the cleaning agent? What temperature will the cleaning be conducted at?
- Will the system be exposed to sunlight or other sources of UV?

Each of the above questions should be answered and the desired material should be checked for suitability based on the above factors, as well as any others that might be special to the system in question.

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System Sizing

It is well known that high-purity water systems are designed to operate in a continuously flowing loop to prevent stagnant water in the system. Stagnant water can proliferate the growth of bacteria and bio-film. The pattern and design of the loop will vary depending on the facility requirements.

The flow rate in the system is important in determining the pipe diameter size. In a pure water system, elevating flow velocities is recommended to reduce the possibility of bio adhesion to the pipe wall or welded surfaces.

Many specifications will state that the flow should be set at a minimum of 5 feet per second, which will always be turbulent flow at this velocity. However, a more sensible approach may be to review the Reynolds' Number of the system to ensure the flow is turbulent (see Section C, Equation C-14, for the calculation). Use of the Reynolds' Number may reduce waste oversizing of pumps to overcome excessive pressure drops due to unnecessarily high velocities.

Since many HP systems are now produced from high-quality Purad PVDF, high velocities in a continuously flowing system may not be as necessary. High velocities are generally accomplished by undersizing the pipe diameter, which is directly proportional to increased pressure drops. In fact, high minimum velocities are detrimental to the ability of a system to deliver adequate point of use pressure during peak demand conditions.(1) Therefore, using cleaner, smoother material such as PVDF is desirable for design and operation.

Sizing Laterals

A pure water and an ultra pure water system will be made of main loop branches known as laterals. It is important in design to not dead end laterals and ensure there is always flow movement in the main and in the lateral. Systems are designed with different loop configurations to accommodate the needs of production. However, all laterals must be designed for continuous flow and should feed back unused water into the return line.

For supply laterals feeding multiple tools, the lateral needs to be sized based on an acceptable pressure drop.(1) A general rule of thumb is 2 psig per 100 feet. Consideration of point of use water consumption, length, and frequency of demand must be factored into the sizing process of the lateral.

Sizing Mains

Main trunk lines are sized using the demand for water by the tools plus the tool and return lateral minimum flows. Tool demand can be calculated by taking the average flow demand and multiplying it by 1.2 to 1.8 to accommodate for peak demand. This should be based on the tool manufacturer's parameters.(1)

The return lines should be sized for minimal pressure drop when the tool demand is at a minimum, thus corresponding to maximum bypass at the end of a main pressure control station(1).

Thermal Expansion

Typically, Purad and PolyPure systems are designed for ambient or cold DI water. In these cases, since the systems operate continuously and are normally inside a fairly constant temperature building, the need to compensate for thermal expansion is not required. Although, it is an important factor that should be reviewed on each and every installation design.

Hot DI systems normally operating at temperatures of 65° C to 120° C, depending on the water usage, require a more complex design. PVDF systems can be used in hot water applications and applications where the temperature is cyclical. These systems require analysis of the thermal expansion effects. Section C walks through the steps of calculating thermal expansion, end loads, and expansion compensating devices. In most cases, the use of expansions, offsets, and proper hanging techniques are all that is required to ensure a proper design.

Hot DI systems also reduce the rigidity of thermoplastic piping systems, which, in turn, decreases the support spacing between pipe hangers. In smaller dimensions, it is recommended to use continuous support made of some type channel or split plastic pipe.

Finally, the use of hangers as guides and anchors becomes important. As the design procedures in Section C indicate, certain hangers should be used as guides to allow the pipe to move back and forth in-line, while other hangers should be anchoring locations used to direct the expansion into the compensating device. The anchors and hangers should be designed to withstand the end load generated by the thermal expansion.

Minimize Dead Legs

The term dead leg refers to a stagnant zone of water in the system. Dead legs are normally formed in the branch of a tee that is closed off with a valve. See Figure D-1.

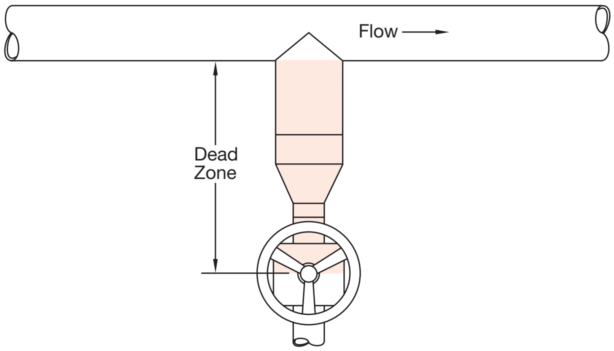

Figure D-1. Dead legs due to poor design

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(1) *Ultra Pure Water*, May/June 2000: "Criteria, Tools and Practices for High Purity Water Distribution"

A rule of thumb in designing a system is to keep all dead legs to a maximum of 6 internal pipe diameters in length. The turbulent flow in the main trunk line will create a significant amount of movement to keep the leg moving and prevent bacteria from adhering to the pipe wall. However, the Purad system allows designers to avoid dead legs altogether with the advent of T-diaphragm valves and zero dead leg fittings.

T-valves (see Figure D-2) take the place of a tee, reducer, and diaphragm valve by combining all three into one component. T-valves reduce the quantity of welds in a system as well. By using a T-valve, branch lines can be shut off at any time without creating a dead leg and turned back on without an extensive flush procedure.

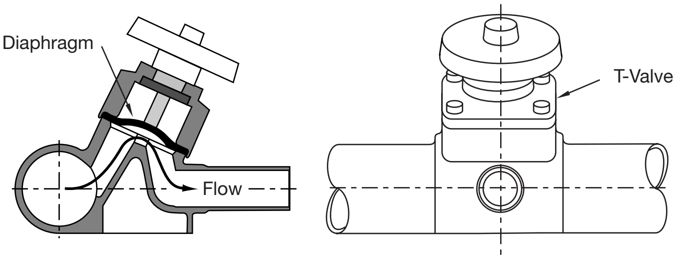

Figure D-2. T-valve eliminates dead leg

Dead legs in a system can be found in more than just branch lines. Often, the introduction of a gauge, measurement device, and/or sampling valve can create a dead leg. Since it is not recommended to tap into the side of a PVDF pipe for safety reasons, gauges are installed using tees and caps as shown in Figure D-3.

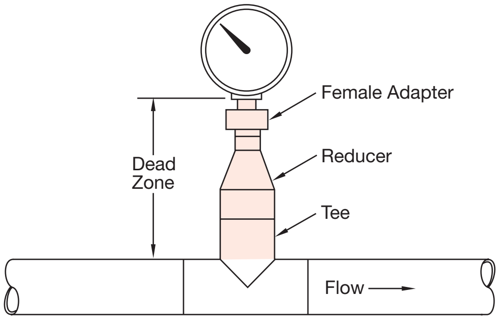

Figure D-3. Dead leg due to improper instrument installation

Since these tee configurations are narrow in diameter, they create a dead leg in the branch where microorganism growth can be initiated. The use of instrumentation fittings eliminate dead legs while being a safe adapter for gauges or sample valves. See Figure D-4.

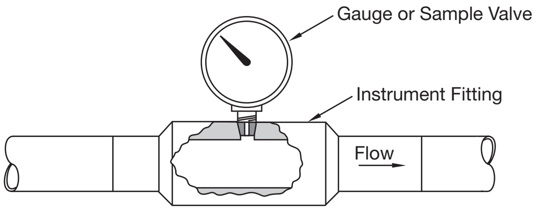

Figure D-4. Proper use of instrument fitting to avoid dead space. Can be used with gauge guard.

The insert of a resistivity probe can also be a possible source for dead legs. Since most probe manufacturers recommend that fluid flows directly at the probe, they are often situated in the leg of a tee and the tee acts as a 90° elbow. Since most probes are supplied as a 3/4" NPT fitting or sanitary adapter, there is the necessity to weld reducers onto the tee leg to accommodate the sensor, which will create dead zone. A simple fitting, the probe adapter, conveniently eliminates the need for reducers and shortens the leg of the tee. See Figure D-5. Probe adapters are available in all sizes and pressure ratings.

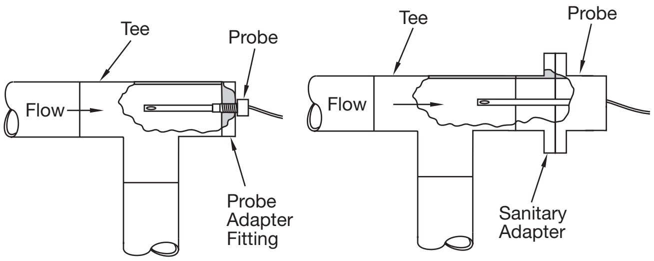

Figure D-5. Proper adapter setups

System Monitoring

In the proper design of an ultra pure water system, it is important to monitor the quality of the water, temperature, pressure, and the flow rate. All devices should be picked on the following criteria:

- Accuracy of indication
- Repeatability
- No moving parts
- Clean
- Devices in contact with the water should be thermoplastic
- Ease of use

In regard to monitoring flow, it is important to use devices that do not have moving parts to determine the flow rate. All thermoplastic construction is ideal to exactly match that of the pipe. An ideal flow measurement device is the vortex meter. A vortex meter from Asahi/America will provide accurate, repeatable flow without any moving parts. The features translate into the benefit of clean operating design and long lifetime. With no moving parts, no particles will be generated and there are no parts to wear out. In addition, vortex meters are simple to install and wire up. With all thermoplastic components, the device is unobtrusive to the process and provides years of reliable, clean operation.

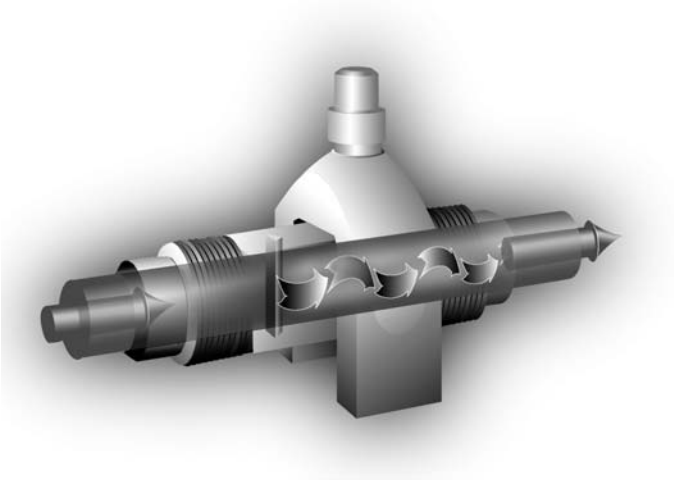

Figure D-6. Vortex meter

Vortex meters operate on the vortex principal. A bluff in the flow body causes a slight pressure drop behind it as the flow passes by. The water turns inward into the pressure differential causing the formation of small eddies or whirlpools. The vortices, as they are called, alternate from one side to the other in direct proportion to the flow. The frequency is calculated to flow and is transmitted as a 4–20 mA signal or a digital pulse, depending on customer preference.

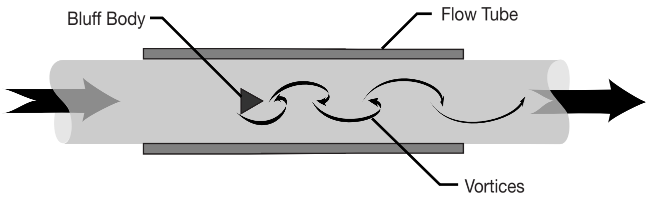

Figure D-7. The vortex principle

Other Considerations

Ultraviolet

All plastics react differently to UV exposure. Section C defines the effects on PVDF, PP, and E-CTFE materials. In addition to the external exposure of UV lights, it is also common for UV sterilizing lamps to be used to control bacteria levels in a water system. These lamps give off high intensity light to break up living bacteria in water. Depending on the wave length of the lamp, trace amounts of ozone can be generated from these lamps. The combination of the intense UV and ozone can create stress cracking in piping components directly in contact with the light source. To avoid a possible problem, build a light trap from stainless steel (SS) components. The use of SS diaphragm valves or a couple of changes in direction will eliminate the concern altogether. Figure D-8 illustrates an efficient light trap.

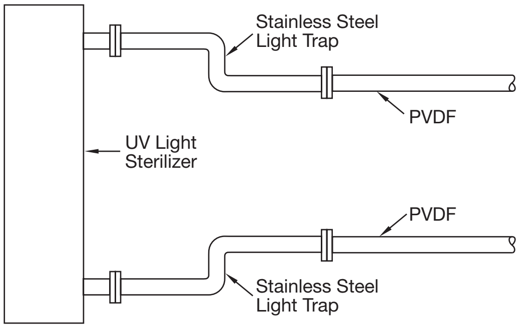

Figure D-8. UV light trap

Ozone

The use of ozone for system sterilization has proven itself as the preferred industry method. Dosing a PVDF or E-CTFE system with ozone for sterilization purposes is acceptable and does not damage the material. The exact concentration and period of ozonation should be verified with the pipe supplier.

Using ozone in polypropylene systems is not recommended. Ozone has a tendency to breakdown PP at an alarming rate. For these systems an alternate chemical, such as hydrogen peroxide, should be used. The piping manufacturer should verify the peroxide concentration and period of exposure to the polypropylene system.

Hanging

See Section C for hanging details and proper placement distances. Since plastic reacts differently than metal, varying hanger styles are required. The designer of a system should specify the exact hanger and location and not leave this portion up to the installer.

Welding Methods

Asahi/America offers several choices for joining PVDF and PP together. The choice of a particular method should be based on the following concerns: purity of the system installation, location, size range, and system complexity.

While the welding method is instrumental in the purity of a water system, the choice of a welding method is not the final factor. The environment where welding occurs may be more important than the actual welding method. Asahi/America recommends the welding method be based on the type of installation, rather than the desire to have the most advanced equipment on site.

PVDF can be installed using butt fusion, IR fusion, socket fusion, and beadless HPF fusion. All methods are proven in DI water systems, and each has its own advantages. Polypropylene is weldable using butt, IR or socket fusion. In addition, Asahi/America offers electro-fusion couplings for PP that are ideal for repairs. E-CTFE can be welded using butt or IR fusion. It is recommended to assemble Halar with IR fusion, as special heating elements are required for welding Halar with conventional butt-fusion equipment.

Socket fusion is ideal for small, simple, low cost systems. In small diameters, 1/2"–11/4" socket fusion can be done quite easily with a hand-held welding plate and a few inserts. With just a limited amount of practice, an installer can make clean and reliable joints. For larger dimensions, up to a maximum of 4", bench style socket fusion equipment is available for keeping joints aligned.

For systems that have larger dimensions above 4", butt and IR fusion make a logical choice. Both systems are available for welding all dimensions from 1/2" to 10". IR fusion has several advantages; during the welding process the material is not in contact with the heat source, thus eliminating a source of contamination. In the course of an IR weld, there is no force against the heating element like in butt fusion, therefore the weld beads are smaller when making an IR weld. In a flowing system, an IR bead will flush cleaner, due to its round, smoother shape as compared to a butt weld. See Figure D-9.

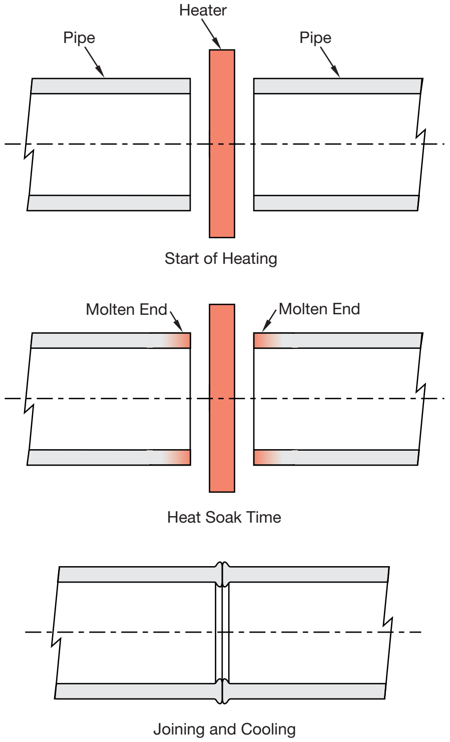

Figure D-9. IR fusion welding process

IR fusion has become the standard welding choice within the semiconductor industry for the above reasons. IR fusion is neat, clean, and reliable. Current day welding equipment is computer controlled, making each weld identical, and inspection processes more reliable. IR fusion equipment also allows for complete traceability of each weld, by each operator.

IR fusion is suited for cleanroom environments and bench top type welding. Equipment is highly sophisticated, making field or location welds difficult.

Butt fusion is similar in practice to IR fusion; however the components to be welded are in contact with the heat source. Butt fusion is the parent of IR fusion and still maintains its one advantage; it can be done in a variety of environments. Wind or a strong breeze can make IR welding troublesome. In these cases butt fusion is preferred. If welds are made outside or in a windy area, butt fusion should be used. Field welds in place can also be accomplished with butt fusion. A variety of different types of butt-fusion equipment are available, making location welds possible, where an IR fusion would not be recommended.

For a more detailed analysis of welding methods and equipment, refer to Section F, *Installation Practices*.