Tempered Water Systems

Timothy A. Smith, CPD

Many years ago, plumbing system designers specified that domestic hot water heating systems should operate at 160°–180°F to maximize their usable hot water capacity. When the effect of temperature exposure and scalding on the human body became more widely recognized, along with perceived energy efficiencies associated with lower operating temperatures, designers started specifying lower system-operating temperatures.

Legionella pneumophila (Legionnaire's disease) and other nasty bacteria that can grow inside a domestic water system were added to the historical chain of events in the 1970s. The result was the evolution and broader application of tempered water systems.

(It should be noted that the arguments for energy efficiency promulgated during the energy crunch of the early 1970s have since been disproved by the ASPE Research Foundation, which has found that a reduction in service hot water temperature, in and of itself, does not result in a reduction in energy use. Furthermore, the Foundation's research shows that a 140°F hot water temperature system is more energy efficient to maintain and operate than a 110°F hot water temperature system. So it has turned out that the plumbing system designers from many years ago were not all wet when they specified higher hot water temperatures.)

The design of domestic water distribution systems is no longer as simple as cold water on the right and hot water on the left. Higher hot water temperatures still maximize a system's usable hot water capacity, improve system efficiency, provide proper temperature for sanitation purposes, and minimize or eliminate harmful bacteria growth. Nonetheless, many building codes now require that moderate temperatures be delivered to the hot water inlet (left side) of the faucet or fixture. These provisions are most prevalent for building programs in which the plumbing fixtures will be used by the general public or physically challenged individuals.

Point-of-use temperature-limiting devices are a good design application for smaller projects, but a central tempered water system is a more cost-effective option for larger commercial and institutional projects. A centralized tempered water system with independent distribution starts becoming more economically desirable when it is compared with 75–100 individual point-of-use temperature-limiting devices. Building layout, temperature requirements, and piping configurations also must be evaluated in determining the total cost and economic feasibility of a centralized tempered water system.

It has been found that pre-engineered three-way mixing valves provide the most accurate control of outlet temperature.

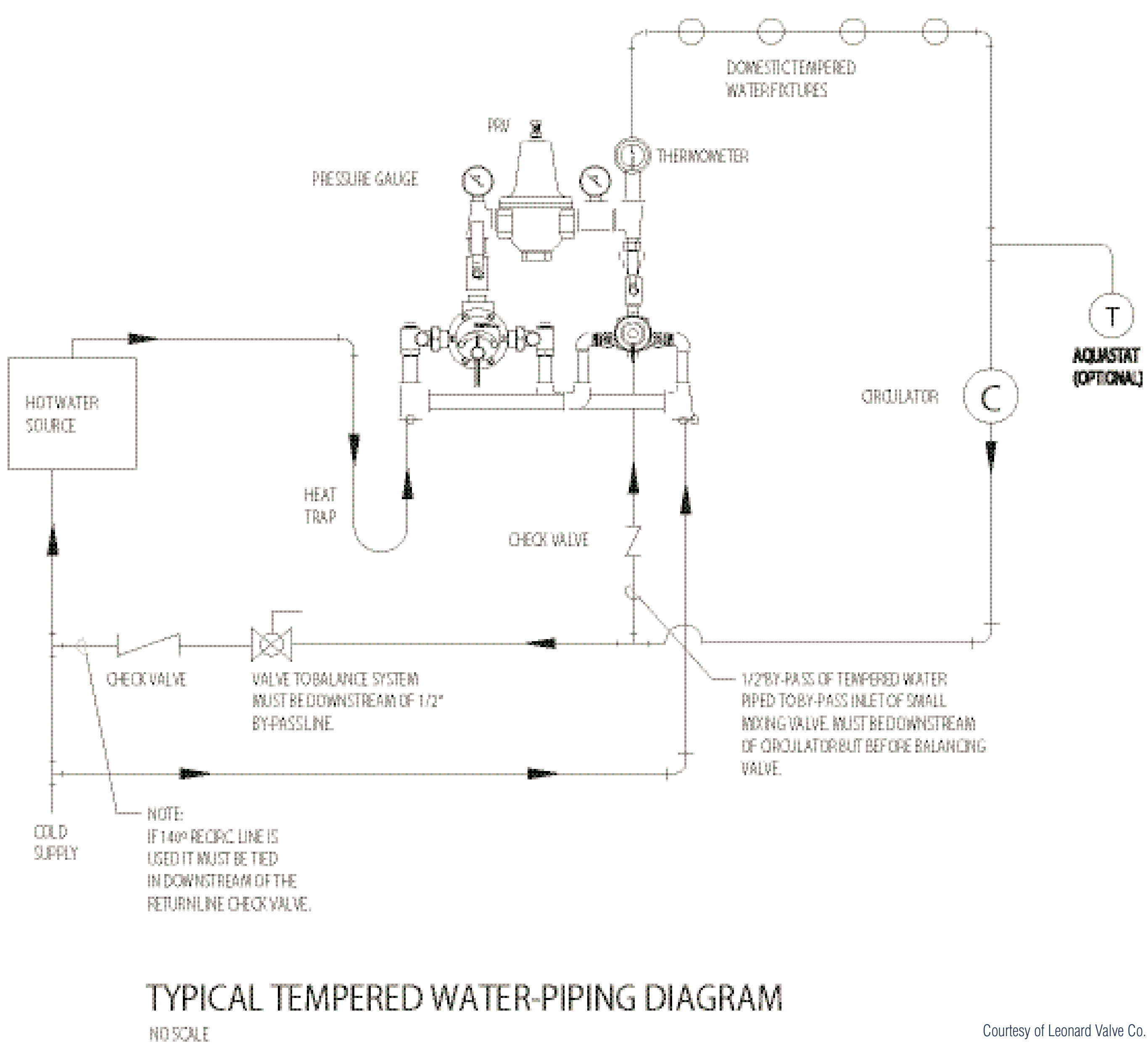
In plumbing design, *tempering* can be defined as "moderating system water temperature by combining or mixing water systems of different temperatures together to achieve a mixed temperature." Tempered water system designs are not limited to reducing hot water temperatures by introducing a cold water admixture. They can also include elevating cold water system temperatures by introducing hotter water temperatures. Typically, a building's cold water temperature is recognized as being equal to the temperature at which it is delivered from the municipal water supply or private well. The building's cold water temperature can fluctuate between 45°F and 60°F depending on the building's water source and climate location. In colder climates, water mains and exterior distribution piping typically are buried 4–8 ft below the surface. Ground temperatures at these depths help maintain constant cooler temperatures. In warmer areas, water mains and exterior distribution piping are buried 2–4 ft below ground, so the building cold water temperature is warmer.

A building's hot water temperature typically is recognized as the delivery temperature at the heating system's outlet. The heat loss and temperature drop in a domestic hot water distribution system is negligible if the system has been installed and insulated in conformance with current American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) energy-efficiency standards.

In many applications, water temperatures must be moderated or tempered. Mixing the building's hot water recirculation system with the cold water supply at the hot water heating system's inlet is one example of tempering cold water to elevate temperature. Elevating the cold water supply temperature reduces the thermal shock to the domestic hot water heating system's heat exchanger. The most common tempered water system design application is to reduce the domestic hot water heating system's outlet temperature to a level acceptable for human contact and to comply with codes developed to prevent scalding. A system can be considered a tempered water system when its delivery temperature falls between the building's cold water and hot water delivery temperature as described above.

What is required to design a tempered water distribution system? If the specified temperature fluctuation or tolerance is large and no one is at risk of being fined or sued because of major or uncontrollable fluctuations, then you can connect the hot and cold water together with manually controlled throttling valves on each side and guess at a correct ratio to deliver the desired temperature. Keep in mind

Figure 1. Typical Piping Diagram for a Tempered Water System



Courtesy of Leonard Valve Co.

that an open plumbing system is dynamic. In an open system, pressures, flow rates, friction losses, and velocities are constantly changing, so temperatures at the outlet of a manual mixing arrangement will fluctuate in response. In contrast, these factors remain constant in a closed system. If the design precepts require more accurate control, you must consider specifying an engineered plumbing product that suits the criteria, code requirements, and application. It has been found that pre-engineered three-way mixing valves provide the most accurate control of outlet temperature. The type of operating motor, the diameter, and the size of the temperature-sensing element in a three-way mixing valve's internal assembly are the critical components to evaluate when matching the valve specification with the designed application.

There are two basic motor configurations:

- The pressure-balanced type has a sliding-sleeve piston motor, which is designed to restrict the applicable inlet port to obtain an equalized pressure within the mixing chamber and thus maintain a constant outlet temperature.
- The thermostatic type has a motor that uses different metals having significantly different properties and expansion coefficients that respond differently to temperature. The expansion and contraction of the opposing metals adjust the volume at the valve's inlets to maintain a constant outlet temperature.

The pressure-balanced type is commonly used as a point-of-use control because the pressure element of the system's dynamics is easily influenced by simultaneous use of adjacent fixtures. The thermostatic type is most commonly used to control central tempered water systems, fixtures, or equipment having continuous or constant flow requirements. By definition, thermostatically operated mixing valves do not react to fluctuating inlet pressures as quickly as pressure-balanced valves.

Design precepts for accurate localized or point-of-use temperature control allow for the use of pressure-balanced, thermostatic, or combination pressure-balanced/thermostatic valves. All three-way mixing valves for central distribution systems are of the thermostatic type. The use of pressure-balanced valves in public and commercial point-of-use applications is recommended, because multiple-fixture use creates significant pressure fluctuations. The American Society of Sanitary Engineering (ASSE) has established criteria for three-way mixing valves under ASSE Standards 1016 and 1017. These standards, in conjunction with ASSE seal authorizations, are widely accepted. They are recognized by the majority of the model national and local code organizations, in conjunction with the manufacturers of three-way mixing valves. ASSE Standard 1016 is for "individual thermostatic, pressure-balancing and combination pressure balancing and thermostatic control valves for individual fixture fittings." ASSE Standard 1017 is the standard for compliance when selecting a three-way mixing valve for a central distribution system.

Be sure to evaluate the accuracy, minimum and maximum flow rates, and associated pressure drop when you select a thermostatic mixing valve for a central distribution system. The valve's accuracy, capacity, and pressure drop may not be indicative of the valve inlet sizes. I have found that 8 out of 10 times, oversized thermostatic valves were selected because the valve connections were matched to the supply pipe sizes. The valve connection sizes are not always indicative of the capacity or pressure drop of specific valves. The characteristics required for a thermostatic mixing valve to meet standards include an inherent temperature and pressure differential between the inlets and outlet. Individual point-of-use pressure-balanced mixing valves require a minimum 20-psi inlet pressure.

Typically, thermostatic mixing valves for central systems need to be recirculated to maintain a uniform tempered water temperature at all fixtures. Recirculation loops are not needed when continuous flow conditions exist or when the fixtures being controlled are very close to the mixing valve, as in a gang shower-room application. The piping and configuration design is very important in a recirculating central tempered water system. It is important to recirculate most of the water through the valve body or cold water inlet of the valve to avoid temperature increase during very low-flow conditions. Most of the recirculation water is diverted back through the valve, since a properly insulated piping system has little temperature loss. A small amount of the water is circulated through the domestic hot water heating system to recover the small temperature loss of the piping system (see **Figure 1**).

A tempered water system is considered a closed system when there is no usage. If 100% of the recirculated water is sent to the water heating system, its temperature eventually reaches the temperature of the heating system when there is no usage. When the system is closed and 100% of the return water is returning to the water heater, the mixing valve cannot introduce new or cold water admixture to temper the water temperature in a system that is filled to its maximum volume. Documented scalding deaths in nursing homes and assisted living facilities have been related to tempered water systems that recirculate 100% of the water to the hot water heating system. Nursing homes and assisted living facilities typically have zero usage during the late evening and early morning hours. Consequently, the water temperature creeps up to the hot water heating system temperature unless the water is recirculated to the mixing valve to bypass the heating system.

It is critical to consider pressure drops and friction losses through the mixing valve when you are sizing the recirculation pump, because most of the water is intended to pass through the valve. When sizing the pump head, you should calculate the friction losses through the recirculation piping and valves, then add in the friction loss through the valve at the recirculation flow rate. Some valves add 10–30 ft of head to the pump size based on the valve's diameter and operating motor.

When there are multiple recirculation zones, it is also important to make sure all of the recirculation loops are balanced to a constant temperature drop. When the zones are not balanced, the recirculation water flowing through the mixing valve will fluctuate in temperature, causing the mixing valve's operating motor to expand and contract or hunt and seek in an effort to maintain a constant discharge temperature. The result is a fluctuating discharge temperature at the mixing valve's outlet.

Manufacturers of mixing valves engineer their valves to maintain a constant tempered water discharge temperature. All ASSE-listed valves do this quite well as long as they are sized properly, piped properly, and installed in accordance with the manufacturer's recommendations. It is important to check pump size and piping configuration against the manufacturer's recommendations when you design a tempered water system that must maintain a constant temperature at a close tolerance. ■

Tim Smith is vice president, partner, and founding member of Metro Design Associates, Inc., in Schaumburg, IL. He has more than 23 years experience covering all aspects of consulting engineering, specializing in plumbing, fire protection, and civil engineering. His e-mail address is tsmith@metrodgn.com.

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